

CTIA GROUP CO., LTD
The Most Important Q&A
About Tungsten-Copper Alloys

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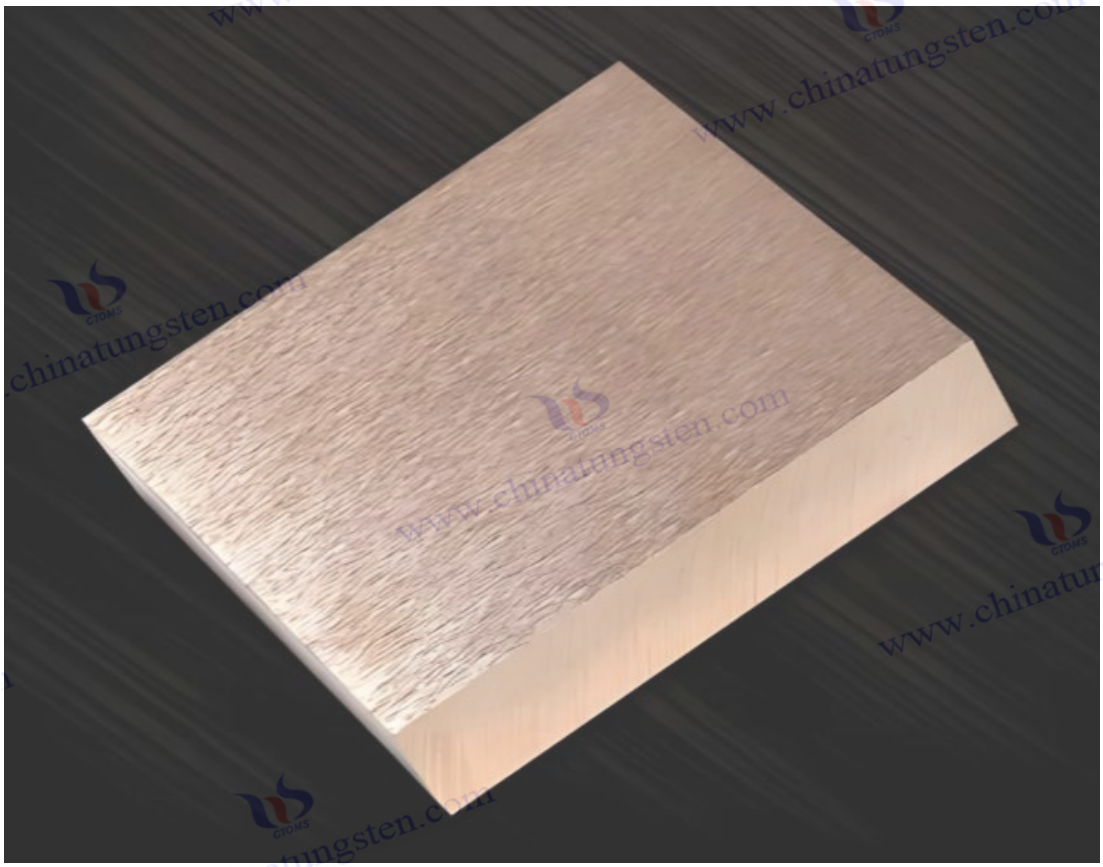

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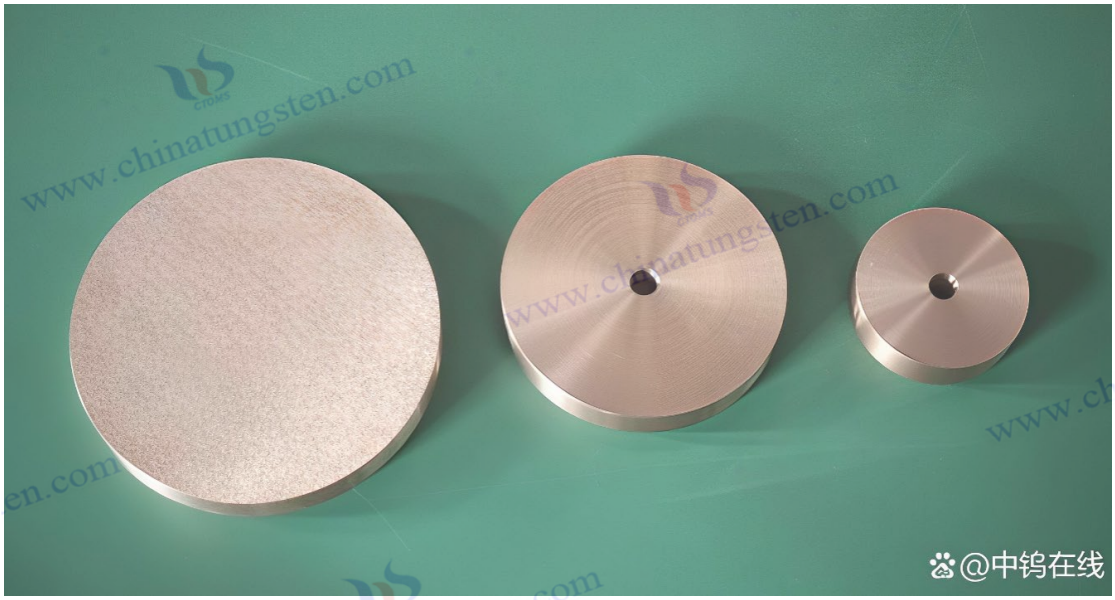


Part One

Basic Knowledge, Grade Performance, and Manufacturing Processes of Tungsten-Copper Alloys

A Review of the Basic Knowledge, Grade Performance, and Manufacturing Processes of Tungsten-Copper Alloys

Tungsten-copper alloy (W-Cu) is a type of metal-matrix composite material made primarily from tungsten (W) and copper (Cu) as its main components, prepared through powder metallurgy and subsequent densification processes. This material combines the high melting point, high hardness, and arc-erosion resistance of tungsten with the good electrical and thermal conductivity of copper, giving it important application value in fields such as electrical discharge machining, electrical switches, resistance welding, electronic packaging, and thermal management of high-power devices.

Tungsten-copper alloys are generally not traditional alloys formed into a uniform solid solution through ordinary melting. Because the solid-state mutual solubility of tungsten and copper is very low and their melting points differ significantly, industrial manufacturing usually relies on forming a microstructure in which the tungsten phase and copper phase cooperate with each other, so that tungsten provides high-temperature resistance, ablation resistance, and structural support, while copper handles electrical conduction, thermal conduction, and pore filling. The final performance depends not only on the tungsten-copper ratio but also closely on powder characteristics, tungsten skeleton structure, copper phase distribution, material density, and subsequent processing quality.

From an engineering application perspective, material selection and manufacturing of

tungsten-copper alloys should be organized around actual operating conditions. EDM electrodes focus on machining efficiency, electrode wear, and precision; electrical contacts focus on arc-erosion resistance, contact stability, and electrical conductivity; electronic packaging places greater emphasis on thermal conductivity, thermal expansion matching, dimensional accuracy, and thermal cycling reliability. Only by clarifying these differences can material grades, manufacturing processes, and subsequent processing methods be reasonably selected.

I. Basic Composition and Material Characteristics of Tungsten-Copper Alloys

Tungsten-copper alloys are mainly composed of a tungsten phase and a copper phase. Tungsten has a relatively high melting point, density, hardness, and high-temperature stability, and can provide structural support under arc and high thermal load environments; copper has relatively high electrical and thermal conductivity, which facilitates current transmission and heat dissipation. By changing the ratio of the two metals, the comprehensive performance of the material can be adjusted.

The main characteristics of tungsten-copper alloys include relatively good arc-erosion resistance, adjustable electrical and thermal conductivity, designable thermal expansion characteristics, and relatively good high-temperature dimensional stability. However, these advantages do not mean that all grades have the same performance. For example, increasing the tungsten content generally helps improve density, hardness, and ablation resistance, but may reduce electrical conductivity and thermal conductivity; increasing the copper content generally helps improve electrical and thermal conductivity, but the ablation resistance and high-temperature stability of the material may decrease accordingly.

Compared with pure tungsten, tungsten-copper alloys are more suitable for scenarios requiring electrical conduction, thermal conduction, or electrode functions; compared with pure copper, their arc-erosion resistance and high-temperature dimensional stability are usually more advantageous. Compared with molybdenum-copper alloys, tungsten-copper alloys generally have higher density and stronger ablation resistance potential, but the specific thermal conductivity, thermal expansion coefficient, and processing adaptability still need to be compared according to grade and manufacturing quality. The performance of tungsten-copper alloys should be understood as the result of the combined action of composition, structure, and process, rather than being determined solely by tungsten content. Even if two products have the same nominal composition, if powder particle size, porosity, copper phase continuity, or processing state differ, the final measured performance may also differ.

II. Common Grades, Composition Ratios, and Material Selection Directions

Tungsten-copper alloys usually use the nominal mass fractions of tungsten and copper to express grades. For example, W70Cu30 means the nominal mass fraction of tungsten is 70% and copper is 30%; W80Cu20 means tungsten is 80% and copper is 20%. Grade designations, permissible composition ranges, and acceptance requirements of different suppliers may differ,

so product technical documents should be checked during procurement.

Common Grade	Nominal W Content	Nominal Cu Content	Common Material Selection Direction
W50Cu50	50%	50%	Focus on electrical conductivity, thermal conductivity, & some thermal management applications
W60Cu40	60%	40%	Balance electrical conductivity, thermal conductivity, and ablation resistance
W70Cu30	70%	30%	EDM electrodes, resistance welding electrodes, electrical contacts, etc.
W75Cu25	75%	25%	Balance electrical conductivity, thermal conductivity, and relatively high ablation resistance requirements
W80Cu20	80%	20%	Focus on arc-erosion resistance, precision EDM, and high-temperature stability
W85Cu15	85%	15%	Higher tungsten content, suitable for some high ablation resistance requirements
W90Cu10	90%	10%	Specific ablation-resistant applications with high tungsten content and low copper ratio

The content in the table is general material selection reference and does not mean that every grade is suitable for all listed scenarios. Actual applications also need to consider operating current, thermal load, contact pressure, discharge frequency, service temperature, product size, and the manufacturer's specific technical capabilities.

In EDM, W70Cu30 and W80Cu20 are materials worth comparing closely. The former usually emphasizes a balance among electrical conductivity, thermal conductivity, and machining performance, while the latter leans more toward ablation resistance and dimensional stability. For resistance welding electrodes, selection should be combined with welding current, workpiece material, contact area, and cycle frequency; for electronic packaging, applicability cannot be judged by grade alone, and thermal expansion coefficient and thermal conductivity should also be confirmed.

III. Key Performance Parameters and Data Interpretation

Technical evaluation of tungsten-copper alloys usually includes indicators such as density, electrical conductivity, thermal conductivity, thermal expansion coefficient, hardness, strength, arc-erosion resistance, and microstructure. The performance priorities of different applications are not the same, and data should be interpreted in combination with material grade, test method, temperature, and supply condition.

1.Density and Product Weight

The density of tungsten is about 19.3 grams per cubic centimeter, and the density of copper is about 8.96 grams per cubic centimeter. The theoretical density of tungsten-copper alloys usually lies between the two and increases with increasing tungsten mass fraction. The density of actual materials is also affected by pores, residual defects, and composition deviations, so theoretical density cannot directly replace measured values of finished products. In product design and procurement, density can be used to estimate material weight, verify product data, and assist in judging densification quality. For plates, rods, electrodes, and complex machined parts, finished product weight should be calculated based on actual dimensions, material

density, and machining allowance. If the product is used for precision assembly or thermal management, dimensional tolerances, flatness, and internal defect requirements should also be checked simultaneously.

2. Electrical Conductivity and Resistivity

Electrical conductivity reflects the ability of a material to conduct current, while resistivity reflects the degree to which the material impedes current transmission. The electrical properties of tungsten-copper alloys are related to copper content, copper phase continuity, impurity level, and pore state. Generally speaking, materials with higher copper content are more conducive to improving electrical conductivity, but the final result still depends on the manufacturing process and material structure. Electrical conductivity is sometimes expressed as a percentage of the International Annealed Copper Standard (IACS). This indicator facilitates comparison with the standard conductive level of annealed copper, but procurement documents should still specify test temperature, specimen condition, and test method. For high-current contacts and welding electrodes, in addition to the electrical conductivity of the material itself, attention should also be paid to contact resistance, surface condition, and the influence of the connection structure on overall electrical performance.

3.Thermal Conductivity and Thermal Management Capability

Thermal conductivity indicates the ability of a material to transfer heat and is an important indicator for resistance welding electrodes, electronic packaging substrates, and thermal management components of power devices. Tungsten-copper alloys, through the synergistic effect of the tungsten phase and copper phase, balance thermal conduction capability and high-temperature resistance within a certain range. Their actual thermal conductivity is affected by copper phase distribution, porosity, impurity content, and interface state and cannot be accurately estimated solely from the tungsten-copper ratio. In high-power devices, the thermal conductivity of the material itself is not the only factor determining heat dissipation. Product thickness, contact interface, bonding layer, cooling conditions, and structural design also affect overall thermal resistance. For heat sinks or packaging base plates, it is recommended to combine material performance data with thermal analysis, temperature-rise testing, and thermal cycling verification of the complete assembly.

4. Thermal Expansion Coefficient

The thermal expansion coefficient reflects the degree of dimensional change of a material when temperature changes. Tungsten-copper alloys can change thermal expansion behavior by adjusting the tungsten-copper ratio and can therefore be used in scenarios requiring matching with semiconductor chips, ceramic substrates, and other packaging materials. For electronic packaging products, attention should be paid to the thermal expansion coefficient within the actual operating temperature range, and it is not advisable to make judgments based only on single-point room-temperature data. If the thermal expansion difference between the material and adjacent components is too large, high thermal stress may be generated during repeated heating and cooling, affecting the long-term reliability of solder layers, bonding interfaces, or devices.

5. Hardness, Strength, and Arc-Erosion Resistance

Hardness and strength reflect the ability of a material to resist local indentation, deformation, and mechanical loads, while arc-erosion resistance is related to surface damage, material migration, local melting, and thermal shock under arc action. Higher tungsten content generally helps improve hardness and ablation resistance potential, but actual performance is also related to tungsten skeleton structure, copper phase distribution, material density, and working conditions. For electrical contacts, arc energy, switching frequency, contact pressure, and service life need to be comprehensively evaluated; for EDM electrodes, evaluation should be combined with electrode wear, machining efficiency, surface roughness, and machining accuracy. Ablation resistance data obtained by different test methods may not be directly comparable, and test conditions should be provided as part of the technical data.

6. How to Use Typical Performance Data

Performance data of tungsten-copper alloys should be based on specific grades and supply conditions. For parameters such as density, electrical conductivity, thermal conductivity, hardness, and thermal expansion coefficient, units, test conditions, and acceptance ranges should be specified, and typical values, guaranteed values, and measured values should be distinguished. Same-named grades from different manufacturers do not necessarily have exactly the same performance, so reference data from one supplier cannot be directly regarded as a unified standard for the entire industry.

In procurement documents, it is recommended to divide data into three categories: first, basic information such as material grade and composition range; second, performance indicators such as density, electrical conductivity, thermal conductivity, hardness, and thermal expansion coefficient; third, dimensions, surface quality, durability, and reliability requirements related to actual applications. Each key indicator should specify units, test conditions, acceptance range, and applicable standards, avoiding directly writing typical values from promotional materials as unconfirmed contractual acceptance values.

IV. Main Manufacturing Processes and Technical Control

Production of tungsten-copper alloys usually includes raw material powder preparation, forming, tungsten skeleton preparation, copper phase introduction, densification treatment, subsequent processing, and inspection. Different process routes are suitable for different compositions, shapes, sizes, and performance targets. For manufacturers, the key is not only to complete the composite process but also to ensure uniform distribution of the tungsten phase and copper phase, controlled internal defects, and achievement of final product dimensions and performance requirements.

1.Powder Preparation and Mixing

Raw material preparation is the foundation determining material consistency. The purity, particle size distribution, particle morphology, and oxygen content of tungsten powder and copper powder affect powder mixing, forming, sintering, and final structure. The mixing process needs to control component ratio and distribution uniformity and reduce the risk of

local segregation, particle agglomeration, and impurity introduction. Powder particle size is not the finer the better. Finer powder may help improve structural refinement and sintering activity, but may also increase oxidation sensitivity, mixing difficulty, and production cost. Therefore, appropriate powder specifications should be selected in combination with target grade, forming method, densification process, and product size.

2.Press Forming and Tungsten Skeleton Preparation

When using the copper infiltration process, it is usually necessary to first press tungsten powder into shape and then pre-sinter it to form a tungsten skeleton with certain mechanical strength and interconnected pores. The skeleton needs to be strong enough to support the subsequent infiltration process while retaining a pore structure that allows molten copper to enter. The porosity, pore size distribution, and connectivity of the tungsten skeleton directly affect copper liquid penetration and final structure. If the skeleton is too dense, the copper liquid may be difficult to fully enter the interior; if the pore distribution is uneven, local copper phase deficiency, residual pores, or composition inhomogeneity may occur. The manufacturing process needs to strike a balance among skeleton strength, pore structure, and final material performance.

3.Copper Infiltration Process

Copper infiltration is one of the commonly used manufacturing routes for tungsten-copper alloys. Its basic idea is to first prepare a porous tungsten skeleton, then under appropriate temperature and atmosphere conditions make copper melt and enter the skeleton pores, and after cooling form a composite structure in which the tungsten phase and copper phase cooperate with each other. The key control points of this process include the quality of tungsten skeleton pre-sintering, pore connectivity, copper liquid wetting and penetration state, infiltration temperature and holding time, protective atmosphere, and cooling conditions. If infiltration is insufficient, internal pores may remain; if the skeleton structure is unsuitable or the copper liquid distribution is uneven, local structural differences may occur, affecting electrical conductivity, thermal conductivity, and mechanical performance.

For tungsten-copper products manufactured by the infiltration process, when evaluating suppliers, focus can be placed on their raw material control, skeleton forming, infiltration process, densification testing, and batch consistency management capabilities. From raw material preparation and composition control to precision machining of complex parts, tungsten-copper alloys require long-term process accumulation and application experience. Taking CTIA GROUP as an example, its nearly thirty years of customized processing experience in tungsten-copper alloys can provide customers with reference in grade selection, specification matching, non-standard size processing, and communication of technical requirements. For specific projects, the technical documents of actual products, test data, and processing requirements confirmed by both parties should still be used as the basis.

4. Mixed-Powder Sintering and Other Densification Methods

Some tungsten-copper products can adopt a combined route of mixed-powder forming, sintering, and subsequent densification. For products with special structures or higher

performance requirements, methods such as hot pressing, hot isostatic pressing, or spark plasma sintering (SPS) may also be evaluated according to technical conditions. Different processes differ in density, grain control, equipment investment, production efficiency, product size range, and cost. Processes such as spark plasma sintering are beneficial in some material systems for shortening sintering cycles and controlling structure, but whether they are suitable for specific tungsten-copper grades still needs to be confirmed through process verification and product testing. Product performance cannot be judged solely by process name, nor should the potential advantages of laboratory processes be directly equated with the stable performance of mass-produced products.

5. Precision Machining and Surface Treatment

After densification, tungsten-copper alloys usually also need to be processed by turning, milling, drilling, grinding, or EDM to meet drawing requirements. Because the tungsten phase in the material has high hardness and the two phases differ in hardness and thermal characteristics, machining requires reasonable selection of tools, cutting parameters, clamping methods, and cooling conditions to reduce chipping, burrs, surface tearing, and dimensional deviation.

For electronic packaging, switch contacts, and high-precision electrodes, grinding, polishing, cleaning, coating, or other surface treatments may also be involved. The surface treatment method should be determined according to electrical contact requirements, connection process, service environment, and subsequent assembly needs. If the product involves high flatness, strict parallelism, or fine hole positions, it is recommended to provide engineering drawings and key dimensional tolerances at the inquiry stage so that the processing route, inspection method, and manufacturing cost can be evaluated.

V. Product Quality Control and Inspection Methods

Quality control of tungsten-copper alloys should cover the entire process of raw materials, forming, densification, processing, and final acceptance. Checking only finished product appearance or a single performance parameter is often insufficient to determine whether the material meets actual working conditions. Common inspection items include chemical composition, density, electrical conductivity, thermal conductivity, hardness, dimensional tolerance, surface roughness, and microstructure. According to product use, porosity and internal defect inspection, non-destructive testing, arc ablation testing, thermal cycling testing, or other reliability verification may also be added. Specific items should be determined based on product risk, customer technical specifications, and applicable standards.

Common problems include internal residual porosity, uneven copper phase distribution, local composition deviation, surface cracks, machining chipping, and dimensional deformation. Porosity may be related to skeleton structure, pre-sintering conditions, or insufficient infiltration; uneven copper phase distribution may be related to powder mixing, skeleton pore structure, or infiltration conditions; machining defects may be related to material structure, tool selection, and machining parameters. Problem analysis should combine process records, test data, and microstructural evidence rather than inferring causes only from appearance.

For standard compliance, the purchaser should clarify the standard name, version, scope of application, and acceptance clauses. For example, when electrical contact materials are involved, it can be evaluated whether ASTM B702, the standard for copper-tungsten electrical contact materials published by ASTM International (American Society for Testing and Materials), is applicable. Which standard to adopt still needs to be confirmed in combination with product category, contract requirements, and the current version of the standard, and it cannot be assumed that a certain standard automatically covers all tungsten-copper plates, electrodes, and electronic packaging parts. For high-reliability projects, suppliers should be required to provide quality certification documents corresponding to the batch, specifying chemical composition, density, key performance, dimensional inspection results, and necessary traceability information. If the product is used in long-term operation or high thermal load conditions, its applicability should also be confirmed through sample testing or actual assembly verification.

VI. Procurement Evaluation, Supplier Selection, and Technical Documents

Procurement of tungsten-copper alloys should not compare only price per kilogram or nominal tungsten content. Raw material prices, tungsten-copper ratio, manufacturing route, density, machining allowance, dimensional tolerances, surface quality, inspection requirements, and order quantity all affect the final quotation. For standard plates, rods, and conventional electrodes, preliminary screening can be carried out first according to grade, size, supply condition, and basic performance; for complex shapes, precision tolerances, or high-reliability applications, technical clarification should be carried out before procurement to confirm manufacturing capability, processing plan, and inspection scope. If the purchaser provides only the material name without clarifying performance and dimensional requirements, suppliers may quote based on different assumptions, resulting in quotations that are not comparable.

It is recommended that inquiry materials include at least the following: material grade, nominal tungsten-copper ratio, and permissible composition range; product form, quantity, blank or finished product state, and complete dimensional drawings; key dimensional tolerances, flatness, parallelism, surface roughness, and machining datum; key performance requirements such as density, electrical conductivity, thermal conductivity, hardness, or thermal expansion coefficient; applicable standards, test methods, quality certification documents, and batch traceability requirements; actual working conditions, including temperature, current, contact pressure, discharge frequency, or thermal cycling requirements; delivery cycle, packaging, transportation, and acceptance methods.

Supplier evaluation should also focus on whether the supplier has stable raw material control capability, appropriate powder metallurgy and densification processes, precision machining equipment, testing conditions, and batch quality management capability. For key components, it is recommended to first purchase samples or trial parts to verify dimensions, performance, and actual application performance before determining a batch procurement plan.

VII. Design and Manufacturing Services for Customized Products

Based on the customer needs accumulated over thirty years, CTIA GROUP believes that customization of tungsten-copper alloys usually involves not only changing external dimensions but may also involve multiple contents such as grade selection, tungsten-copper ratio, blank size, machining allowance, surface treatment, performance acceptance, and batch consistency. For non-standard products, customers should provide application scenarios, structural drawings, assembly relationships, and key performance indicators as early as possible so that manufacturers can judge whether existing grades can meet requirements or whether material specifications and processing routes need to be adjusted.

From the perspective of procurement collaboration, customized projects can be advanced according to the following logic: first confirm working conditions and performance priorities, then determine material grade and manufacturing route, then conduct drawing review and cost accounting, then verify dimensions and performance through samples or first-article inspection, and finally establish batch production and acceptance standards. This can reduce rework and delivery risks caused by unclear material selection, machining allowance, or technical requirements.

For complex machined parts, drawings should specify key dimensions, datum system, tolerances, surface roughness, hole positions, and assembly requirements. If the product is used for thermal management, the mating material, operating temperature range, and thermal cycling conditions should also be provided; if it is used for electrical contacts or welding electrodes, current load, contact form, operating frequency, and expected service life should be stated. The more complete the working condition information, the more targeted the material and process evaluation.

VIII. Main Product Applications and Material Selection Focus

1.EDM Electrodes

Tungsten-copper alloys can be used in mold manufacturing, hard material processing, and other scenarios requiring EDM. Such applications focus on electrode wear, machining efficiency, discharge stability, surface quality, and dimensional accuracy. Material grade should be comprehensively selected according to the workpiece material, machining parameters, cavity shape, and precision requirements, rather than simply pursuing the highest tungsten content. The final performance of the electrode depends not only on the material but is also affected by electrode structure, machining program, flushing conditions, and discharge parameters. Therefore, in high-precision machining projects, it is recommended to compare material wear and machining quality through trial machining and use the results as the basis for subsequent batch material selection.

2.Electrical Switch Contacts and Vacuum Electrical Components

Tungsten-copper alloys have relatively good arc-erosion resistance potential and can be used for some high-current switch contacts and related electrical components. The material needs

to achieve a balance among electrical conductivity, ablation resistance, mechanical stability, and contact reliability. Actual selection should consider voltage level, current load, switching frequency, contact pressure, and electrical structure, and verification should be carried out through arc testing or life testing when necessary. Requirements for different contact structures and electrical systems vary greatly, and material grade cannot replace design verification of the entire contact system. Contact surface condition, connection method, assembly accuracy, and operating environment also affect final life. For non-standard contacts and precision electrical parts, acceptance requirements for composition, dimensions, surface quality, and key performance should be specified in the technical agreement.

3. Resistance Welding Electrodes

In resistance welding, electrodes need to conduct current, transmit pressure, and control heat distribution while enduring repeated contact, heating, and cooling. Tungsten-copper alloys can be used in some welding scenarios requiring a balance of thermal conductivity, wear resistance, and ablation resistance, but applicability depends on workpiece material, welding current, contact area, and work rhythm. During material selection, electrode tip shape, cooling conditions, dressing frequency, and electrode life should also be considered simultaneously. For continuous production lines, in addition to material unit price, electrode replacement frequency, downtime, and processing and maintenance costs also affect overall economics.

4.Semiconductor Packaging and Electronic Thermal Management

Tungsten-copper alloys can be used for some electronic packaging base plates, heat dissipation components, and thermal management parts. Their value lies in the ability to design a balance between thermal conductivity and thermal expansion coefficient by adjusting the composition ratio. For such applications, priority should be given to checking thermal expansion matching, thermal conductivity, flatness, surface quality, and bonding interface requirements. If the product needs to be connected to ceramics, semiconductor chips, or other metal materials, welding or brazing processes, bonding layer thickness, thermal resistance, and thermal cycling reliability should also be evaluated. Meeting the performance requirements of the material itself does not necessarily mean that the final packaging assembly meets reliability indicators, so assembly-level verification should be carried out when necessary.

5.Special Thermal Load and Customized Structural Components

In some scenarios with high heat flux density or local arc action, tungsten-copper alloys can serve as candidate materials for specific functional components. However, whether they are suitable for extreme temperatures, complex atmospheres, or special thermal load environments needs to be verified in combination with thermal stress, oxidation behavior, cooling conditions, structural constraints, and actual service life, and it should not be inferred solely from the material's high melting point or ablation resistance that it can reliably work in all extreme environments. For such customized parts, it is recommended to advance material evaluation, structural design, processing feasibility, and working condition verification as a whole. When necessary, the design scheme can be gradually confirmed through sample testing, prototype testing, and small-batch verification.

IX. Technical Development and Cost Control Directions

Technical progress in tungsten-copper alloys is mainly concentrated in areas such as powder raw material control, microstructure homogenization, densification quality improvement, precision machining, and application customization. By optimizing powder particle size, tungsten skeleton structure, copper phase distribution, and infiltration conditions, it is expected to improve performance consistency of the material; by improving dimensional processing and testing capabilities, the requirements of electrodes, electronic packaging, and precision electrical components can be better met.

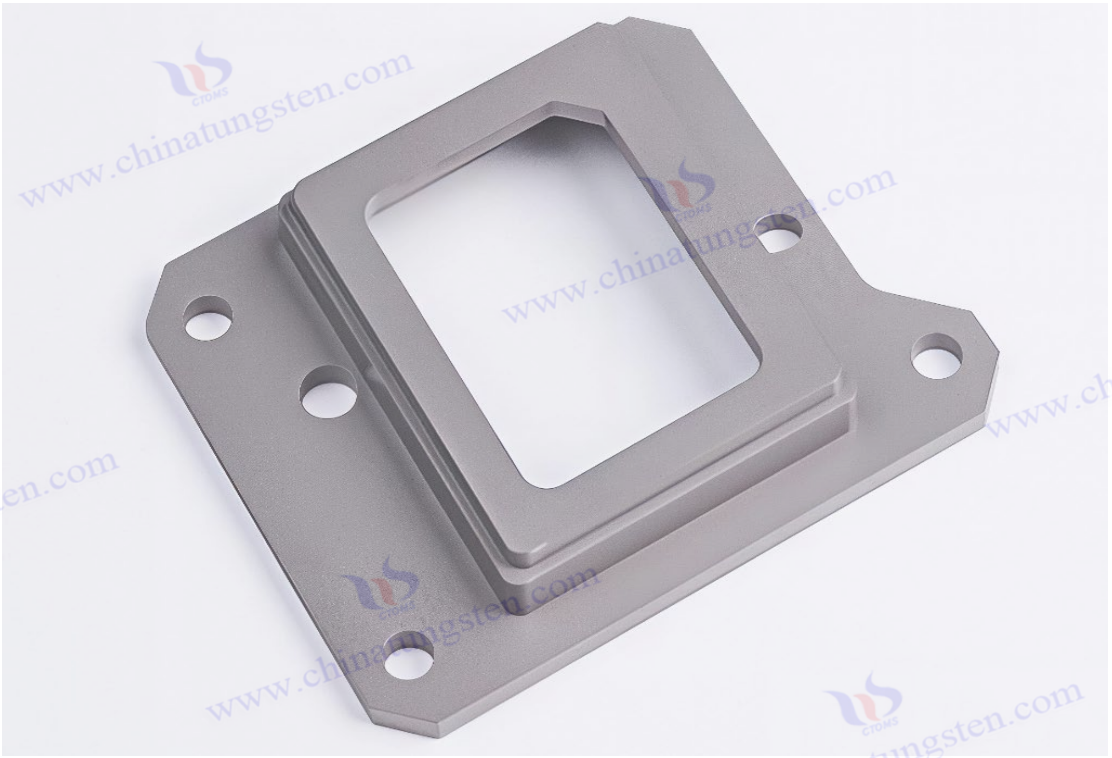
At the same time, tungsten raw material prices, copper price fluctuations, energy costs, machining allowance, material utilization, and order scale all affect the final product cost. For customized machined parts, the price difference between blanks and finished products may be quite significant, especially when complex shapes, strict tolerances, fine surface treatment, and higher inspection requirements are involved. Purchasers should include material costs, processing costs, testing costs, scrap risk, and delivery costs in the evaluation rather than comparing only raw material unit prices.

For projects requiring continuous supply, supplier batch stability, quality traceability, and customized processing collaboration capabilities should also be examined. Clarifying material performance, processing requirements, and acceptance methods in the early stage helps reduce trial-and-error repetition, control overall costs, and improve consistency in subsequent batch procurement.

X. Conclusion

Tungsten-copper alloy is a metal-matrix composite material that meets requirements such as electrical conduction, thermal conduction, arc-erosion resistance, and thermal expansion regulation through the complementary performance of the tungsten phase and copper phase. Its actual performance depends on composition ratio, powder characteristics, tungsten skeleton structure, copper phase distribution, densification process, and precision machining quality. Understanding these factors helps to more accurately carry out grade screening, technical data verification, supplier evaluation, and customized product development. In engineering practice, working conditions and key performance requirements should be clarified first, then appropriate material grades and manufacturing routes should be selected, and the final scheme should be confirmed through drawing review, sample testing, and application verification. For procurement and customization projects, complete technical documents, traceable test data, and clear acceptance standards are often as important as the material itself.

Through the coordination of material, process, processing, and application verification, the application value of tungsten-copper alloys in fields such as precision electrodes, electrical contacts, and electronic thermal management can be more effectively realized.



A. Tungsten-Copper Alloy Fundamentals

Q1. What is tungsten-copper alloy? What are the main characteristics of tungsten-copper alloy?

Tungsten-copper alloy (W-Cu) is a metal composite material with tungsten (W) and copper (Cu) as its main constituent elements. It combines the high melting point, high hardness, and good resistance to arc erosion of tungsten with the high electrical conductivity and high thermal conductivity of copper. It is usually not formed by ordinary melting to completely mix tungsten and copper into a uniform solid solution; instead, taking advantage of the differences in melting point and mutual solubility between the two metals, it is prepared through processes such as powder metallurgy and copper infiltration of tungsten skeletons. Tungsten-copper alloy can maintain good comprehensive performance under working conditions such as high temperature, high current, high heat flux density, and repeated arc action, and is therefore widely used in fields such as electrical switch contacts, resistance welding electrodes, electrical discharge machining electrodes, electronic packaging, and thermal management of high-power devices.

I. Main characteristics of tungsten-copper alloy

Good high-temperature resistance

The melting point of tungsten is approximately 3422°C, giving it excellent high-temperature stability. The tungsten phase in tungsten-copper alloy can maintain structural stability in high-temperature environments and is suitable for high thermal load and arc action environments. However, the melting, migration of the copper phase, and the overall thermal stress of the

material can still affect the actual service temperature; the melting point of tungsten cannot simply be regarded as the service temperature of tungsten-copper alloy.

Good electrical conductivity

Copper has high electrical conductivity and can provide tungsten-copper alloy with good electrical conduction capability. Compared with pure tungsten, tungsten-copper alloy is more suitable for electrical components that need to combine resistance to arc erosion with electrical conductivity. Its electrical conductivity is affected by factors such as tungsten content, porosity, density, microstructural uniformity, and processing state.

Good thermal conductivity

The copper phase helps conduct heat, enabling tungsten-copper alloy to be used in high-power electronic devices, heat sinks, and thermal management parts. Reasonable selection of the tungsten-copper ratio helps achieve a balance among thermal conductivity, thermal expansion matching, and structural stability.

Outstanding resistance to arc erosion

Tungsten has a high melting point and good resistance to high-temperature erosion, while copper helps conduct electricity and dissipate heat. Combined, the material can adapt to working conditions with repeated arc action and is therefore often used in high-voltage or medium-high-voltage electrical switch contacts, vacuum electrical components, and other parts that need to withstand arc impact. Actual service life also depends on current level, breaking conditions, contact pressure, and material grade.

High hardness and good wear resistance

The tungsten phase can increase the hardness and deformation resistance of the material, making tungsten-copper alloy suitable for some high-load electrodes and wear-resistant parts. Generally, under otherwise similar conditions, increasing tungsten content increases hardness, but may also reduce electrical and thermal conductivity and increase processing difficulty.

Adjustable coefficient of thermal expansion

Tungsten has a low coefficient of thermal expansion, while copper has a high coefficient of thermal expansion. By adjusting the ratio of the two, the thermal expansion characteristics of tungsten-copper alloy can be adjusted within a certain range, making it suitable for electronic packaging and precision structural parts that require control of thermal deformation, reduction of thermal stress, or thermal expansion matching with other materials.

II. How does the composition ratio of tungsten-copper alloy affect performance?

The performance of tungsten-copper alloy is closely related to the mass proportions of tungsten and copper. Common grades include W50Cu50, W60Cu40, W70Cu30, W75Cu25, W80Cu20, and W90Cu10. Among them, W70Cu30 means tungsten accounts for approximately 70% of the total mass and copper approximately 30%. Typical properties differ among grades, and specific values are also affected by manufacturing processes and testing conditions.

Composition	Main performance tendency	Common application directions
W50Cu50	Higher Cu content, better electrical & thermal conductivity	Electrodes, conductive & heat-dissipating parts
W60Cu40	Balances electrical conductivity, thermal conductivity	Electrical contacts, electrodes
W70Cu30	Relatively balanced comprehensive performance	Resistance welding electrodes, electrical contacts
W75Cu25	Good strength, hardness, thermal expansion control capability	Electrical switches, precision electrodes
W80Cu20	Higher W content, higher hardness, lower thermal expansion	High-load electrodes, electronic thermal management parts
W90Cu10	Higher density, higher hardness, lower thermal expansion	Specific high-hardness contacts &precision functional parts

The above are common material selection tendencies, and do not mean that the higher the tungsten content, the better all properties are. As tungsten content increases, the density and hardness of the material usually increase and the coefficient of thermal expansion usually decreases, but electrical conductivity and thermal conductivity often decrease. Therefore, material selection should be determined according to specific working conditions rather than simply pursuing higher tungsten content.

III. What are the limitations of tungsten-copper alloy?

Although tungsten-copper alloy has outstanding comprehensive performance, there are also some factors that need to be considered. First, the melting points of tungsten and copper differ greatly, and their mutual solubility under conventional conditions is extremely low, so the manufacturing process places high requirements on powder quality, tungsten skeleton structure, copper infiltration, and densification control. Porosity, microstructural non-uniformity, or insufficient infiltration may all affect the electrical conductivity, thermal conductivity, and mechanical properties of the material. Second, tungsten-copper alloy has relatively high density, and some high-tungsten-content grades are difficult to cut, grind, and process precisely, and production costs may also be higher than those of ordinary copper alloys. For parts with complex structures, strict dimensional tolerances, or special surface requirements, it is usually necessary to comprehensively consider blank manufacturing, subsequent machining, and quality inspection. In addition, different manufacturing processes, raw material purity, and densification levels may cause performance differences among the same nominal grade. Therefore, when purchasing, product quality should not be judged only by the tungsten-copper ratio; density, electrical conductivity, hardness, dimensional tolerances, and other relevant inspection indicators should also be checked against actual application requirements.

IV. In which fields are tungsten-copper alloys mainly applied?

Power and electrical equipment

Tungsten-copper alloy can be used for electrical switch contacts, vacuum arc-extinguishing components, etc., giving full play to the comprehensive advantages of resistance to arc erosion, electrical conductivity, and heat dissipation. For electrical equipment that needs to repeatedly break current, the material's arc erosion resistance, contact resistance, and microstructural

uniformity are all important.

Electrical discharge machining and resistance welding

Tungsten-copper alloy can be used as EDM electrodes and resistance welding electrodes, suitable for working conditions that require a combination of electrical conductivity, wear resistance, heat resistance, and erosion resistance. The specific grade should be determined in combination with the workpiece material, machining current, machining accuracy, electrode wear, and working temperature.

Electronic packaging and thermal management

Tungsten-copper alloy can be used for heat sinks, heat spreader components, and some electronic packaging structures. With adjustable thermal expansion characteristics and thermal conductivity, the material can meet the requirements of specific devices for heat transfer, dimensional stability, and thermal stress control. For high-power electronic devices, it is also necessary to comprehensively evaluate the material's thermal conductivity, coefficient of thermal expansion, connection method, and service environment. In actual projects, the selection of tungsten-copper alloy usually needs to be judged in combination with working current, thermal load, mechanical load, dimensional tolerances, and service environment. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, non-standard size processing, and technical requirement communication for related projects; specific product performance should still be based on the technical documents and inspection data of the corresponding grade.

V. How to reasonably select tungsten-copper alloy?

When selecting tungsten-copper alloy, the main function of the product should first be clarified, and then the composition ratio and manufacturing process should be matched. If the application focuses more on electrical and thermal conductivity, priority can be given to evaluating grades with relatively higher copper content; if the application focuses more on hardness, arc erosion resistance, or a lower coefficient of thermal expansion, grades with relatively higher tungsten content can be considered. However, these are only preliminary screening directions, and the final decision should still be based on specific working conditions and performance indicators.

For precision parts, the product size, geometric tolerance, surface roughness, machining allowance, inspection method, and batch consistency requirements should also be clarified in advance. When necessary, sample testing or actual working condition verification can be used to confirm whether the material can meet the expected service life and reliability requirements. The core advantage of tungsten-copper alloy lies in combining the high-temperature stability, hardness, and arc erosion resistance of tungsten with the electrical and thermal conductivity of copper. Only by reasonably controlling the tungsten-copper ratio and selecting an appropriate manufacturing process can the material better adapt to different application needs in electrical, welding, precision machining, and electronic thermal management fields.

Q2. Is tungsten-copper alloy an alloy or a metal composite?

Tungsten-copper alloy can be called an alloy in the industrial field, and can also be classified as a metal composite from the perspective of materials science and microstructure. More rigorously, conventional tungsten-copper materials usually belong to two-phase metal composites composed of a tungsten phase and a copper phase, rather than typical single-phase solid-solution alloys.

Why is tungsten-copper alloy both called an alloy and classified as a metal composite?

The key lies in the different emphases of everyday industrial naming and materials science classification. From the perspective of industrial applications and commercial naming, tungsten-copper alloy (W-Cu) is a long-established name widely used for electrical contacts, resistance welding electrodes, EDM electrodes, and electronic thermal management components. Therefore, calling it tungsten-copper alloy is reasonable and common. From the perspective of materials science, the melting points of tungsten and copper differ greatly, approximately 3422°C and 1084.6°C respectively, and their mutual solubility under conventional conditions is extremely low. Common tungsten-copper materials are usually manufactured by powder metallurgy or copper infiltration of tungsten skeletons, ultimately forming a structure in which the tungsten phase and copper phase are combined with each other while each still maintains an independent phase structure. Therefore, calling it tungsten-copper metal composite can more accurately reflect its microstructure and manufacturing characteristics.

Comparison item	Typical single-phase alloy	Conventional tungsten-copper material
Constituent elements	Two or more elements	Mainly tungsten and copper
Phase structure	May be single-phase or multi-phase	two-phase structure composed of W& Cu
Atomic level	May form solid solutions or intermetallic compounds	Tungsten and copper usually do not form a significant continuous solid solution
manufacturing methods	Melting, casting, hot working, etc.	PM, copper infiltration of tungsten skeletons, etc.
More accurate materials science description	Depends on the specific alloy microstructure	Metal matrix composite

Which name is more accurate?

If used for product names, procurement documents, industry articles, or daily technical communication, using tungsten-copper alloy is fine; if used for materials science papers, technical principle introductions, or microstructural analysis, using tungsten-copper metal composite is usually more rigorous. It should also be noted that not all materials called alloys must be single-phase materials. An alloy itself may also have a multi-phase structure, so the existence of two phases alone cannot be used to conclude that a material is definitely not an alloy. The reason tungsten-copper materials are often specifically classified as metal composites is mainly that the mutual solubility between tungsten and copper is very low, and the two metals usually form the material together as relatively independent phases and are combined through specific processes. In one sentence: tungsten-copper alloy is the commonly used industrial name, and tungsten-copper metal composite is the materials science description that better reflects its typical microstructure; the two names are not contradictory, but in rigorous technical expression it is best to choose according to the specific context.

Q3. What elements does tungsten-copper alloy consist of? What roles do tungsten and copper play respectively?

Tungsten-copper alloy (W-Cu) mainly consists of two elements, tungsten (W) and copper (Cu), and is a typical metal composite composed of a tungsten phase and a copper phase. Tungsten and copper each play different roles in the material: tungsten mainly provides a high melting point, high hardness, resistance to arc erosion, and a relatively low coefficient of thermal expansion, while copper mainly provides good electrical conductivity and thermal conductivity and helps transfer heat.

I. What elements does tungsten-copper alloy consist of?

The main components of tungsten-copper alloy are tungsten and copper, usually manufactured by processes such as powder metallurgy and copper infiltration of tungsten skeletons. The mutual solubility of the two elements under conventional conditions is very low, so the finished product usually retains relatively independent tungsten and copper phases rather than forming a uniform single-phase solid solution. Common tungsten-copper grades include W50Cu50, W60Cu40, W70Cu30, W75Cu25, W80Cu20, and W90Cu10. Among them, W70Cu30 means the mass fraction of tungsten is approximately 70% and the mass fraction of copper is approximately 30%. The specific composition range should be based on the technical standard or product inspection report of the corresponding grade.

II. What roles do tungsten and copper play respectively?

Main role of tungsten in tungsten-copper alloy

Tungsten is an important component in tungsten-copper alloy that bears the functions of high-temperature resistance and ablation resistance. The melting point of tungsten is approximately 3422°C, and it has relatively high hardness, good high-temperature stability, and a relatively low coefficient of thermal expansion. In tungsten-copper alloy, tungsten mainly plays the following roles: (1) improving resistance to arc erosion, suitable for components such as electrical switch contacts that withstand arc impact. (2) Improving hardness and deformation resistance, helping the material maintain structural stability under certain mechanical loads. (3) Reducing the coefficient of thermal expansion of the material, suitable for precision parts that require dimensional stability and thermal expansion matching. (4) Improving structural stability under high-temperature working conditions, but the actual service temperature is still limited by the copper phase, microstructure, and working environment. Generally, under otherwise similar conditions, increasing tungsten content helps increase hardness and reduce the coefficient of thermal expansion, but may also increase processing difficulty and reduce the electrical and thermal conductivity of the material.

Main role of copper in tungsten-copper alloy

Copper is an important component in tungsten-copper alloy that bears the functions of electrical and thermal conduction. The melting point of copper is approximately 1084.6°C, and it has good electrical conductivity and thermal conductivity, helping the material transmit current and dissipate heat. In tungsten-copper alloy, copper mainly plays the following roles:

(1) improving electrical conductivity to meet the conductive requirements of components such as electrodes and electrical contacts. (2) Improving thermal conductivity, helping heat transfer away from local high-temperature areas. (3) In the copper infiltration of tungsten skeleton process, molten copper can enter the pores of the tungsten skeleton to form a dense composite structure. (4) By adjusting copper content, regulating the electrical and thermal conductivity of the material and its overall comprehensive performance. When copper content is relatively high, the material usually has better electrical and thermal conductivity, but arc erosion resistance, hardness, and thermal expansion control capability also need to be evaluated in combination with the specific grade.

III. How do tungsten and copper cooperate with each other?

The core advantage of tungsten-copper alloy lies in the performance complementarity between tungsten and copper. Tungsten is responsible for improving high-temperature resistance, ablation resistance, and structural stability, while copper is responsible for electrical and thermal conduction; through a reasonable composition ratio and manufacturing process, the two form a material that balances multiple properties.

Performance indicator	Main contribution of tungsten	Main contribution of copper
High-temperature resistance	Provides high melting point and high-temperature stability	Provides thermal conductivity; the copper phase may soften or melt at high temperature
Electrical conductivity	Relatively low	Provides the main conductive path
Thermal conductivity	Has certain thermal conductivity	significantly improves overall thermal performance
Hardness & deformation resistance	Main contributing component	Usually relatively low hardness
Thermal expansion control	Reduces the overall tendency toward thermal expansion	Increases the overall tendency toward thermal expansion
Arc erosion resistance	Bears high-temperature resistance and ablation resistance functions	Helps conduct electricity and dissipate heat, but may also melt and migrate

IV. Why is the ratio of tungsten to copper important?

The tungsten-copper ratio directly affects the comprehensive performance of the material. Taking common grades as examples, W50Cu50 has a relatively high copper content and usually places more emphasis on electrical and thermal conductivity; W70Cu30 has a good comprehensive balance among electrical conductivity, thermal conductivity, hardness, and ablation resistance; W90Cu10 has a relatively high tungsten content and usually places more emphasis on hardness, ablation resistance, and a lower coefficient of thermal expansion. Actual material selection cannot look only at the single content of tungsten or copper; density, porosity, microstructural uniformity, manufacturing process, and service environment should also be considered. For electrical contacts, resistance welding electrodes, EDM electrodes, and electronic thermal management components, appropriate grades should be selected according to working current, thermal load, mechanical load, and dimensional requirements.

For products requiring custom dimensions or specific performance, CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide relevant

reference for grade selection, specification matching, and non-standard processing requirements; specific performance should still be based on product technical documents and inspection data. Tungsten-copper alloy mainly consists of tungsten and copper: tungsten is mainly responsible for high-temperature resistance, arc erosion resistance, increasing hardness, and reducing the coefficient of thermal expansion, while copper is mainly responsible for electrical and thermal conduction. Only by reasonably adjusting the ratio of the two can the material adapt to the needs of different electrical, welding, precision machining, and electronic thermal management applications.

Q4. Why is tungsten-copper alloy usually manufactured by powder metallurgy?

Tungsten-copper alloy (W-Cu) is usually manufactured by powder metallurgy, mainly because the melting points of tungsten and copper differ greatly and their mutual solubility under conventional conditions is extremely low, making it difficult to obtain materials with uniform composition and dense microstructure through ordinary melting and casting. Powder metallurgy can separately control the composition and distribution of the tungsten phase and copper phase, and through processes such as pressing, sintering, and copper infiltration, enable the two metals to form a composite structure with good comprehensive performance.

I. The physical properties of tungsten and copper differ greatly

The melting point of tungsten is approximately 3422℃, while the melting point of copper is approximately 1084.6℃, a difference of about 2337℃. If ordinary melting methods were used to manufacture tungsten-copper alloy, when the temperature reached the melting point of tungsten, copper would already be in a high-temperature molten state, making problems such as copper volatilization, composition loss, and difficulty in microstructure control likely. In addition, the mutual solubility of tungsten and copper under conventional conditions is extremely low, and they cannot form a uniform solid solution through melting, mixing, and solidification like many common metal alloys. Therefore, traditional melting and casting are usually not the preferred route for manufacturing conventional tungsten-copper materials. Powder metallurgy can bypass the difficulty that the two metals must be melted and fully mixed at the same time, and combine tungsten particles with copper without melting tungsten.

II. Why is powder metallurgy suitable for tungsten-copper alloy?

Ability to control the tungsten-copper ratio

By weighing and mixing tungsten powder and copper powder, or first preparing a tungsten skeleton and then performing copper infiltration, the composition ratio of the material can be controlled relatively precisely. For example, W70Cu30 means tungsten accounts for approximately 70% of the total mass and copper approximately 30%. Different tungsten-copper ratios affect the density, hardness, electrical conductivity, thermal conductivity, and coefficient of thermal expansion of the material. The powder metallurgy process makes it easy to adjust the ratio according to different application requirements.

Favorable for forming a uniform composite structure

Powder metallurgy can control the microstructure of the material through aspects such as powder particle size, mixing method, pressing conditions, sintering schedule, and infiltration parameters. A reasonable process helps improve tungsten particle distribution, copper phase continuity, and material density, thereby improving the stability of product performance. However, microstructural uniformity is not determined only by powder mixing; it is also closely related to the pore structure of the tungsten skeleton, the degree of copper infiltration, and subsequent densification processes.

Ability to balance density and comprehensive performance

The performance of tungsten-copper materials depends not only on the tungsten-copper ratio but also on porosity and density. Excessive residual porosity may reduce current conduction and heat transfer efficiency and weaken the mechanical properties of the material. Through press forming, liquid-phase sintering, copper infiltration, and necessary subsequent densification treatment, the internal pore state of the material can be improved to meet the corresponding performance requirements. Different process routes are suitable for different composition ratios and product specifications and need to be selected according to target performance.

Suitable for manufacturing industrial parts of different specifications

Powder metallurgy can be used to manufacture blanks for products such as rods, plates, blocks, electrical contacts, electrodes, and thermal management components. After blank forming, machining methods such as turning, milling, and grinding can also be used to achieve the required dimensions, tolerances, and surface quality. For parts with complex structures or high precision requirements, the manufacturing plan still needs to be determined in combination with mold design, blank shape, machining allowance, and subsequent precision machining capability.

III. Common powder metallurgy manufacturing processes for tungsten-copper alloy

Powder mixing, pressing, and sintering

Tungsten powder and copper powder are mixed in proportion, pressed into shape, and then formed into a material through appropriate sintering or other densification processes. This route makes it easy to adjust the composition directly, but for high-tungsten-content materials, achieving high density and a uniform structure may be somewhat difficult.

Copper infiltration of tungsten skeleton

Tungsten powder is first pressed and sintered to make a tungsten skeleton with certain strength and interconnected pores, and then molten copper is made to enter the pores of the skeleton to form a tungsten-copper composite material. This is a common tungsten-copper manufacturing route, especially suitable for many medium- and high-tungsten-content products.

Other densification and post-treatment

According to material composition, dimensions, and performance requirements, other sintering densification technologies can also be used, together with heat treatment, precision machining, and surface treatment. The specific process needs to comprehensively consider material performance, equipment conditions, product dimensions, and cost.

IV. What impact does the powder metallurgy process have on the performance of tungsten-copper alloy?

Powder metallurgy not only determines whether the material can be formed but also affects final service performance. The particle size and distribution of tungsten powder affect the pore

structure of the tungsten skeleton, pressing and sintering conditions affect skeleton strength and dimensional stability, and the copper infiltration process is related to pore filling, density, and copper phase distribution. If the process is not properly controlled, products may have problems such as residual porosity, insufficient copper infiltration, non-uniform structure, or dimensional deviation, which in turn affect electrical conductivity, thermal conductivity, hardness, and arc erosion resistance. Therefore, in actual production, raw material quality, forming parameters, sintering schedule, and infiltration effect need to be controlled according to grade and application, and quality verification should be carried out through items such as density, electrical conductivity, hardness, dimensions, and microstructure. For tungsten-copper products with specific performance and dimensional requirements, CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide relevant reference for grade selection, specification matching, and non-standard processing requirements; the specific manufacturing route and performance indicators should still be based on product technical requirements and inspection results.

V. Why not directly use ordinary melting processes?

The core difference between the two manufacturing approaches lies in the different material formation mechanisms.

Comparison item	Ordinary melting and casting	Powder metallurgy
Requirement for melting tungsten	Conventional melting routes find it difficult to balance the melting conditions of tungsten and copper	Usually does not require melting tungsten
Composition control	Easily affected by factors such as melting point differences and copper loss	Can be controlled through powder ratio or infiltration
Structure formation	Difficult to form an ideal uniform tungsten-copper composite structure	Can form a composite structure combining tungsten and copper phases
Densification control	Relatively difficult for conventional melting routes	Can be adjusted through pressing, sintering, infiltration, and other processes
Industrial applicability	Usually not the preferred route for conventional tungsten-copper materials	Is a common manufacturing method

It should be added that powder metallurgy does not mean the manufacturing process is completely free of high-temperature melting. In the copper infiltration process, copper needs to be melted and then enter the pores of the tungsten skeleton; the key is that it is usually not necessary to melt tungsten and copper simultaneously and rely on melt mutual solubility to form the material.

Tungsten-copper alloy is usually manufactured by powder metallurgy because it can avoid the manufacturing difficulties caused by the large melting point difference and low mutual solubility between tungsten and copper, and can control material composition, structure, and density through powder ratio, pressing, sintering, and copper infiltration, thereby obtaining comprehensive performance that meets the needs of electrical, welding, precision machining, and electronic thermal management.

Q5. What are the differences between tungsten-copper alloy, pure tungsten, and pure copper?

The main differences among tungsten-copper alloy (W-Cu), pure tungsten (W), and pure copper (Cu) lie in material composition, electrical and thermal conductivity, high-temperature resistance, hardness, thermal expansion characteristics, and applicable working conditions. Tungsten-copper alloy combines the different properties of tungsten and copper to achieve a balance among arc erosion resistance, electrical conductivity, thermal conductivity, and dimensional stability. Pure tungsten is more suitable for occasions that emphasize high melting point, hardness, and high-temperature stability, while pure copper is more suitable for applications that emphasize high electrical conductivity and high thermal conductivity.

I. Core differences among the three materials

The following data are typical reference values; actual performance is affected by purity, material state, manufacturing process, and testing conditions.

Performance	Tungsten-copper alloy	Pure tungsten	Pure copper
Main composition	Two-phase composite of W-Cu	Mainly tungsten	Mainly copper
Melting point	No single, fixed melting point; Cu phase melts first	Appr. 3422°C	Appr. 1084.6°C
Density	Varies with W content, usually relatively high	Appr. 19.25 g/cm³	Appr. 8.96 g/cm³
Electrical conductivity	Medium to high depending on W-Cu ratio	Relatively low	Very high
Thermal conductivity	Adjustable, between typical levels of W-Cu	Relatively low	Very high
Hardness & wear resistance	Usually higher than pure copper	Usually relatively high	relatively low
Coefficient of thermal expansion	Can be adjusted by adjusting composition	Relatively low	Relatively high
Arc erosion resistance	Usually relatively good	High-temperature resistant; electrical conduction	More prone to melt erosion under strong arc conditions
Typical applications	Electrical contacts, electrodes, electronic thermal management components	High-temperature components, special electrodes, etc.	Cables, conductive bars, heat exchangers

One point worth distinguishing: the performance of tungsten-copper alloy is not simply the arithmetic average of the data of pure tungsten and pure copper. Its actual performance also depends on the tungsten-copper ratio, phase structure, porosity, density, and manufacturing process.

II. What are the differences between tungsten-copper alloy and pure tungsten?

The greatest advantage of pure tungsten is its high melting point, good high-temperature stability, and relatively high hardness, making it suitable for special working conditions that require withstanding high temperatures or maintaining structural stability. However, the electrical conductivity of pure tungsten is lower than that of pure copper, and it has a relatively obvious brittle tendency at room temperature, which may make machining into complex precision parts more difficult. Tungsten-copper alloy improves electrical and thermal

conductivity by introducing a copper phase. Copper can help conduct current and dissipate heat, while the tungsten phase provides relatively good arc erosion resistance and hardness. Therefore, in applications that need to withstand current, thermal load, and arc impact at the same time, tungsten-copper alloy is often more suitable than pure tungsten. However, tungsten-copper alloy cannot completely replace pure tungsten. If the service environment requires extremely high temperature resistance and does not need the electrical and thermal conductivity advantages provided by the copper phase, then pure tungsten or other high-temperature materials may be more suitable.

III. What are the differences between tungsten-copper alloy and pure copper?

Pure copper has excellent electrical and thermal conductivity, as well as good plasticity and ductility, and is suitable for manufacturing wires, cables, conductive bars, and conventional heat-dissipating components. However, the hardness of pure copper is usually relatively low, and under high temperature, high contact pressure, or repeated strong arc action, problems such as softening, deformation, melting, and ablation may occur. After adding a high-melting-point, high-hardness tungsten phase, tungsten-copper alloy can improve the stability of the material in arc and thermal load environments while retaining certain electrical and thermal conductivity. Therefore, for applications such as high-load electrical contacts, resistance welding electrodes, and EDM electrodes, tungsten-copper alloy is usually more advantageous than pure copper. But if the application mainly focuses on minimum resistance, maximum thermal conductivity, good plasticity, and lower material cost, pure copper is often more suitable. The advantage of tungsten-copper alloy lies in comprehensive performance, not in being superior to pure copper in every indicator.

IV. Why does the tungsten-copper ratio affect material performance?

Common grades of tungsten-copper alloy include W50Cu50, W60Cu40, W70Cu30, W80Cu20, and W90Cu10. Among them, W70Cu30 means tungsten accounts for approximately 70% of the total mass and copper approximately 30%. Generally, under otherwise similar conditions, increasing tungsten content causes the density, hardness, and arc erosion resistance of the material to show a certain upward trend while reducing the coefficient of thermal expansion; increasing copper content is usually beneficial for improving electrical and thermal conductivity. However, the specific changes are not strictly linear under all process conditions.

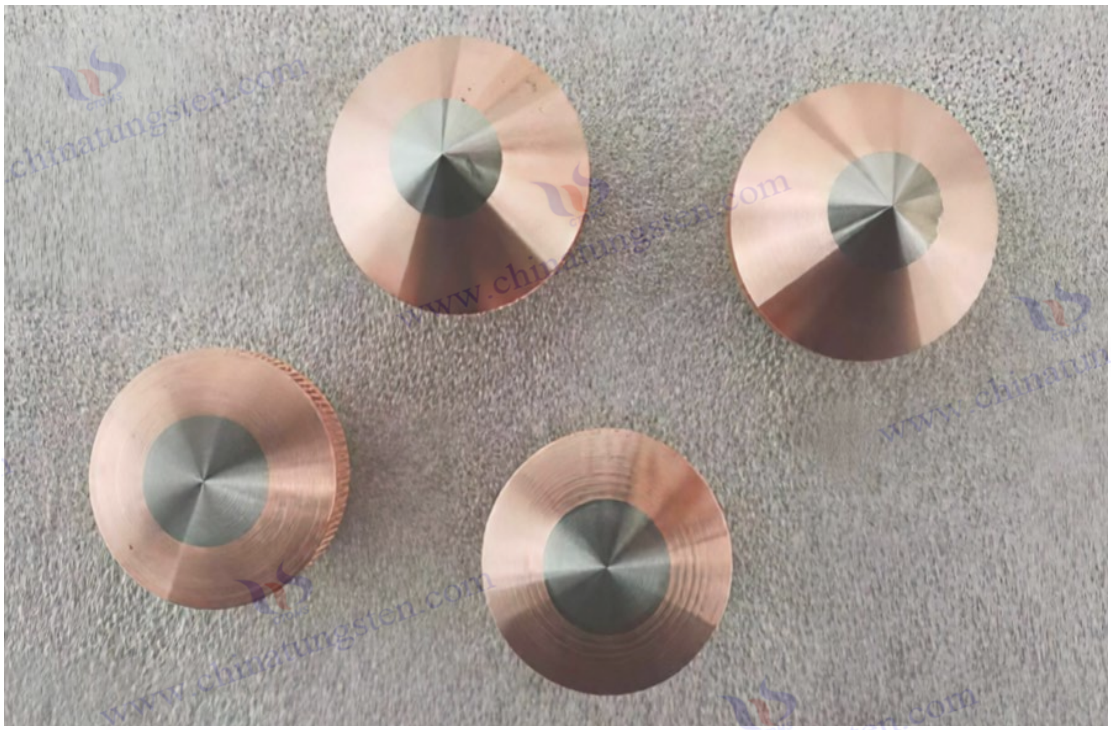
Material/grade	Main advantages	Focus when selecting
tungsten	High melting point, high-temperature stability	Extreme temperature and structural stability
copper	High electrical & thermal conductivity, good plasticity	Current transmission and heat transfer
W50Cu50	Relatively high Cu content, relatively prominent electrical and thermal conductivity	Electrical conduction and heat dissipation requirements
W70Cu30	Relatively balanced comprehensive performance	Various working conditions such as electrodes and electrical contacts
W90Cu10	Relatively high tungsten content, lower thermal expansion, usually higher hardness	Specific performance requirements for high-tungsten-content materials

For specific products, the grade should be selected in combination with working current, thermal load, mechanical load, dimensional tolerances, and service environment, and it should not be judged whether the material is better only by the level of tungsten content.

V. How should selection be made in practical applications?

If ordinary conductive components, cables, or conventional heat exchange elements need to be manufactured, pure copper is usually more economical and easier to process; if extremely high temperatures need to be withstood and the requirements for electrical and thermal conductivity are not the primary factors, pure tungsten can be considered; if electrical conduction, heat dissipation, hardness, and arc erosion resistance need to be considered at the same time, then tungsten-copper alloy can be evaluated as a priority. For electrical contacts, resistance welding electrodes, EDM electrodes, and electronic thermal management components, the density, microstructural uniformity, surface quality, and machining accuracy of the material should also be considered. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard size processing requirements; final material selection should still be based on actual working conditions, technical documents, and inspection data.

Pure tungsten highlights high-temperature resistance and structural stability, pure copper highlights electrical and thermal conductivity, and tungsten-copper alloy focuses on combining the advantages of both to achieve more suitable comprehensive performance under complex working conditions such as high current, high thermal load, and arc action.



Q6 What are the differences between tungsten-copper alloy, molybdenum-copper alloy, and silver-tungsten alloy?

Tungsten-copper alloy (W-Cu), molybdenum-copper alloy (Mo-Cu), and silver-tungsten alloy (Ag-W) all belong to composite materials composed of refractory metals and conductive metals, and are often manufactured through processes such as powder metallurgy, sintering, or metal infiltration. However, the three differ significantly in composition, performance focus, and application scenarios. Tungsten-copper alloy mainly utilizes the arc erosion resistance of tungsten and the electrical and thermal conductivity of copper, and is suitable for electrical contacts, electrodes, and thermal management components; molybdenum-copper alloy mainly utilizes the low thermal expansion characteristics of molybdenum and the thermal conductivity of copper, and is commonly used in electronic packaging and heat dissipation substrates for power devices; silver-tungsten alloy combines the high electrical conductivity of silver with the arc erosion resistance of tungsten, and is commonly used in electrical contacts that have high requirements for contact resistance, resistance to welding, and arc performance.

I. Composition and basic characteristics of the three materials

Comparison	Tungsten-copper alloy	Molybdenum-copper alloy	Silver-tungsten alloy
Main composition	Tungsten and copper	Molybdenum and copper	Silver and tungsten
Source of performance	Erosion resistance of tungsten and electrical/thermal conductivity of copper	Low thermal expansion of Mo & thermal conductivity of copper	Arc erosion resistance and high electrical conductivity of tungsten-silver
Typical performance	Balanced arc resistance, electrical conductivity, and thermal conductivity	Thermal expansion control, thermal conductivity, and dimensional stability	Electrical conductivity, resistance to welding, arc erosion resistance
Common applications	Electrical contacts, resistance welding electrodes, EDM electrodes, thermal management components	Semiconductor packaging, power device substrates, heat sinks	Electrical switch contacts, relay contacts, special electrical contacts
Main factors	Tungsten-copper ratio, erosion resistance requirements, machining accuracy	Thermal expansion matching, heat conduction requirements, weight restrictions	Contact resistance, breaking conditions, silver cost

It should be noted that the three are usually not uniform single-phase solid solutions formed by ordinary melting. Because the mutual solubility of refractory metals with copper or silver is low, actual materials often retain their respective phase structures and are combined through processes such as powder metallurgy. Therefore, in the context of materials science, it is usually more accurate to call them metal composite materials, while "alloy" remains a commodity name widely used in industry. In the table, W is tungsten, Cu is copper, Mo is molybdenum, and Ag is silver.

II. Differences between tungsten-copper alloy and molybdenum-copper alloy

Tungsten-copper alloy and molybdenum-copper alloy have similar compositional structures: both use a refractory metal phase to provide lower thermal expansion and structural support,

and then use a copper phase to improve thermal conductivity. However, tungsten and molybdenum differ in density, melting point, and mechanical properties, so the two materials have different emphases in weight, thermal expansion control, and high-temperature applications.

Different density and weight

The density of tungsten is approximately 19.25 g/cm³, and the density of molybdenum is approximately 10.28 g/cm³. Therefore, under similar refractory metal content and similar structural conditions, tungsten-copper alloy is usually heavier than molybdenum-copper alloy. Molybdenum-copper alloy has advantages in some electronic packaging, power semiconductor heat dissipation substrates, and lightweight thermal management components, especially when products need to combine a lower coefficient of thermal expansion, higher thermal conductivity, and weight control.

Different thermal expansion and thermal conductivity performance

Both tungsten-copper and molybdenum-copper can adjust the coefficient of thermal expansion by changing the copper content. Molybdenum-copper alloy is often used in applications requiring thermal expansion matching with materials such as semiconductor chips and ceramic substrates; tungsten-copper alloy has a mature application foundation in many high thermal load, electrical contact, and electrode applications. The thermal conductivity of the two cannot be judged only from the properties of elemental tungsten and molybdenum. Actual values also depend on copper content, density, manufacturing process, and microstructure. Under certain identical thermal expansion targets, the thermal conductivity performance of tungsten-copper and molybdenum-copper may differ, and comparison should be made using the data sheets of specific grades.

Different typical applications

Molybdenum-copper alloy is commonly found in semiconductor packaging, power device heat sinks, heat dissipation substrates, and precision structural parts requiring thermal expansion control; tungsten-copper alloy is more often used in electrical switch contacts, resistance welding electrodes, EDM electrodes, and parts that combine electrical conductivity, thermal conductivity, and arc erosion resistance.

III. Differences between tungsten-copper alloy and silver-tungsten alloy

The difference between tungsten-copper alloy and silver-tungsten alloy mainly lies in the conductive metal matrix. Tungsten-copper uses copper as the conductive and thermally conductive phase, while silver-tungsten uses silver as one of the matrix metals, utilizing the high electrical conductivity of silver and the arc erosion resistance of tungsten to form a composite material suitable for specific electrical contact working conditions.

Different electrical conductivity and contact characteristics

The electrical conductivity of silver is higher than that of copper, so silver-tungsten alloy can achieve higher electrical conductivity under appropriate composition and manufacturing conditions. For relay contacts, electrical switch contacts, and other applications with strict

requirements for contact resistance and contact temperature rise, silver-tungsten is worth focusing on in evaluation. However, the actual performance of contacts does not depend only on the electrical conductivity of the material; it is also related to contact pressure, surface condition, breaking current, working atmosphere, and arc duration. Silver-tungsten and tungsten-copper also cannot be directly interchanged based solely on electrical conductivity.

Different arc erosion resistance and application conditions

The tungsten phase in silver-tungsten helps improve resistance to arc erosion and reduce the tendency of contacts to weld under certain working conditions, while the silver phase provides good electrical conductivity. Tungsten-copper also has the comprehensive advantages of arc erosion resistance and electrical conductivity, but its applicable range, contact resistance performance, and requirements for the working environment are not completely the same. For example, in some high-voltage switch and vacuum switch applications, tungsten-copper may better meet design requirements; in some relay, electrical contact, and specific resistance welding applications, silver-tungsten may be more suitable. The final choice should refer to the material system specified by the equipment manufacturer and actual test results.

Different material costs

The raw material price of silver is usually higher than that of copper, so under otherwise similar conditions, the raw material cost of silver-tungsten material is often higher. However, the finished product cost also depends on silver content, tungsten content, machining accuracy, manufacturing process, and product specifications, and the final purchase price cannot be judged only by the material name.

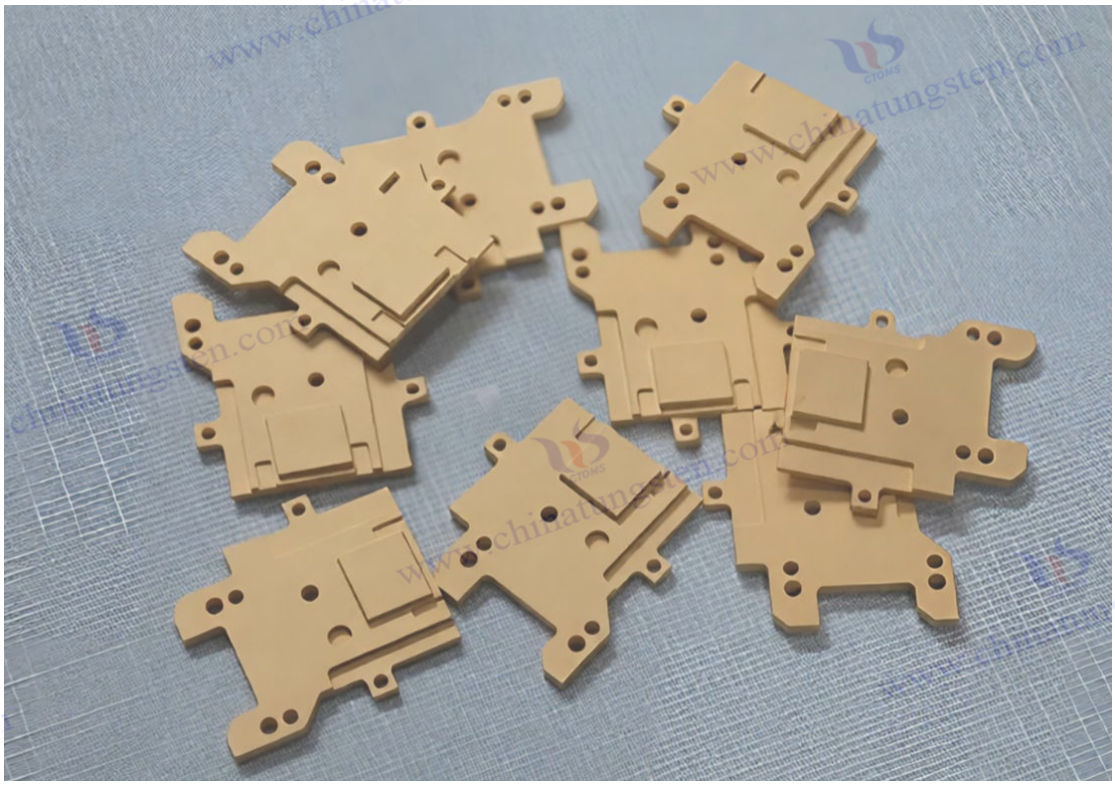
IV. How should the three materials be selected?

Actual requirement	Material that can be evaluated first	Basis for selection
High-voltage electrical contacts, arc erosion-resistant parts	Tungsten-copper alloy	Combines electrical conductivity, thermal conductivity, and arc erosion resistance
Resistance welding electrodes, EDM electrodes	Tungsten-copper alloy	Select grade according to electrode wear, electrical conductivity, and thermal load requirements
Semiconductor packaging, heat sinks, power device heat dissipation plates	Molybdenum-copper alloy or tungsten-copper alloy	Compare coefficient of thermal expansion, thermal conductivity, weight, and dimensional requirements
Electrical contacts with high requirements for contact resistance	Silver-tungsten alloy	Combine current level, contact temperature rise, and resistance-to-welding breaking requirements
Thermal management components sensitive to weight	Molybdenum-copper alloy	Evaluate density, thermal expansion matching, and thermal conductivity
Electrical components sensitive to material cost	W-Cu alloy or other applicable materials	Compare material and processing costs on the premise of meeting performance requirements

For specific projects, if tungsten-copper alloy is the main consideration, the grade and processing route can be determined in combination with operating current, working temperature, thermal load, dimensional tolerances, and product shape. CTIA GROUP, with

nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard part processing requirements of tungsten-copper materials; molybdenum-copper and silver-tungsten products should be evaluated separately according to the technical parameters and supply conditions of the corresponding materials. When selecting materials, it is recommended to focus on checking electrical conductivity, thermal conductivity, coefficient of thermal expansion, density, hardness, density/compactness, and relevant working condition test results, rather than making judgments only based on material names or a single performance item.

Tungsten-copper alloy focuses on the comprehensive balance of arc erosion resistance, electrical conductivity, and thermal conductivity; molybdenum-copper alloy focuses on the coordination among thermal expansion matching, heat dissipation, and weight; silver-tungsten alloy emphasizes electrical conductivity, arc erosion resistance, and resistance to welding in specific electrical contact applications. None of the three has an absolute advantage or disadvantage applicable to all scenarios; the key lies in whether the material characteristics match the actual working conditions.



Q7 What are the differences between tungsten-copper alloy and tungsten-nickel-iron heavy alloy?

Tungsten-copper alloy (W-Cu) and tungsten-nickel-iron heavy alloy (W-Ni-Fe) both use tungsten as an important constituent element, but the two have obvious differences in material design objectives, compositional structure, physical properties, and application directions. The most critical point is that tungsten-copper alloy mainly utilizes the high-temperature resistance and arc erosion resistance of tungsten and the high electrical and thermal conductivity of copper, while tungsten-nickel-iron heavy alloy mainly utilizes the high density of tungsten and, with the help of a binder phase formed by metals such as nickel and iron, obtains better strength, toughness, and machinability. Therefore, the two are not materials that can be directly interchanged. If the product is used for electrical contacts, electrodes, or thermal management components, tungsten-copper alloy is usually evaluated first; if it is used for high-density counterweights, radiation shielding, inertial components, or structural parts requiring relatively high mass concentration, tungsten-nickel-iron heavy alloy is often more suitable.

I. Different material composition and internal structure

Tungsten-copper alloy (W-Cu)

It is usually composed of a tungsten skeleton and copper, and is often prepared by powder metallurgy combined with liquid-phase sintering, infiltration, and other processes. Tungsten provides arc erosion resistance and high-temperature skeleton support, while copper mainly undertakes electrical and thermal conduction functions. The mutual solubility of tungsten and copper under conventional conditions is very low, so the material usually presents a composite structure in which tungsten and copper phases are distributed with each other.

Tungsten-nickel-iron heavy alloy (W-Ni-Fe)

It uses a high proportion of tungsten as the main body, and nickel and iron form a binder phase that bonds tungsten particles into a dense metal material. It is often manufactured through powder mixing, pressing, liquid-phase sintering, and subsequent processing. Its design focus is high density, relatively high strength, certain toughness, and the manufacturing capability for complex-shaped parts. The tungsten content of common tungsten-copper alloy grades is approximately 70%–90%, with the remainder mainly copper; the tungsten content of tungsten-nickel-iron heavy alloy is often approximately 90%–97%, with the remainder mainly nickel and iron. Actual composition ranges vary with grade, standard, and manufacturer, and the specific ratio cannot be determined only by material name.

II. Comparison of main performance parameters

The following table lists the typical performance ranges of the two types of materials. Specific values will vary with tungsten content, manufacturing process, porosity, and product state, so they are suitable for preliminary material selection and cannot replace the data sheets of specific grades.

Comparison item	Tungsten-copper alloy (W-Cu)	Tungsten-nickel-iron heavy alloy (W-Ni-Fe)
Main components	Tungsten, copper	Tungsten, nickel, iron
Typical tungsten content	70%–90%	90%–97%
Typical density	Approximately 13.8–17.0 g/cm³	Approximately 17.0–18.5 g/cm³
Electrical conductivity	Relatively good, suitable for electrical conduction and electrical contact applications	Usually does not take high electrical conductivity as its main advantage
Thermal conductivity	Usually relatively good, suitable for heat dissipation and heat conduction	Has certain thermal conductivity, but usually not the primary material selection advantage
Thermal expansion characteristics	Low coefficient of thermal expansion, can be used for thermal management components	Low coefficient of thermal expansion, specific value depends on grade
Strength and toughness	Relatively high strength, but ductility is usually limited	Usually combines relatively high strength and certain elongation, with better impact resistance
Arc erosion resistance	One of the main advantages	Usually not the main design purpose
High-density counterweight capability	Relatively high density, but generally lower than high-tungsten-content heavy alloy	Outstanding density advantage, suitable for increasing mass within limited space
Common processing methods	Powder metallurgy, infiltration, precision cutting and grinding	Powder metallurgy, liquid-phase sintering, cutting and grinding

From the perspective of density, the advantage of tungsten-nickel-iron heavy alloy is relatively obvious. For example, tungsten-nickel-iron heavy alloy with a tungsten content of 90% has a typical density of approximately 17.0 g/cm³; tungsten-copper alloy with a tungsten content of 80% has a typical density of approximately 15.15 g/cm³. Under the same volume, the former is usually heavier.

However, it cannot therefore be considered that tungsten-nickel-iron heavy alloy is superior to tungsten-copper alloy in all performance aspects. For requirements such as current conduction, rapid heat dissipation, and arc erosion resistance, the material characteristics of tungsten-copper alloy are more targeted.

III. What are the differences in application fields?

Tungsten-copper alloy: electrical and thermal management components

It is mainly used for high-voltage switch contacts, vacuum electrical contacts, resistance welding electrodes, EDM electrodes, heat dissipation substrates and heat sinks for electronic devices, etc. These applications usually focus simultaneously on electrical conductivity, thermal conductivity, thermal expansion control, and arc erosion resistance.

Tungsten-nickel-iron heavy alloy: high-density and structural-functional components

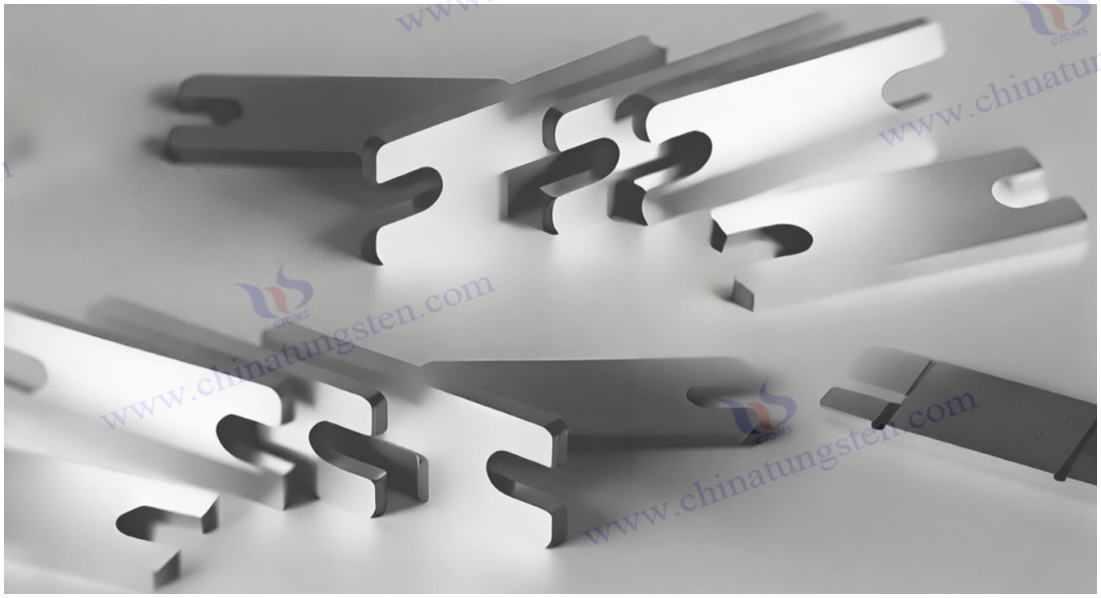
It is mainly used for precision counterweights, aerospace inertial components, vibration and recoil control components, industrial equipment counterweights, and some radiation shielding components. Its high density can achieve greater mass in a smaller volume, and good strength and toughness are conducive to manufacturing complex-shaped parts. It should be

distinguished that although tungsten-nickel-iron heavy alloy contains a large amount of tungsten, it is not pure tungsten, nor is it a tungsten-based electrical contact material specially designed for high-temperature electrodes. If it is used to replace tungsten-copper alloy for making electrical contacts or electrodes, contact resistance, temperature rise, arc erosion, and service life must be re-evaluated, and judgment cannot be made only based on tungsten content.

IV. How to judge in actual material selection?

If the project mainly focuses on current carrying, electrical conduction, heat dissipation, and arc erosion resistance, tungsten-copper alloy should be evaluated first, and an appropriate tungsten-copper ratio should be selected according to working current, working temperature, thermal load, and product size. For parts that need to increase mass, control the center of gravity, improve inertia, or achieve high density within limited space, tungsten-nickel-iron heavy alloy should be evaluated first, and density, strength, elongation, dimensional tolerances, and processing requirements should be further checked.

For custom requirements for tungsten-copper alloy parts, CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard processing requirements; when tungsten-nickel-iron heavy alloy is involved, it should be evaluated separately according to the density, mechanical properties, and processing conditions of the specific grade. In addition, if the part needs to combine shielding capability with structural strength, the design should be carried out in combination with radiation type, energy, required attenuation degree, part thickness, and actual service environment, rather than determining the shielding effect solely by material density. The core advantages of tungsten-copper alloy are electrical conductivity, thermal conductivity, and arc erosion resistance; the core advantages of tungsten-nickel-iron heavy alloy are higher density, relatively good strength and toughness, and high mass concentration. The selection of the two should be determined by the actual function of the part, rather than simply comparing which has higher tungsten content.



Q8 What are the main classifications and application fields of tungsten-copper alloy?

Tungsten-copper alloy (W-Cu) is a composite material composed of tungsten (W) and copper (Cu), combining the high hardness and arc erosion resistance of tungsten with the good electrical and thermal conductivity of copper. Because the mutual solubility of tungsten and copper under conventional conditions is very low, industrial tungsten-copper alloy is usually manufactured by processes such as powder metallurgy and copper infiltration, rather than a uniform solid solution alloy formed by ordinary melting. Tungsten-copper alloy does not have a single classification method; actual material selection is usually distinguished in combination with the tungsten-copper ratio, use, product shape, and manufacturing process. Among them, the tungsten-copper ratio is the core factor affecting material performance and application direction.

I. Classification according to tungsten-copper ratio

Common grades include tungsten-copper (W-Cu) 50/50, 60/40, 70/30, 75/25, 80/20, and 90/10. The first number usually represents the mass percentage of tungsten, and the second number represents the mass percentage of copper. For example, W80Cu20 means the nominal composition is 80% tungsten and 20% copper. Grade standards and performance indicators of different manufacturers may differ.

Common grade	Main performance tendency	Typical application
W50Cu50	Higher copper content, better electrical and thermal conductivity	Specific electrodes and functional parts for electrical conduction and heat dissipation
W60Cu40	Balances electrical conductivity, thermal conductivity, and wear resistance	Some electrical machining electrodes, conductive parts
W70Cu30	Relatively balanced electrical conductivity, thermal conductivity, and erosion resistance	Resistance welding electrodes, some electrical contacts
W75Cu25	Balances strength, wear resistance, and electrical conductivity	Welding mold inserts, electrodes, and high-load contact parts
W80Cu20	Relatively outstanding arc erosion resistance while retaining certain thermal and electrical conductivity	Medium- and high-voltage electrical contacts, precision EDM electrodes
W90Cu10	High tungsten content, usually higher density, hardness, and lower coefficient of thermal expansion, with relatively reduced electrical and thermal conductivity	Specific high-erosion-resistance electrodes, precision electrical machining, and high-tungsten-content functional parts

The above are general material selection directions, not fixed applicable ranges for all products. Actual performance is also affected by powder particle size, density, microstructural uniformity, processing state, and technical standards. For example, it cannot be assumed that W90Cu10 is necessarily more suitable for a certain electrode than W80Cu20 simply because of its higher tungsten content; electrode wear, machining efficiency, surface quality, and working conditions also need to be compared.

II. Classification according to main application fields

Power equipment and high-voltage electrical contacts

Mainly used for medium- and high-voltage circuit breaker contacts, vacuum switch contacts, load switch contacts, and other electrical components that need to withstand arcs. The tungsten phase helps improve arc erosion resistance, while the copper phase helps conduct electricity and dissipate heat, reducing local heat accumulation. Such applications often use ratios such as W70Cu30 and W80Cu20, depending on breaking current, voltage level, contact structure, and life requirements.

EDM electrodes

Electrical discharge machining (EDM) uses pulsed discharge to remove workpiece material and is suitable for machining cemented carbide, hardened steel, and complex mold cavities. Tungsten-copper electrodes have relatively good erosion resistance, electrical conductivity, and dimensional stability, and can be used for precision mold electrodes and complex contour machining. W70Cu30, W80Cu20, and W90Cu10 all have corresponding applications, and selection should be based on electrode wear, machining accuracy, discharge parameters, and surface quality requirements.

Resistance welding and electrical machining molds

Used as inserts for resistance spot welding, projection welding, seam welding, electric upsetting, and some electrical machining molds. The material needs to maintain certain shape stability under the action of current, pressure, and repeated thermal cycles, while controlling wear and heat accumulation. Actual material selection should be combined with the type of metal to be welded, welding pressure, working cycle, and electrode cooling conditions, and cannot rely only on the tungsten-copper ratio.

Electronic packaging and thermal management

Used for power semiconductor device substrates, heat sinks, heat spreader plates, and some packaging components of high-power electronic equipment. Tungsten-copper alloy has a relatively low coefficient of thermal expansion and certain thermal conductivity, which can help reduce thermal stress caused by thermal expansion mismatch of materials. For such products, in addition to thermal conductivity, the coefficient of thermal expansion, flatness, surface roughness, airtightness requirements, and packaging connection process should also be mainly checked.

Special thermal load and high-temperature functional components

In some high heat flux density, strong thermal shock, or special arc environments, tungsten-copper alloy can be used for electrodes, conductive components, and local erosion-resistant parts. Its applicability depends on working temperature, heat flux density, cooling method, and environmental medium. Because the melting point of copper is significantly lower than that of tungsten, tungsten-copper alloy is not equivalent to pure tungsten material that can be used for a long time at arbitrary high temperatures; high-temperature applications must verify whether the copper phase will soften, melt, or be lost.

III. Classification according to product form

In procurement and manufacturing, tungsten-copper alloy can also be distinguished according to product form. Common forms include rods, plates, discs, blocks, tubular parts, contact blanks, electrode blanks, and special-shaped parts processed according to drawings. Standard rods and plates are suitable for subsequent machining; electrode and contact products usually need to control working-end dimensions, coaxiality, and surface quality; electronic packaging components pay more attention to flatness, thickness tolerance, thermal expansion matching, and surface treatment. If non-standard parts are involved, in addition to determining the tungsten-copper ratio, product drawings, dimensional tolerances, service environment, electrical or thermal conductivity requirements, and expected service life should also be provided. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard part processing requirements of tungsten-copper alloy.

IV. How to choose tungsten-copper alloy for different requirements?

Actual requirement	Direction to evaluate first	Key points for material selection
High-voltage electrical contacts	W70Cu30, W80Cu20, etc.	Arc erosion resistance, contact resistance, breaking life
Precision EDM	W70Cu30, W80Cu20, W90Cu10, etc.	Electrode wear, machining accuracy, surface quality
Resistance welding electrodes	Select an appropriate ratio according to welding load	Electrical and thermal conductivity, wear resistance, deformation resistance
Electronic packaging and heat sinks	Select composition according to thermal expansion matching	Thermal conductivity, coefficient of thermal expansion, dimensional tolerances
High-temperature or special thermal load components	Evaluate according to specific working conditions	Upper temperature limit, copper phase stability, cooling conditions

It needs to be particularly distinguished that the application classification and grade classification of tungsten-copper alloy are not in one-to-one correspondence. The same ratio may be used in different fields, and the same application may also use different ratios. The final choice should be based on actual technical indicators, product standards, and test verification, and judgment cannot be made solely by material name or tungsten content.



B. Tungsten-Copper Alloy Grades and Compositions

Q9. What are the common grades of tungsten-copper alloy?

The common grades of tungsten-copper alloy (W-Cu) are mainly classified according to the mass percentages of tungsten and copper, such as W50Cu50, W60Cu40, W70Cu30, W75Cu25, W80Cu20, W85Cu15, and W90Cu10. Different grades differ in electrical conductivity, thermal conductivity, hardness, density, and resistance to arc erosion, so they need to be selected according to specific applications.

I. Common tungsten-copper alloy grades

grade	Tungsten	Copper	Main performance characteristics
W50Cu50	50%	50%	High copper content, relatively good electrical and thermal conductivity
W55Cu45	55%	45%	Balances electrical conductivity, thermal conductivity, and a certain degree of wear resistance
W60Cu40	60%	40%	Relatively good electrical and thermal conductivity, with a certain strength
W65Cu35	65%	35%	Achieves a balance between electrical conductivity, thermal conductivity, and erosion resistance
W70Cu30	70%	30%	Relatively balanced comprehensive performance, widely used
W75Cu25	75%	25%	Good erosion resistance, hardness, and dimensional stability
W80Cu20	80%	20%	Relatively outstanding arc erosion resistance, lower coefficient of thermal expansion
W85Cu15	85%	15%	High tungsten content, usually higher density and hardness
W90Cu10	90%	10%	High tungsten content, suitable for some high erosion resistance and low thermal expansion requirements

The above grades and composition ranges may refer to the technical data of tungsten-copper

alloy suppliers. The ratios in the table represent nominal mass percentages, and actual permissible deviations should be based on product standards and supply technical agreements.

II. In which fields are different grades mainly used?

Grades with relatively high copper content, such as W50Cu50, W55Cu45, and W60Cu40, usually focus more on electrical and thermal conductivity and can be used for some conductive parts and specific electrodes. W70Cu30 and W75Cu25 have relatively balanced comprehensive performance and are often used for resistance welding electrodes, electrical machining electrodes, and some electrical contact parts. Grades with relatively high tungsten content, such as W80Cu20, W85Cu15, and W90Cu10, usually have higher density, higher hardness, and a lower coefficient of thermal expansion, and are suitable for some electrical contacts, precision EDM electrodes, and parts with higher requirements for erosion resistance and dimensional stability. The specific grade still needs to be determined according to actual working conditions.

III. What should be noted when selecting a grade?

For tungsten-copper alloy, higher tungsten content is not necessarily better. As tungsten content increases, material density, hardness, and erosion resistance usually increase, but electrical and thermal conductivity often decrease. For electrical contacts, the breaking current, contact resistance, and arc life should be evaluated with emphasis; for EDM electrodes, electrode wear, machining efficiency, and surface quality should be considered; for electronic packaging and heat dissipation parts, thermal conductivity, coefficient of thermal expansion, and dimensional tolerances should be checked with emphasis. If standard materials or custom machined parts need to be purchased, the specific grade can be determined according to product drawings, working environment, and target performance. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard part processing requirements.

In addition, W70Cu30, W75Cu25, etc. are composition designation methods, and different suppliers may also use other internal grades or standard classifications. During inquiry and procurement, it is recommended to simultaneously confirm the tungsten and copper contents and permissible deviations, density, electrical conductivity, hardness, product dimensions, and inspection requirements, so as to avoid judging whether materials are completely identical solely by grade name.

Q10. What is the difference between W70Cu30 and W80Cu20?

W70Cu30 and W80Cu20 are both common tungsten-copper alloy (W-Cu) grades. The main difference lies in the different tungsten and copper contents: W70Cu30 contains 70% tungsten and 30% copper; W80Cu20 contains 80% tungsten and 20% copper, with the ratios calculated by mass. The performance trade-off between the two can be summarized as follows: W70Cu30 usually has better electrical and thermal conductivity; W80Cu20 usually has higher density, hardness, and strength and a lower coefficient of thermal expansion, making it suitable for some applications with higher requirements for arc erosion resistance and dimensional stability.

I. Main performance comparison between W70Cu30 and W80Cu20

The following table uses typical data from publicly available supplier technical data for comparison. Different manufacturing processes, material density, testing methods, and standards may cause numerical differences, so these data are suitable for preliminary material selection and should not be directly regarded as guaranteed values for all products.

Performance	W70Cu30	W80Cu20	Main difference
Tungsten	70%	80%	W80Cu20 has higher tungsten content
Copper	30%	20%	W70Cu30 has higher copper content
Density	Approx. 13.8–14.2 g/cm³	Approx. 15.15 g/cm³	W80Cu20 is higher
Hardness	Approx. 175 HB	Approx. 220 HB	W80Cu20 is usually harder
Bending strength	Approx. 667–790 MPa	Approx. 736–980 MPa	W80Cu20 is usually higher
Electrical conductivity	Approx. 42% International Annealed Copper Standard (IACS)	Approx. 34% IACS	W70Cu30 is usually higher
Thermal conductivity	Approx. 200–220 W/(m·K)	Approx. 180–200 W/(m·K)	W70Cu30 is usually higher
Coefficient of thermal expansion	Approx. 9–10 × 10^{-6}/K	Approx. 7.7–8.3 × 10^{-6}/K	W80Cu20 is usually lower

Data sources: publicly available tungsten-copper alloy performance tables from Midwest Tungsten, Torrey Hills Technologies, and other suppliers. Specific values for indicators such as hardness, bending strength, and thermal conductivity will vary with product processes.

II. Why do W70Cu30 and W80Cu20 have different performance?

The main reason is the different ratio of tungsten to copper. When the tungsten content increases from 70% to 80%, the proportion of the tungsten phase in the material increases and the proportion of the copper phase decreases, which usually increases material density, hardness, and bending strength while reducing the coefficient of thermal expansion. W70Cu30, with higher copper content, usually has better electrical and thermal conductivity, which is conducive to current transmission and heat dissipation. However, arc erosion resistance is not determined solely by tungsten content; it is also closely related to microstructural uniformity, density, manufacturing process, and actual working conditions.

III. Which applications are the two grades suitable for?

W70Cu30: Scenarios that place more emphasis on electrical and thermal conductivity

W70Cu30 is often used for resistance welding electrodes, some EDM electrodes, electrical conductive parts, and parts that need to combine heat dissipation and wear resistance. If the equipment operates with relatively high current, heat needs to be dissipated quickly, or both machinability and material cost need to be considered, this grade can be evaluated first.

W80Cu20: Scenarios that place more emphasis on erosion resistance, hardness, and dimensional stability

W80Cu20 is often used for some medium- and high-voltage electrical contacts, vacuum switch contacts, precision EDM electrodes, and parts with requirements for low thermal expansion and relatively high hardness. If the part needs to withstand repeated arc action, maintain a relatively stable shape, or needs to match low-thermal-expansion materials, W80Cu20 is usually worth evaluating first.

IV. Which one should be selected in actual material selection?

Usage requirement	Recommended priority evaluation	Key judgment basis
Higher electrical & thermal conductivity	W70Cu30	Electrical conductivity, thermal conductivity, working temperature rise
Higher hardness & strength	W80Cu20	Hardness, bending strength, mechanical load
Resistance welding electrodes	Select according to welding conditions	Workpiece material, welding current, cooling conditions
High-voltage electrical contacts	W70Cu30, W80Cu20	Breaking current, arc erosion resistance, contact life
Precision EDM	Select according to electrode wear & machining accuracy	Electrode wear rate, machining efficiency, surface quality
Parts requiring low thermal expansion	Usually prioritize evaluation of W80Cu20	Thermal expansion matching, thermal cycle stability

For specific projects, judgment should not be based solely on the grade; density, hardness, electrical conductivity, thermal conductivity, dimensional tolerances, and corresponding inspection standards should also be confirmed. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard part processing requirements.

If the main goal is electrical and thermal conductivity, W70Cu30 can be considered first; if more attention is paid to hardness, strength, low thermal expansion, and arc erosion resistance, W80Cu20 can be considered first, and the final decision should be made according to actual working conditions and material inspection data.



11. What scenarios are W50Cu50, W60Cu40, and W90Cu10 respectively suitable for?

The main differences among W50Cu50, W60Cu40, and W90Cu10 lie in copper content, electrical and thermal conductivity, hardness, and thermal expansion characteristics. W50Cu50 focuses more on electrical and thermal conductivity, W60Cu40 is suitable for scenarios that require a balance of electrical conductivity, thermal conductivity, and certain mechanical properties, while W90Cu10 focuses more on high hardness, low thermal expansion, and arc erosion resistance.

I. Performance comparison of the three grades W50Cu50, W60Cu40, and W90Cu10

Performance indicator	W50Cu50	W60Cu40	W90Cu10
Tungsten content (mass fraction)	50%	60%	90%
Copper content (mass fraction)	50%	40%	10%
Typical density	≥11.85 g/cm³	≥12.75 g/cm³	≥16.75 g/cm³
Typical hardness	≥115 HB	≥140 HB	≥260 HB
Typical electrical conductivity	≥54% IACS	≥47% IACS	≥27% IACS
Thermal expansion coefficient trend	Relatively high	Medium	Relatively low

The table lists typical indicators or minimum guaranteed values published by suppliers, and data from different suppliers cannot be directly regarded as precise comparisons under the same testing conditions. IACS (International Annealed Copper Standard) is used to express relative electrical conductivity; HB (Brinell Hardness) is used to express material hardness.

II. W50Cu50: suitable for scenarios that place more emphasis on electrical and thermal conductivity

W50Cu50 has a copper content of 50% and generally has the highest electrical conductivity and thermal conductivity among these three grades, making it suitable for specific electrodes and conductive parts that require good current transmission and heat dissipation.

Typical applications include some resistance welding electrodes, conductive connection parts, thermal management components, and certain electrical parts that need to combine electrical conductivity with a certain degree of arc erosion resistance. For structures requiring efficient heat dissipation, it can also be listed as a candidate material. However, the hardness, density, and low thermal expansion capability of W50Cu50 are generally inferior to those of higher-tungsten-content grades. If the working conditions involve strong arc erosion, high mechanical loads, or strict thermal expansion matching requirements, materials with higher tungsten content need to be further evaluated.

III. W60Cu40: suitable for scenarios that balance electrical conductivity, thermal conductivity, and mechanical properties

W60Cu40 has a tungsten content of 60% and a copper content of 40%. Compared with W50Cu50, it generally has higher hardness and density while still maintaining good electrical and thermal conductivity, and can be used for electrical machining and electrical parts that require a certain degree of wear resistance and structural stability. Common evaluation directions include resistance welding electrodes, some EDM electrodes, conductive contacts, and conductive parts requiring certain mechanical strength. It is suitable for applications that require electrical conductivity, heat dissipation, and wear resistance but do not need particularly high tungsten content. It should be noted that W60Cu40 is not necessarily the best compromise in all applications. Electrode wear, machining efficiency, working temperature, and cooling method differ, and the ultimately suitable tungsten-copper ratio may also differ.

IV. W90Cu10: suitable for high hardness, low thermal expansion, and arc erosion resistance requirements

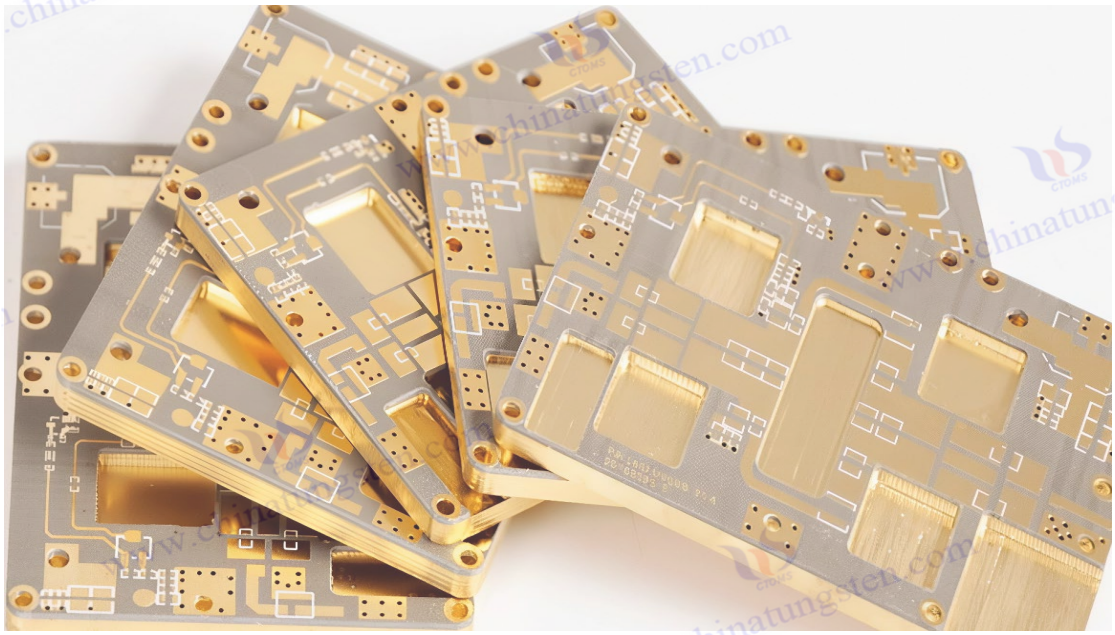
W90Cu10 has a tungsten content of 90%, and its density and hardness are generally higher than those of the previous two grades, with a lower coefficient of thermal expansion, but its electrical conductivity and thermal conductivity generally decrease. Its main evaluation directions include precision functional parts with relatively high low-thermal-expansion requirements, some EDM electrodes, and special electrical parts requiring relatively high hardness and arc erosion resistance. When used for electrical contacts, dedicated verification is also required based on voltage, current, breaking method, contact resistance, and arc life. W90Cu10 does not mean that it can withstand high temperatures without limit. Tungsten-copper materials still contain a copper phase, and the actual working temperature and thermal load must match the material structure, cooling conditions, and service environment.

V. Practical material selection recommendations for W50Cu50, W60Cu40, and W90Cu10

Application requirement	Grade to evaluate first	Main considerations
Higher electrical , thermal conductivity	W50Cu50	Electrical conductivity, thermal conductivity, temperature rise
Balance of electrical conductivity, thermal conductivity, hardness	W60Cu40	Electrical performance, wear resistance, mechanical load
Higher hardness, low thermal expansion	W90Cu10	Hardness, coefficient of thermal expansion, dimensional stability
Resistance welding electrodes	W50Cu50, W60Cu40,	Welding current, pressure, cooling conditions
EDM electrodes	Evaluate W60Cu40 or W90Cu10	Electrode wear, machining efficiency, precision
Special arc contacts	Select according to breaking conditions	Arc erosion resistance, contact resistance, service life

For specific tungsten-copper alloy projects, the material ratio can be determined in combination with product drawings, working current, thermal load, dimensional tolerances, and performance indicators. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, specification matching, and non-standard part processing requirements.

W50Cu50 leans more toward electrical and thermal conductivity, W60Cu40 leans more toward balancing electrical conductivity, thermal conductivity, and mechanical properties, and W90Cu10 leans more toward high hardness, low thermal expansion, and arc erosion resistance. In actual material selection, the basis should be the actual working conditions and the inspection data of the corresponding grade.



Q12. How are the tungsten content and copper content in tungsten-copper alloy determined?

The contents of tungsten and copper in tungsten-copper alloy (W-Cu) are mainly determined according to the product's service conditions, target performance, structural dimensions, and manufacturing process, rather than simply pursuing the highest possible content of a certain element. The basic rule is: increasing tungsten content generally helps increase material density, hardness, and dimensional stability, and reduces the coefficient of thermal expansion; increasing copper content generally helps improve electrical and thermal conductivity. Actual material selection requires a balance among these properties.

I. First clarify the most important performance requirements of the tungsten-copper alloy product

Before determining the tungsten-copper ratio, it should first be determined what function the product mainly undertakes.

Main requirement	Content selection direction	Key considerations
High electrical conductivity, high thermal conductivity	Appropriately increase copper content	Electrical conductivity, thermal conductivity, temperature rise
High hardness, relatively high strength	Appropriately increase tungsten content	Hardness, strength, wear resistance
Arc erosion resistance	Usually prioritize evaluation of higher-tungsten-content grades	Arc energy, breaking conditions, material loss
Low thermal expansion	Usually increase tungsten content	Coefficient of thermal expansion, expansion matching with mating materials
Electronic packaging and heat dissipation	Determined jointly according to thermal expansion and thermal conductivity targets	Thermal conductivity, coefficient of thermal expansion, packaging reliability
High-temperature or thermal cycling environments	Determined according to actual temperature and cooling conditions	Thermal shock, copper phase stability, cycle life

A special distinction needs to be made here: high thermal conductivity and low thermal expansion are not the same goal. Some electronic packaging components need to simultaneously satisfy good heat dissipation capability and a coefficient of thermal expansion matching that of chips and ceramic materials, so the ratio cannot be determined solely by copper content or tungsten content.

II. Determine a preliminary ratio based on common tungsten-copper alloy grades in the industry

The following table can be used for preliminary material selection; actual performance should be based on the technical data and inspection reports of the specific supplier.

Common tungsten-copper alloy grades of CTIA GROUP

Grade	Tungsten	Copper	Main selection tendency
W50Cu50	50%	50%	Emphasis on electrical and thermal conductivity
W60Cu40	60%	40%	Balance of electrical conductivity, thermal conductivity, and certain hardness
W70Cu30	70%	30%	Relatively balanced comprehensive performance
W75Cu25	75%	25%	Balance of strength, arc erosion resistance, and electrical conductivity
W80Cu20	80%	20%	Emphasis on arc erosion resistance, hardness, and low thermal expansion
W85Cu15	85%	15%	Emphasis on dimensional stability and hardness brought by high tungsten content
W90Cu10	90%	10%	Emphasis on low thermal expansion, relatively high hardness, and specific arc erosion resistance requirements

These ratios of CTIA GROUP generally represent mass fractions, not volume fractions. For example, W80Cu20 means tungsten accounts for 80% of the total mass and copper accounts for 20%. Because the densities of tungsten and copper differ greatly, the same mass ratio does not mean that the two occupy the same volume ratio.

III. Determine the theoretical ratio of tungsten-copper alloy by calculation

If the product needs to meet a specific target density, the tungsten-copper ratio can first be estimated using the theoretical density relationship of mixed materials, and then verified through trial production and testing. Under ideal conditions ignoring porosity, impurities, and volume changes, the theoretical density can be approximately expressed as: $\rho = 1 / (w/\rho_W + (1-w)/\rho_{Cu})$. Where ρ is the theoretical density of tungsten-copper alloy, w is the mass fraction of tungsten, ρ_W is the density of tungsten, and ρ_{Cu} is the density of copper. At room temperature, the density of tungsten can be approximately taken as 19.3 g/cm³ and the density of copper as 8.96 g/cm³.

However, this calculation can only provide a theoretical estimate. The density of actual powder metallurgy products is also affected by porosity, densification degree, copper infiltration conditions, and manufacturing process. If the goal is to determine the actual product formula, electrical conductivity, thermal conductivity, hardness, and microstructural uniformity must also be verified simultaneously.

IV. Do not rely only on the tungsten-copper ratio; also consider the manufacturing process

Even if two batches of material are both marked as W80Cu20, their actual performance may differ. Factors such as powder particle size, pore structure of the tungsten skeleton, copper infiltration integrity, sintering conditions, and subsequent heat treatment can all affect final performance. Therefore, when purchasing or customizing, it is recommended to write tungsten content and copper content into the technical requirements together with density, hardness, electrical conductivity, thermal conductivity, coefficient of thermal expansion, and dimensional tolerances. For electrical contacts and electrodes, verification should also be carried out in combination with actual current, pressure, temperature, and arc conditions.

If a tungsten-copper alloy with a specific ratio needs to be customized, material selection can

be carried out in combination with product drawings, target performance, and manufacturing method. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for material grades, composition ratios, specification matching, and non-standard processing requirements.

In short, first determine the core performance requirements of the product, then select a preliminary tungsten-copper ratio, and then verify it through theoretical calculation, manufacturing process, and actual testing. This is the reliable method for determining the tungsten content and copper content in tungsten-copper alloy.





Q13. Does higher tungsten content mean better comprehensive performance of tungsten-copper alloy?

Based on CTIA GROUP's many years of accumulated experience, it is believed that higher tungsten content in tungsten-copper alloy (W-Cu) does not mean better comprehensive performance, but rather means that the performance focus of the material changes. As tungsten content increases, the material generally has higher density, hardness, and a lower coefficient of thermal expansion, and under certain working conditions it is also beneficial for improving arc erosion resistance; at the same time, electrical conductivity and thermal conductivity generally decrease, and the processing characteristics of the material may also change. Therefore, the key to judging whether a tungsten-copper alloy is suitable is not to pursue the highest tungsten content, but to see whether the material performance matches the actual working conditions.

I. Which properties change when tungsten content increases?

Performance indicator	Common trend when W increases	Impact on actual application
Density	Generally increases	Greater mass for the same volume
Hardness	Generally increases	Beneficial for some wear-resistant and high-load applications
Coefficient of thermal expansion	Generally decreases	More suitable for parts with low thermal expansion requirements
Electrical conductivity	Generally decreases	May increase resistance and current transmission loss
Thermal conductivity	Generally decreases	Heat dissipation capability may weaken
Arc erosion resistance	May improve under appropriate conditions	Beneficial for some electrical contact and electrode applications, not determined solely by tungsten content
Processing characteristics	Changes with composition and process	Cutting, grinding, processing costs need to be considered

These trends are general rules, and specific values also depend on material density, tungsten particle size, microstructural uniformity, manufacturing process, and testing conditions.

II. Understanding performance differences through common grades

The following takes W50Cu50, W70Cu30, W80Cu20, and W90Cu10 as examples. The numbers in the grades represent the nominal mass percentages of tungsten and copper.

Grade	Main performance tendency	Applications more worth evaluating
W50Cu50	High copper content, generally more focused on electrical and thermal conductivity	Specific conductive parts, thermal management components
W70Cu30	Relatively balanced electrical conductivity, thermal conductivity, and arc erosion resistance	Resistance welding electrodes, some electrical contacts
W80Cu20	Higher tungsten content, generally higher hardness and lower coefficient of thermal expansion	Some electrical contacts, precision EDM electrodes
W90Cu10	High tungsten content, generally higher density, hardness, and lower coefficient of thermal expansion	Specific high-arc-erosion-resistance electrodes, low-thermal-expansion functional parts

The above applications are preliminary material selection directions and do not mean that the same grade is suitable for all corresponding working conditions. In particular, electrical contacts and electrodes still need to be judged in combination with current, working temperature, contact resistance, arc energy, and service life.

III. Why does high tungsten content not necessarily bring better comprehensive performance?

First, electrical and heat dissipation requirements may conflict with the advantages of high tungsten content. If a part needs to quickly conduct current and heat, a material with higher copper content may be more suitable; if tungsten content is increased blindly, resistance may instead increase and heat dissipation efficiency may decrease.

Second, the arc erosion resistance of the material is not completely determined by tungsten content. The porosity, microstructural uniformity, copper phase distribution, and processing quality of tungsten-copper alloy are equally important. In some cases, improvements in microstructure and manufacturing process are more valuable than simply increasing tungsten content.

Third, low thermal expansion, high hardness, and high thermal conductivity cannot always reach their best states simultaneously. For example, electronic packaging components need to achieve a balance between thermal conductivity and thermal expansion matching; EDM electrodes need to comprehensively consider electrode wear, machining speed, and workpiece surface quality.

IV. How should tungsten content be determined in actual material selection?

It is recommended to determine priorities according to the main function of the product, and then select the corresponding tungsten-copper ratio. If the main goal is electrical and thermal

conductivity, key comparisons should be made among electrical conductivity, thermal conductivity, and working temperature rise; if the main goal is arc erosion resistance, attention should be paid to arc conditions, contact life, and material loss; if the main goal is low thermal expansion and dimensional stability, the coefficient of thermal expansion, working temperature, and expansion characteristics of mating materials should be compared.

For non-standard tungsten-copper alloy parts, density, hardness, dimensional tolerances, product shape, and manufacturing process should also be checked simultaneously. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, composition ratios, specification matching, and non-standard processing requirements.

Higher tungsten content generally means the material leans toward high density, high hardness, and low thermal expansion; higher copper content is generally more conducive to electrical and thermal conductivity. There is no optimal tungsten content suitable for all scenarios, and a truly reasonable ratio should be jointly determined by the product's working conditions and target performance.

Q14 How to choose the tungsten-copper ratio according to electrical conductivity, thermal conductivity, and arc resistance requirements?

When choosing the ratio of tungsten-copper alloy (W-Cu), the core is to strike a balance among electrical conductivity, heat dissipation efficiency, and resistance to arc erosion according to the main working conditions of the product. Generally, grades with higher copper content are more conducive to electrical and thermal conductivity, while grades with higher tungsten content usually have higher hardness, a lower coefficient of thermal expansion, and are suitable for some scenarios with relatively high requirements for resistance to arc erosion. In actual material selection, it is recommended to first determine the most important performance indicators and then select candidate grades, rather than directly choosing the material with the highest tungsten content.

I. Determine the preliminary ratio according to the three core performance requirements

Main performance requirement	Grades that can be evaluated first	Selection logic
Electrical conductivity priority	W50Cu50, W60Cu40	Higher copper content, usually more conducive to current transmission
Thermal conductivity priority	W50Cu50, W60Cu40, W70Cu30	Usually more conducive to heat conduction, but actual thermal conductivity needs to be checked
Balanced electrical conductivity& arc erosion resistance	W60Cu40, W70Cu30	Balance among electrical conductivity, thermal conductivity, and arc erosion resistance requirements
Electrical performance & arc erosion resistance	W70Cu30, W75Cu25, W80Cu20	Suitable for further evaluation of some electrical contact and electrode working conditions
Arc erosion resistance priority	W80Cu20, W85Cu15, W90Cu10	High tungsten content is conducive to hardness, low thermal expansion, and some arc erosion resistance requirements

The above is only a preliminary screening range, not a fixed grade correspondence. Product performance, material density, and testing conditions may differ among different manufacturers, and the final judgment should be based on specific technical data and actual working condition verification.

II. How to choose for different application scenarios?

High electrical conductivity requirements: prioritize evaluating high-copper-content grades

If the part mainly undertakes large-current transmission, the focus should be on electrical conductivity, contact resistance, and working temperature rise. Evaluation can start with W50Cu50 and W60Cu40; if certain wear resistance, strength, or arc erosion resistance is also required, W70Cu30 can also be compared. Electrical conductivity cannot be judged only by the nominal composition of the material; the part's cross-sectional area, conductive path length, contact pressure, and connection interface must also be considered. For current-carrying parts, actual resistance and temperature rise tests should be used to confirm whether the material meets the requirements.

High thermal conductivity requirements: compare thermal conductivity and coefficient of thermal expansion at the same time

For electronic packaging, heat sinks, and heat dissipation parts of high-power devices, copper content alone cannot be used to judge whether the material is suitable. Grades with higher copper content usually have better thermal conductivity, but if the part needs to be connected to ceramic substrates or semiconductor materials, thermal expansion matching must also be considered. If the main goal is heat dissipation, W50Cu50, W60Cu40, and W70Cu30 can be evaluated first; if a lower coefficient of thermal expansion is also required, W70Cu30, W80Cu20, etc. need to be included in the comparison, and the selection should be made based on actual thermal conductivity and coefficient of thermal expansion data.

High arc resistance requirements: prioritize evaluating high-tungsten-content grades

For circuit breaker contacts, vacuum switch contacts, and other parts that repeatedly withstand arc action, grades such as W70Cu30, W80Cu20, or W90Cu10 can be evaluated first. However, arc resistance does not necessarily continue to improve as tungsten content increases. Arc energy, breaking current, contact structure, material microstructure, and copper phase distribution all affect the amount of erosion, welding tendency, and service life. Therefore, comparative tests should be carried out based on actual breaking conditions as far as possible, rather than judging only by tungsten content.

III. When all three properties are important at the same time, how to determine the ratio?

If electrical conductivity, thermal conductivity, and resistance to arc erosion are all important, a step-by-step screening method is recommended. First, clarify the indicators that cannot be compromised. For example, the minimum electrical conductivity, maximum allowable temperature rise, maximum electrode wear, or target service life. First exclude grades that cannot meet the hard requirements. Second, compare actual material data. Check the electrical conductivity, thermal conductivity, hardness, density, coefficient of thermal expansion, and material density of candidate grades to avoid selecting materials based only on nominal composition. Then, verify under real working conditions. Confirm the material's performance under actual current, temperature, pressure, and cooling conditions through temperature rise tests, thermal cycle tests, or arc life tests.

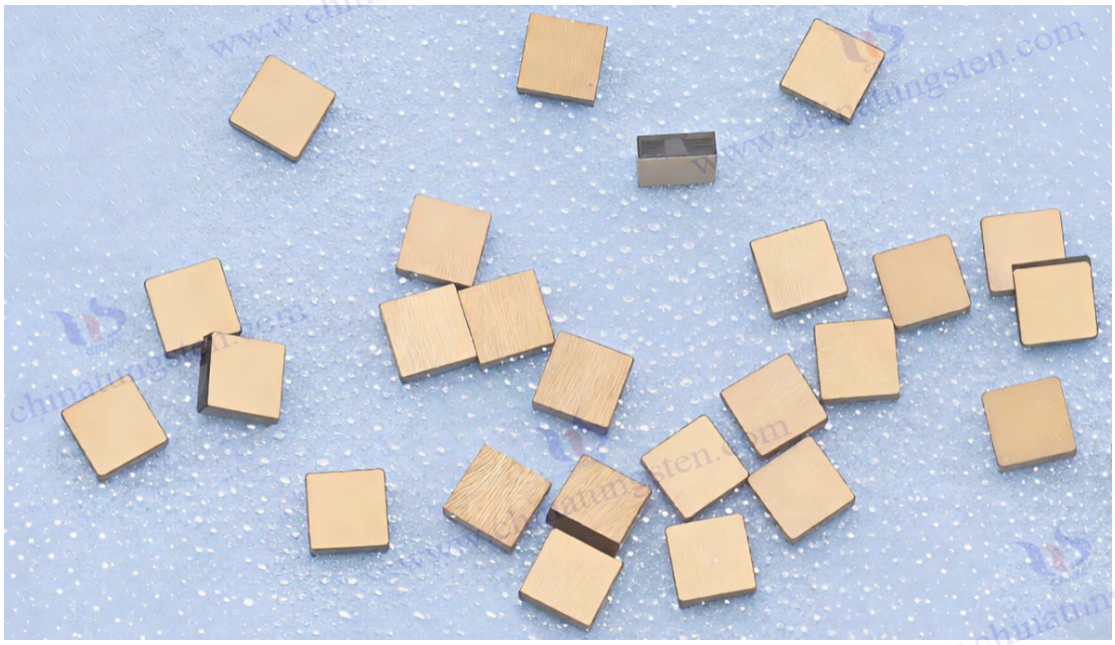
For tungsten-copper parts that require custom processing, the product shape, dimensional tolerances, processing method, and batch consistency should also be considered. CTIA GROUP, with nearly thirty years of experience in custom processing of tungsten-copper alloy, can provide reference for grade selection, composition ratio, specification matching, and non-standard processing requirements.

IV. A simple principle can be used for preliminary judgment

Use objective	Recommended starting evaluation direction
Mainly pursuing electrical conductivity	W50Cu50, W60Cu40
Mainly pursuing heat dissipation	W50Cu50, W60Cu40, W70Cu30
Balanced electrical conductivity, thermal conductivity & arc erosion resistance	W70Cu30, W75Cu25
Relatively high requirements for arc erosion resistance & low thermal expansion	W80Cu20, W90Cu10

This table is suitable for determining the initial candidate range, not for replacing material selection verification. Different applications have different priorities for performance, and the same grade may also show obvious differences due to different manufacturing processes.

If the range is to be further narrowed, the most valuable information is the specific use of the product: is it a high-voltage electrical contact, a resistance welding electrode, an EDM electrode, or an electronic packaging heat dissipation part? After the use is clarified, the tungsten-copper ratio can be further screened in combination with the main working conditions.



Q15 What do the numbers in tungsten-copper alloy grades represent? Are grades from different manufacturers interchangeable?

The numbers in the grades of tungsten-copper alloy (W-Cu) are usually used to indicate the content ratio of tungsten (W) to copper (Cu), but the specific meaning needs to be judged in combination with the naming rules of the grade, product standards, and manufacturer's technical data. Different manufacturers using similar or even identical grades does not mean that the composition, performance, and quality of the products are completely consistent.

I. What do the numbers in tungsten-copper alloy grades represent?

Taking the common W70Cu30, W80Cu20, and W90Cu10 as examples, in such grades named according to composition ratio, the numbers usually represent the mass percentages of tungsten and copper, respectively.

grade	Tungsten	Copper	General performance tendency
W50Cu50	50%	50%	Higher copper content, usually more focused on electrical and thermal conductivity
W60Cu40	60%	40%	Balances electrical conductivity, thermal conductivity, and certain arc resistance
W70Cu30	70%	30%	Achieves a balance among electrical and thermal conductivity, hardness, and arc resistance
W80Cu20	80%	20%	Usually has higher density, lower coefficient of thermal expansion, and better arc erosion resistance potential
W90Cu10	90%	10%	More inclined toward high tungsten content, low thermal expansion, and specific arc erosion resistance applications

For example, W70Cu30 usually means that tungsten accounts for 70% of the total mass of the alloy and copper accounts for 30%, rather than the atomic number ratio of the two metals. The numbers here are mass percentages (wt.%), and cannot be directly understood as volume percentages.

Because the densities of tungsten and copper differ greatly, the mass ratio and volume ratio are not the same. For an alloy with a tungsten content of 70 wt.%, the volume occupied by tungsten is usually significantly lower than 70%. If density, volume fraction, or thermophysical properties need to be estimated according to the grade, the calculation should be combined with the densities of the two metals, the actual material density, and the manufacturing process. It is also necessary to distinguish composition grades from manufacturer internal models. The numbers in some product names may represent composition ratios, while others may be product series, specification codes, or internal enterprise codes, and cannot be judged directly by the numbers alone.

II. Are tungsten-copper alloy grades from different manufacturers interchangeable?

The answer is: grade names are interchangeable to a certain extent, but the materials cannot be considered completely equivalent based on the grade alone. For example, multiple manufacturers may use the name W70Cu30, indicating a nominal tungsten content of about 70% and copper content of about 30%. However, the actual product's allowable composition

deviation, impurity content, density, hardness, electrical conductivity, thermal conductivity, and internal microstructure may still differ. The W70Cu30 data published by different manufacturers show that some performance indicators are not completely consistent. There are three main factors affecting the interchangeability of grades.

First, whether the applicable standards are consistent. Chinese national standards (GB/T), American Society for Testing and Materials (ASTM) standards, and the material classification systems used in the resistance welding industry may adopt different grade rules and performance requirements. For example, ASTM B702 for copper-tungsten electrical contact materials made by powder metallurgy specifies composition and performance requirements that need to be confirmed in combination with the applicable version and procurement agreement, and similar grades in all systems cannot simply be regarded as equivalent.

Second, whether the manufacturing process is consistent. Tungsten-copper alloy is usually manufactured by powder metallurgy. Different tungsten powder particle sizes, pressing and sintering conditions, copper infiltration effects, and subsequent heat treatment and processing may all affect the final performance. Therefore, even if the nominal composition is the same, the density, porosity, microstructural uniformity, and mechanical properties of the product may also differ.

Third, whether the product application and acceptance indicators are consistent. Electrical contacts, resistance welding electrodes, EDM electrodes, and electronic packaging heat dissipation substrates have different requirements for electrical conductivity, arc erosion resistance, hardness, thermal conductivity, and coefficient of thermal expansion. Even if a manufacturer's grade meets the nominal composition requirements, it may not directly replace another manufacturer's product produced for a specific application.

III. How to judge whether grades from different manufacturers can be interchanged during procurement?

It is recommended not to check only the grade name, but to check the following information at the same time:

Check item	Specific content to confirm
Chemical composition	Actual content ranges of tungsten and copper, limits of impurities and added elements
Applicable standard	Standard number, version, and corresponding material grade
Density	Minimum requirement, typical value, and actual test results
Electrical and thermal conductivity	Electrical conductivity, thermal conductivity, and corresponding test conditions
Mechanical properties	Key indicators such as hardness and flexural strength
Manufacturing and inspection	Process route, batch stability, inspection report, and acceptance requirements
Product state	Dimensions, machining accuracy, heat treatment state, and surface quality

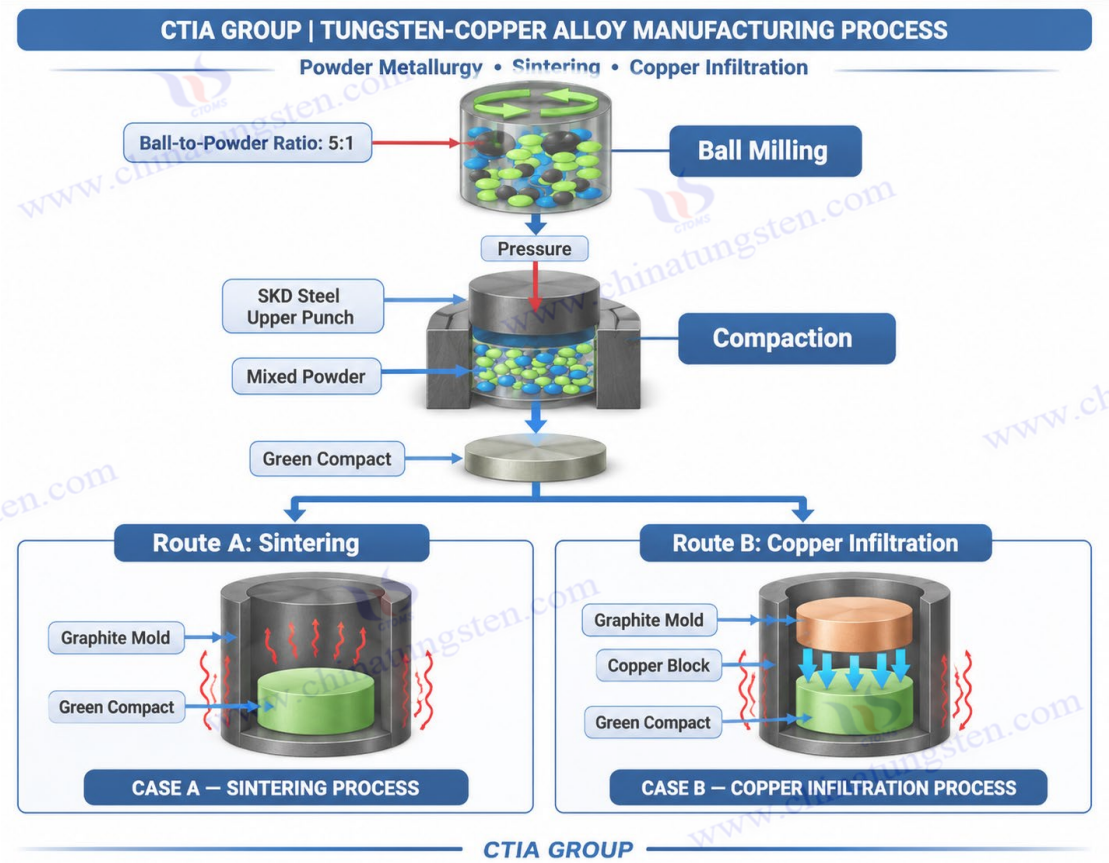
If used for equipment maintenance or mass production, it is best to first obtain the supplier's material specification sheet and batch inspection report, and then compare the key performance with the original supplier's product item by item. When critical components such

as high-voltage electrical contacts and precision electronic packaging are involved, sample testing and working condition verification should also be carried out when necessary, rather than directly replacing them simply because the grades are the same.

For example, CTIA GROUP, which has experience in custom processing of tungsten-copper alloy, can serve as a consultation reference for grade selection, composition ratio confirmation, specification matching, and non-standard processing requirements; specific products should still be based on the technical requirements and inspection results confirmed by both parties.

In short, grades such as W70Cu30 can usually help identify the nominal composition of the material, but cannot alone prove that products from different manufacturers are completely interchangeable. The real judgment of whether they can be substituted should be based on applicable standards, composition ranges, key performance indicators, and actual use requirements.





Q16 Why may the actual chemical composition of tungsten-copper alloy differ from the nominal composition?

The nominal composition of tungsten-copper alloy (W-Cu) is the target ratio marked in the grade or technical document; the actual chemical composition is the composition result obtained by testing the material after production. The two may differ, mainly due to raw material purity, powder metallurgy process, copper infiltration and loss, sampling and testing methods, and product acceptance standards. For example, the grade W70Cu30 usually indicates a nominal tungsten content of 70% and copper content of 30%, generally calculated by mass percentage. This represents the target ratio, and does not necessarily mean that every test point will measure exactly 70.00% tungsten and 30.00% copper. Whether the actual value is qualified needs to be judged according to the applicable standard or the allowable composition deviation agreed by both parties in procurement.

I. Raw material purity and batching errors

The production of tungsten-copper alloy usually uses tungsten powder and copper powder as the main raw materials. Impurities such as oxygen, iron, and nickel in the raw materials, as well as purity differences between powder batches, may affect the final material test results. In addition, the measurement accuracy of batching equipment, the uniformity of powder mixing, and material loss during production will also cause the actual composition to deviate from the target value. If tungsten powder and copper powder are not mixed uniformly, even if the average composition of the entire batch is close to the nominal ratio, the local composition at

different positions may also differ.

II. The sintering and copper infiltration process affects the final ratio

Tungsten-copper alloy is usually manufactured by powder metallurgy. Because the melting points of tungsten and copper differ greatly, production often uses the infiltration combination of a tungsten skeleton and liquid copper to obtain the required material.In this process, whether copper infiltration is sufficient, whether pores remain, whether local copper loss occurs, and whether the process temperature and holding time are stable will all affect the composition and microstructure of the final product. If copper infiltration is not uniform, the tungsten-copper ratio in different regions of the material may not be exactly the same. Two situations should also be distinguished: one is that the ratio of tungsten to copper has indeed changed; the other is that pores exist in the material, causing the measured volume density to be lower than the theoretical density. The latter does not necessarily mean that the tungsten-copper mass ratio has changed, but it will affect the density and some performance indicators of the product.

III. Different testing methods and sampling positions can also cause result differences

The actual composition depends not only on the material itself, but also on the testing method, sampling position, and data expression. Common testing methods include X-ray fluorescence spectrometry (XRF), scanning electron microscopy with energy-dispersive X-ray spectroscopy (SEM-EDS), and chemical analysis methods suitable for the corresponding elements and matrix. Among them, XRF is often used for material composition screening, but the test results may be affected by surface state, calibration method, and matrix effects; SEM-EDS is suitable for observing micro-area composition and element distribution, but local results may not represent the average composition of the entire material. If the sample has uneven copper distribution, surface oxidation, or pores, different testing positions may also give different results. In addition, mass percentage and atomic percentage should be distinguished. The atomic mass of tungsten is much greater than that of copper, and the numbers corresponding to the same mass ratio and atomic ratio are not the same. If the report does not clearly indicate wt.% (mass percentage) or at.% (atomic percentage), a situation may appear that seems inconsistent with the nominal ratio.

IV. Does a difference between nominal composition and actual composition mean the product is unqualified?

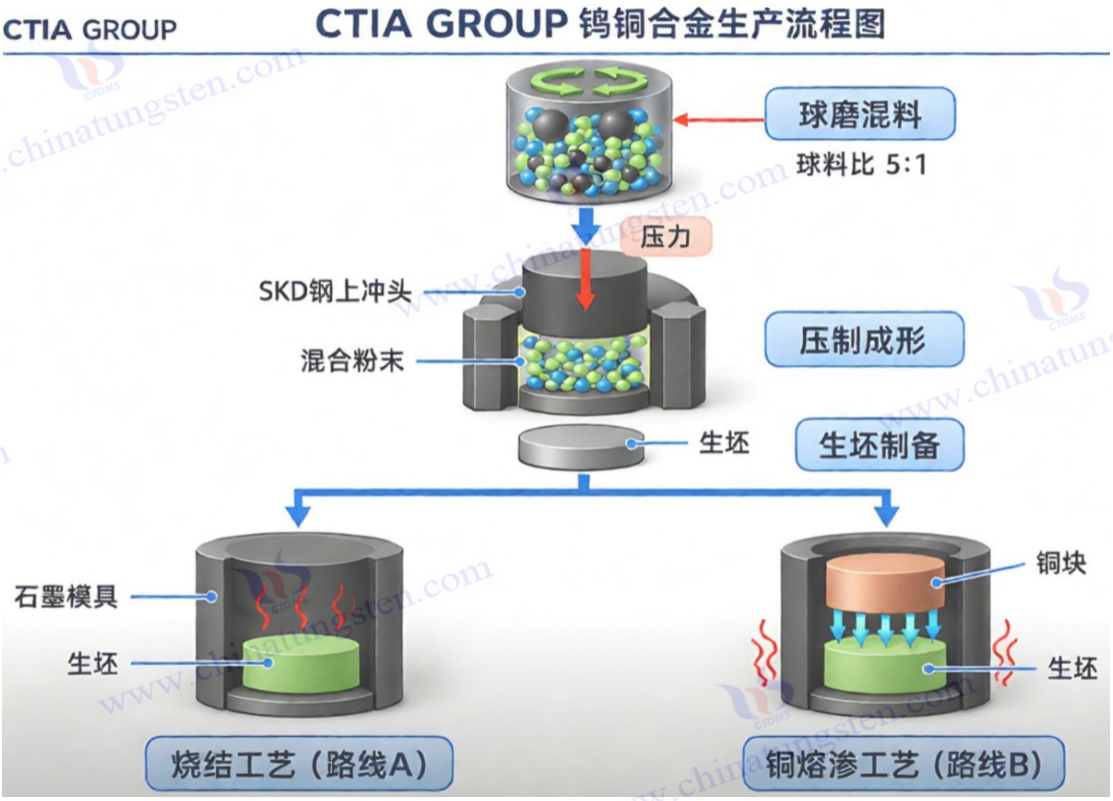
Not necessarily; the key lies in whether it meets the agreed allowable deviation and other acceptance indicators. For example, some manufacturers' tungsten-copper alloy technical data specify the copper content corresponding to W70Cu30 as 30%±2%, with tungsten content expressed as the balance. That is, under the premise that the data apply, the copper content is not required to be exactly 30.00% every time. However, this range is only an example in specific technical data and cannot be directly applied to all manufacturers, standards, or applications. To judge whether a product is qualified, the following factors should be considered: nominal composition and allowable deviation, impurity limits, density and porosity, key properties such as electrical conductivity and thermal conductivity, and the sampling and testing methods agreed by both parties. Even if the composition is qualified, if the density or electrical

conductivity does not meet the requirements, it may still not meet the use requirements.

For tungsten-copper alloy procurement and custom processing, reference can be made to CTIA GROUP, which has relevant product experience, to clarify the nominal composition, allowable deviation, inspection items, and acceptance standards during the inquiry and technical confirmation stage, reducing disputes between different suppliers caused by inconsistent technical calibers.

V. How to reduce disputes between nominal composition and actual composition?

A relatively reliable approach is to specify in the procurement technical agreement the composition range corresponding to the grade, the mass percentage basis, impurity control requirements, testing methods, sampling positions, and batch inspection rules. For high-requirement products, indicators such as density, electrical conductivity, and hardness can also be agreed upon, and the supplier can be required to provide inspection reports corresponding to the delivered batch. If the test results show an obvious deviation from the nominal composition, first confirm whether the units, testing methods, and sampling methods used by both parties are consistent, and then judge whether it is an actual batching deviation, a manufacturing process abnormality, or a testing error. Therefore, we believe that: the nominal composition is the target ratio, and the actual composition is the test result; the two do not have to be absolutely equal, but the difference must be within the range specified by the applicable standard or contract. For tungsten-copper alloy, only by combining composition, microstructure, density, and key properties can the material quality be judged more accurately.





C. Physical Properties of Tungsten-Copper Alloy

Q17. What is the density of tungsten-copper alloy? What are the differences among different grades?

The density of tungsten-copper alloy (W-Cu) mainly depends on the mass ratio of tungsten (W) to copper (Cu), the material density, and the manufacturing process. Generally, the higher the tungsten content, the greater the alloy density, because the density of tungsten is much higher than that of copper. The density of common tungsten-copper alloys is roughly between 11.8 and 17.0 g/cm³. Specific values vary with grade, porosity, and production process; during material selection, the supplier's technical specifications and actual test data should be used as the basis.

I. Density of common tungsten-copper alloy grades

The following table shows estimated theoretical density values for common grades, suitable for preliminary material selection and weight estimation; these are not uniform guaranteed values for all manufacturers.

Grade	Appr. theoretical density (g/cm³)	Density characteristics
W50Cu50	11.8	Relatively low density among common grades
W55Cu45	12.3	Slightly higher than W50Cu50
W60Cu40	12.9	Medium density
W65Cu35	13.5	Density continues to increase
W70Cu30	14.1	Balances density with electrical and thermal conductivity requirements
W75Cu25	14.8	Relatively high density
W80Cu20	15.6	High density and a more obvious tendency toward low thermal expansion
W85Cu15	16.3	High tungsten content
W90Cu10	17.0	Relatively high density among common grades

These values can be estimated from the theoretical densities of tungsten and copper and their mass ratios. If actual products have residual porosity, composition deviation, or other trace elements, the measured density may be lower than or deviate from the theoretical value.

II. Why are density values in different sources not completely consistent?

From publicly available manufacturer information, the density of W70Cu30 may be listed as 13.8, 14.0, or 14.18 g/cm³; W80Cu20 may be listed as 15.15 or 15.6 g/cm³. Different data may correspond to different manufacturing processes, material density, definitions of technical indicators, or theoretical estimation methods. Strictly speaking, the values in the previous table should be regarded as reference densities of common products rather than uniform theoretical densities. When calculating the ideal mixed density according to the densities and mass ratios of tungsten and copper, the following formula can be used:

$\rho = 1 / (w_W/\rho_W + w_Cu/\rho_Cu)$, where ρ is the ideal mixed density, w_W and w_Cu are the mass fractions of tungsten and copper respectively, and ρ_W and ρ_Cu are the densities of tungsten and copper respectively. Using tungsten at approximately 19.25 g/cm³ and copper at approximately 8.96 g/cm³, the ideal mixed density of W70Cu30 is approximately 14.32 g/cm³, and that of W80Cu20 is approximately 15.65 g/cm³. The measurement results of actual materials should be based on the samples.

III. What impact does the different density of grades have on actual use?

As tungsten content increases, density usually increases, but other properties also change with composition; it cannot simply be assumed that the higher the density, the better the comprehensive performance. Taking common product data as an example, the density of W60Cu40 is approximately 12.75 g/cm³, and its electrical conductivity is approximately 47% of the International Annealed Copper Standard (IACS); the density of W80Cu20 is approximately 15.15–15.6 g/cm³, and its electrical conductivity is approximately 28%–34% IACS. Specific indicators may differ among manufacturers. Therefore, when selecting, the focus should be determined according to the application: if electrical and thermal conductivity are prioritized, W50Cu50 and W60Cu40 can be mainly evaluated; if density, hardness, and arc erosion resistance need to be balanced, W70Cu30 and W80Cu20 can be evaluated; if higher density and a lower coefficient of thermal expansion are more important, W85Cu15 and W90Cu10 can be further evaluated, while electrical and thermal conductivity indicators are checked at the same time.

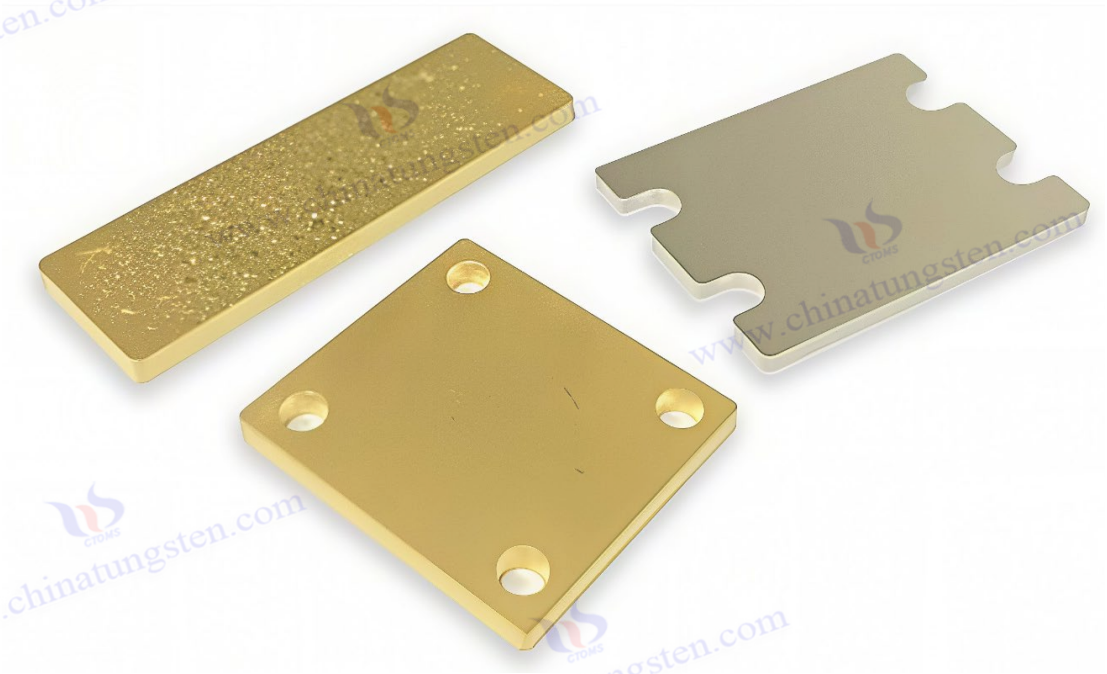
For custom processing and grade selection of tungsten-copper alloy, relevant product and technical information from CTIA GROUP can also be consulted, and suppliers should be required to clearly provide the lower density limit, typical value, or measured value, avoiding inferring product density solely from the grade.

IV. How to calculate workpiece weight based on density?

If the workpiece volume is known, the weight can be estimated using $m = \rho V$, where m is mass, ρ is density, and V is volume. For regular workpieces whose dimensions are in millimeters, the volume should first be converted to cubic centimeters before being substituted into the density calculation. For example, for a W80Cu20 workpiece with a volume of 10 cm³, if estimated at a

density of 15.6 g/cm³, the mass is approximately 156 g. If used for counterweights, precision electrodes, or batch production, the actual material density should be used first, and the calculation should be checked against the finished product dimensions and machining allowance.

In brief, the density of tungsten-copper alloy usually increases with increasing tungsten content, and common grades are approximately 11.8–17.0 g/cm³; however, theoretical density, typical product density, and actual measured density are not the same concept, and it should be clarified which type of data is used during procurement and design.



Q18 How to calculate weight based on the dimensions and density of tungsten-copper alloy?

The weight of tungsten-copper alloy (W-Cu) mainly depends on the geometric dimensions of the workpiece and the material density. After clarifying the workpiece shape, dimension units, and the density corresponding to the grade, the theoretical weight can be estimated, which is suitable for the design and procurement of electrodes, contacts, heat-dissipating parts, and counterweight parts.

I. Weight calculation formula for tungsten-copper alloy

The basic relationship for weight calculation is: weight = density × volume.

Here, weight in engineering calculations usually refers to mass, in grams (g) or kilograms (kg); density is in grams per cubic centimeter (g/cm³); volume is in cubic centimeters (cm³). When workpiece dimensions are in millimeters (mm), since 1 cm³ = 1000 mm³, therefore: mass (g) = density (g/cm³) × volume (mm³) ÷ 1000.

II. How to calculate for tungsten-copper alloy of different shapes?

Rectangular cuboid tungsten-copper alloy

Volume of a rectangular cuboid = length × width × height.

Mass (g) = density × length × width × height ÷ 1000

Here, length, width, and height are all in millimeters (mm).

For example, if the dimensions of a tungsten-copper alloy rectangular cuboid are 100 mm × 50 mm × 10 mm and the density is 14.1 g/cm³, then the volume is 50,000 mm³ and the mass is 14.1 × 50,000 ÷ 1000 = 705 g.

Solid cylindrical tungsten-copper alloy

Volume of a cylinder = 3.1416 × diameter × diameter × height ÷ 4.

Mass (g) = 3.1416 × density × diameter² × height ÷ 4000

Here, diameter and height are both in millimeters (mm).

For example, if the cylinder diameter is 20 mm, the height is 50 mm, and the density is 14.1 g/cm³, then the mass is approximately 221.48 g.

Hollow cylindrical tungsten-copper alloy

Volume of a hollow cylinder = 3.1416 × (outer diameter² – inner diameter²) × height ÷ 4.

Mass (g) = 3.1416 × density × (outer diameter² – inner diameter²) × height ÷ 4000

Here, outer diameter, inner diameter, and height are all in millimeters (mm), and the inner diameter must be smaller than the outer diameter.

For example, if the outer diameter of a hollow cylinder is 30 mm, the inner diameter is 10 mm, the height is 20 mm, and the density is 14.1 g/cm³, then the mass is approximately 280.96 g.

For parts with steps, grooves, or through holes, they can be divided into multiple regular geometric bodies, calculated separately, and then added or subtracted; for complex parts, computer-aided design (CAD) software can also be used to obtain the volume, which is then multiplied by the material density.

III. Weight differences among different tungsten-copper alloy grades

For workpieces of the same dimensions, the higher the tungsten content, the greater the

density, and therefore the greater the mass. The following takes a rectangular cuboid with dimensions of 100 mm × 50 mm × 10 mm as an example; its volume is 50 cm³.

Grade	Reference density (g/cm³)	Theoretical mass (g)
W50Cu50	11.8	590
W60Cu40	12.9	645
W70Cu30	14.1	705
W80Cu20	15.6	780
W90Cu10	17.0	850

The densities in the table are reference values for estimation and are not uniform guaranteed values for all manufacturers' products. Actual products may be affected by factors such as material density, porosity, composition deviation, and manufacturing process. During procurement or processing calculations, the technical specifications or measured density provided by the supplier should be used first.

IV. What should be noted in actual calculations?

First, unify the dimension units. If length, width, and height are in millimeters, cubic millimeters must be converted to cubic centimeters; the millimeter values cannot be directly multiplied by g/cm³. Second, distinguish theoretical mass from actual mass. Theoretical calculations are based on nominal dimensions and reference density; actual workpieces may have dimensional tolerances, internal porosity, machining allowance, and structural differences, so the calculation results may differ slightly from the weighing results. Third, use the correct material density. The density differences among different tungsten-copper alloy grades are obvious, and even for the same grade, actual products from different suppliers may differ. For precision electrodes, counterweight parts, or batch-processed parts, actual material data should be used as the basis.

For custom processing and grade selection of tungsten-copper alloy, relevant product and technical information from CTIA GROUP can be consulted, and the material grade, density indicators, finished product dimensions, and machining tolerances should be confirmed before procurement.

In short, first calculate the volume according to the workpiece shape, then multiply by the density of the corresponding grade to obtain the theoretical mass. The above formulas can be used directly for regular parts; for complex parts, it is recommended to first determine the volume through a 3D model to improve the accuracy of weight estimation.



Q19 What are the electrical conductivity and resistivity of tungsten-copper alloy?

The electrical conductivity and resistivity of tungsten-copper alloy (W-Cu) are mainly affected by the ratio of tungsten to copper, material density, microstructure, and manufacturing process. Generally, the higher the copper content, the higher the electrical conductivity and the lower the resistivity; the higher the tungsten content, the lower the electrical conductivity and the higher the resistivity. The electrical conductivity of common tungsten-copper alloys is approximately 27%–54% of the International Annealed Copper Standard, and the resistivity is approximately 3.2–6.5 μΩ·cm. Specific values vary by grade, production process, and manufacturer technical requirements.

I. Electrical conductivity and resistivity of common grades

The following table uses typical indicators from publicly available manufacturer technical data, suitable for preliminary material selection and grade comparison, and does not represent uniform guaranteed values for all manufacturers' products.

Electrical conductivity and resistivity of common grades from CTIA GROUP

grade	Copper content (mass percentage)	Electrical conductivity (% IACS)	Resistivity (μΩ·cm)
W50Cu50	50%	≥54	≤3.2
W55Cu45	45%	≥49	≤3.5
W60Cu40	40%	≥47	≤3.7
W65Cu35	35%	≥44	≤3.9
W70Cu30	30%	≥42	≤4.1
W75Cu25	25%	≥38	≤4.5
W80Cu20	20%	≥34	≤5.0
W85Cu15	15%	≥30	≤5.7
W90Cu10	10%	≥27	≤6.5

The above data are based on the historical data of CTIA GROUP and publicly available standard technical tables for tungsten-copper alloy products. The electrical conductivity in the table is a percentage relative to the International Annealed Copper Standard (IACS), and the resistivity is the upper limit value marked by the manufacturer. As can be seen from the table, the electrical conductivity of W50Cu50 is usually better, making it suitable for applications with higher requirements for current conduction; W70Cu30 has a certain balance among electrical conductivity, arc erosion resistance, and mechanical properties; W80Cu20 and W90Cu10 usually have higher hardness and a lower coefficient of thermal expansion, but relatively lower electrical conductivity.

II. What is the difference between electrical conductivity and resistivity?

Electrical conductivity indicates the ability of a material to conduct current; the higher the value, the stronger the current conduction ability. Resistivity indicates the degree to which a material obstructs current; the lower the value, the stronger the current conduction ability. The two are inversely related at the same temperature and under consistent test conditions. The electrical conductivity calculation formula for tungsten-copper alloy is:

Resistivity $\rho = R A / L$, where ρ is resistivity, R is the measured resistance, A is the cross-sectional area of the conductor, and L is the length of the conductor. Conductivity $\sigma = 1 / \rho$, where σ is conductivity.

Common unit conversions are as follows: 1 μΩ·cm = 0.01 μΩ·m = 10 nΩ·m. The reference resistivity of the International Annealed Copper Standard at 20°C is approximately 1.724 μΩ·cm, and the conductivity is defined as 100% IACS.

III. Why does higher tungsten content usually mean lower electrical conductivity?

Copper itself has high electrical conductivity, while the electrical conductivity of tungsten is lower than that of copper. As tungsten content increases, the proportion of the copper phase usually decreases, and the current conduction paths and interface characteristics inside the material also change, so the overall electrical conductivity of tungsten-copper alloy usually decreases. However, electrical conductivity is not determined only by composition ratio.

Powder particle size, sintering and copper infiltration effects, porosity, impurity content, and test temperature may all affect actual results. Even if different manufacturers produce the same nominal grade, the published electrical conductivity and resistivity may differ.

IV. How to choose for different applications?

If mainly used for high-current conduction, W50Cu50 and W60Cu40 can be evaluated first; if used for resistance welding electrodes or electrical contacts, where electrical conductivity, hardness, and arc erosion resistance need to be balanced, W60Cu40, W70Cu30, and W75Cu25 can be evaluated; if used for high-temperature contacts, erosion-resistant parts, or parts with higher requirements for thermal expansion control, W80Cu20 and W90Cu10 can be further evaluated, but whether the electrical conductivity and thermal conductivity meet actual requirements should be checked at the same time.

For electronic packaging and heat-dissipating parts, attention should also be paid to thermal conductivity, coefficient of thermal expansion, and the degree of matching with chips or substrates; whether the material is suitable cannot be judged solely by resistivity. CTIA GROUP, which has experience in tungsten-copper alloy products and custom processing, can serve as a consultation reference for grade screening, performance indicator confirmation, and specification matching; specific parameters should be based on product technical data and inspection reports.

During material selection, it is recommended to clarify the working temperature, allowable resistance or voltage drop, working current, and arc resistance requirements, and then compare the measured data of different grades. If you provide the specific application, such as high-voltage electrical contacts, resistance welding electrodes, or electronic packaging heat-dissipating substrates, the grade range can be further narrowed.



Q20 What is the thermal conductivity of tungsten-copper alloy? What factors affect thermal conductivity?

The thermal conductivity of tungsten-copper alloy (W-Cu) mainly depends on the ratio of tungsten (W) to copper (Cu), material density, microstructure, and manufacturing process. The thermal conductivity of common grades is roughly in the range of 170–300 W/(m·K), and specific values vary with the material system, product process, and testing conditions. In publicly available technical data, the thermal conductivity of W70Cu30 is seen at approximately 200–220 W/(m·K), while W80Cu20 is seen at approximately 172–210 W/(m·K).

I. Thermal conductivity of common tungsten-copper alloy grades

Thermal conductivity indicates the ability of a material to transfer heat, in watts per meter-kelvin, written as W/(m·K). The larger the value, the more favorable the material is usually for conducting heat under the same geometric dimensions and temperature difference.

Tungsten-copper alloy grade	Nominal tungsten content	Reference thermal conductivity (W/(m·K))
W50Cu50	50%	Approx. 240–300
W60Cu40	60%	Approx. 220–260
W70Cu30	70%	Approx. 200–220
W75Cu25	75%	Approx. 210–220
W80Cu20	80%	Approx. 172–210
W85Cu15	85%	Approx. 170–200
W90Cu10	90%	Approx. 160–190

The table shows reference ranges visible in different public sources, not uniform standard values, and the ranges may overlap. Some tungsten-copper materials specially used for electronic packaging may have higher thermal conductivity than conventional grades of the same name through specific processes and microstructure control, so the actual value cannot be inferred solely from the grade.

II. What factors affect the thermal conductivity of tungsten-copper alloy?

Ratio of tungsten to copper

Copper has strong thermal conductivity, while tungsten mainly provides a high melting point, high hardness, and low thermal expansion characteristics. Generally, increasing copper content helps improve the thermal conductivity of tungsten-copper alloy, but the specific trend is also affected by microstructure and manufacturing process. For example, in a manufacturer's thermal management material data, the thermal conductivity of W75Cu25 is 220 W/(m·K), W80Cu20 is 200 W/(m·K), W85Cu15 is 190 W/(m·K), and W90Cu10 is 180 W/(m·K), reflecting the trend in this product series that thermal conductivity gradually decreases as tungsten content increases.

Material density and porosity

Tungsten-copper alloy is usually prepared by powder metallurgy. If sintering or copper infiltration is insufficient, pores may remain inside the material. Pores obstruct heat transfer and reduce actual thermal conductivity. Therefore, under similar composition, materials with higher density and more uniform internal microstructure are usually more conducive to obtaining stable thermal conductivity.

Manufacturing process and microstructure

Tungsten powder particle size, tungsten skeleton structure, copper infiltration uniformity, sintering temperature, and holding time all affect the contact state between the tungsten phase and the copper phase. Proper process control helps reduce defects and improve microstructural uniformity. Some special tungsten-copper materials also adjust the process and composition design to meet higher thermal management requirements.

Impurities and sintering activation elements

Impurities in the material or additionally added sintering activation elements may change the interface state and heat conduction paths. Some elements help improve sintering and densification but may also adversely affect thermal conductivity. Therefore, product performance cannot be judged only by the tungsten-copper ratio; impurity limits and material formulation should also be checked.

Working temperature and test conditions

Thermal conductivity is not constant at all temperatures. Test temperature, sample size, test method, and material batch may all affect measurement results. When comparing data from different manufacturers, it should be confirmed as far as possible that the test temperature and test method are consistent, avoiding direct comparison of data obtained under different

conditions.

III. How to choose for different applications?

Application direction	Selection recommendation	Main considerations
High-thermal-conductivity heat-dissipating parts	Prioritize evaluation of W50Cu50, W60Cu40, W70Cu30	Thermal conductivity, coefficient of thermal expansion, and machinability
Chip & power semiconductor packaging	Evaluate W70Cu30, W75Cu25, W80Cu20	Thermal conductivity and thermal expansion matching with chips
High-temperature electrical contacts	Evaluate W70Cu30, W80Cu20, etc.	Thermal conductivity, electrical conductivity, hardness, and arc erosion resistance
Low-thermal-expansion precision parts	Evaluate W80Cu20, W85Cu15, W90Cu10	Coefficient of thermal expansion, thermal conductivity, and dimensional stability

For products that need to balance heat dissipation and dimensional stability, relevant tungsten-copper alloy products and technical information from CTIA GROUP can be consulted, and the thermal conductivity, coefficient of thermal expansion, density, and test conditions should be clearly required during material selection.In short, the thermal conductivity of tungsten-copper alloy depends not only on the tungsten-copper ratio but is also affected by density, microstructure, impurities, manufacturing process, and test temperature. If used for a specific heat dissipation design, the measured data provided by the target supplier should be used first rather than estimating solely from the grade.

Q21 What is the coefficient of thermal expansion of tungsten-copper alloy?

The coefficient of thermal expansion of tungsten-copper alloy is usually approximately 6.0–13.0×10⁻⁶ K⁻¹, and the specific value mainly depends on the mass ratio of tungsten to copper, material density, manufacturing process, and test temperature. Generally, the higher the tungsten content, the lower the coefficient of thermal expansion; the higher the copper content, the higher the coefficient of thermal expansion is usually. Data differ among manufacturers, and it should be confirmed whether the test temperature ranges are consistent when comparing.

Coefficient of thermal expansion of common grades

The following table shows reference values from publicly available product technical data, with units of $10^{-6}\,\mathrm{K}^{-1}$; data from different material suppliers are not necessarily completely identical.

grade	Reference coefficient of thermal expansion	Typical characteristics
W50Cu50	11.5–13.0	Relatively large thermal expansion, high copper content
W60Cu40	Approx. 11.0–12.0	Balances electrical conductivity, thermal conductivity, and dimensional stability
W70Cu30	9.3–10.2	Commonly used for electrical contacts, electronic packaging, and heat-dissipating parts
W75Cu25	9.0–10.2	Suitable for thermal management parts with thermal expansion matching requirements
W80Cu20	7.4–8.9	Relatively low thermal expansion, suitable for precision electronic packaging
W85Cu15	6.4–7.4	Low thermal expansion, suitable for matching with low-expansion materials
W90Cu10	6.0–7.0	Relatively low thermal expansion, suitable for occasions requiring high dimensional stability

Some public technical data provide the average linear coefficient of thermal expansion over the range from room temperature to 400°C; other suppliers may use different temperature ranges or test methods, so the values in the table are for preliminary material selection and should not directly replace procurement technical indicators.

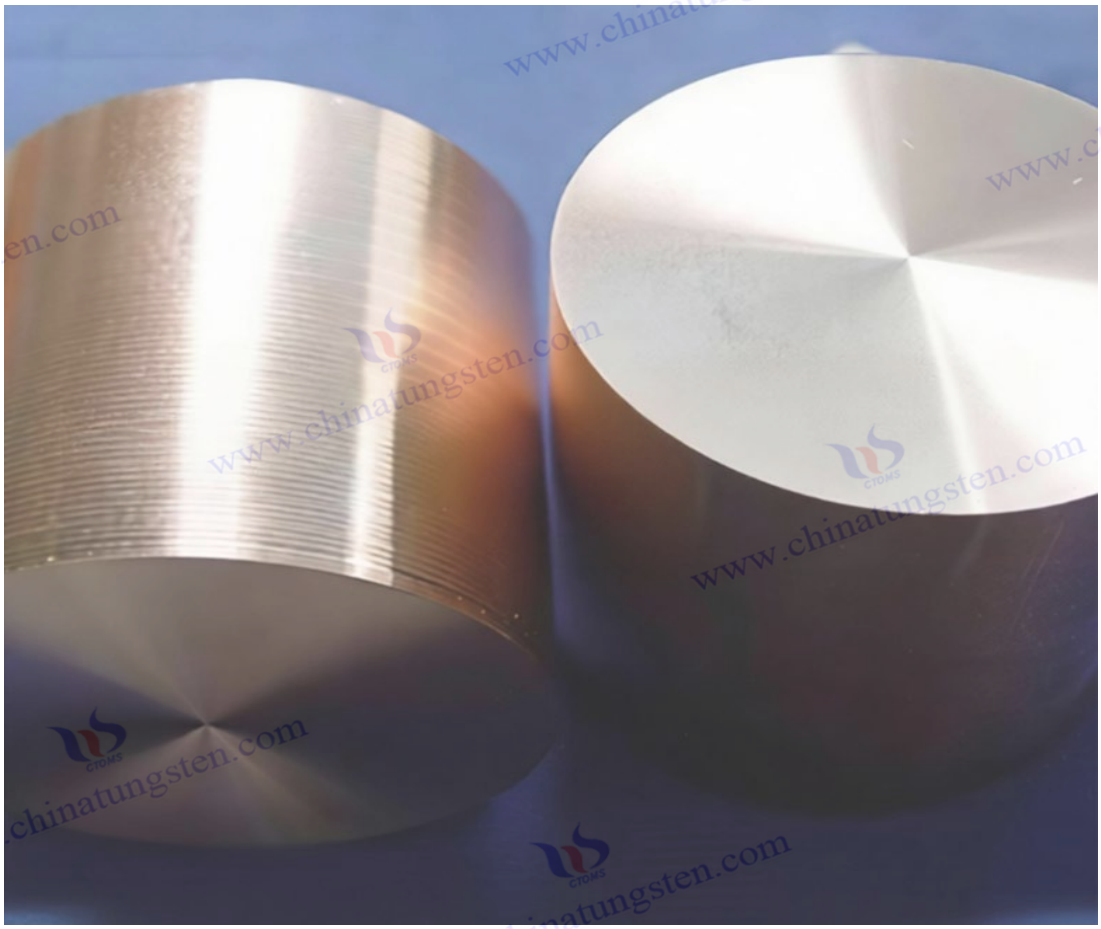
How does the coefficient of thermal expansion affect material selection?

The coefficient of thermal expansion (CTE) indicates the degree of dimensional change of a material when temperature changes. Its linear calculation formula is: $\Delta L = \alpha \times L_0 \times \Delta T$. Here, ΔL is the change in length, α is the linear expansion coefficient, L_0 is the initial length, and ΔT is the temperature change. For example, for a W80Cu20 tungsten-copper alloy part with a length of 100 mm, if the linear expansion coefficient is taken as 8.3×10⁻⁶ K⁻¹ and the temperature increases by 100°C, the theoretical length change is approximately 0.083 mm.

In actual material selection, if used for semiconductor packaging, ceramic substrates, or precision thermal management parts, priority should be given to matching the coefficient of thermal expansion of adjacent materials to reduce the risk of thermal stress, warping, and interface cracking caused by temperature cycling. If further verification of material parameters for different grades is needed, relevant products and technical data from CTIA GROUP can be

consulted.

When finalizing specifications, CTIA GROUP recommends clarifying the test temperature range, average linear expansion coefficient or instantaneous linear expansion coefficient, as well as material density and batch requirements, avoiding judging actual performance solely from the grade.



Q22 What are the hardness, flexural strength, and tensile strength of tungsten-copper alloy?

The hardness, flexural strength, and tensile strength of tungsten-copper alloy (W-Cu) do not have uniform values applicable to all products and mainly depend on the tungsten-copper ratio, material density, powder metallurgy process, and subsequent processing state. According to publicly available manufacturer technical data, the hardness of common grades is approximately 115–300, and the flexural strength is approximately 667–1160 MPa; tensile strength needs to be verified separately according to the specific grade and manufacturing process.

Mechanical properties of common tungsten-copper alloys

The following table lists reference values based on public product data. Different manufacturers, product forms, and test methods may cause differences, so these data are suitable for preliminary material selection and should not be directly used as acceptance standards.

Grade	Brinell hardness (HB)	Flexural strength (MPa)	Tensile strength (MPa)
W50Cu50	Approx. 115	No uniform reference value currently	Requires actual measurement or specification sheet
W60Cu40	Approx. 140	No uniform reference value currently	Requires actual measurement or specification sheet
W70Cu30	Approx. 175	Approx. 667–790	Approx. 440–560
W75Cu25	Approx. 195	Approx. 706–885	Requires verification
W80Cu20	Approx. 220	Approx. 736–980	Approx. 700
W85Cu15	Approx. 240	Approx. 765–1080	Requires verification
W90Cu10	Approx. 260	Approx. 804–1160	Requires verification

Data source: publicly available technical data of CTIA GROUP. The hardness data in the table mainly use Brinell hardness (HB); some manufacturers use Vickers hardness (HV10); the two hardness scales cannot be directly compared at the same numerical values. Flexural strength data differ significantly due to different suppliers and product specifications.

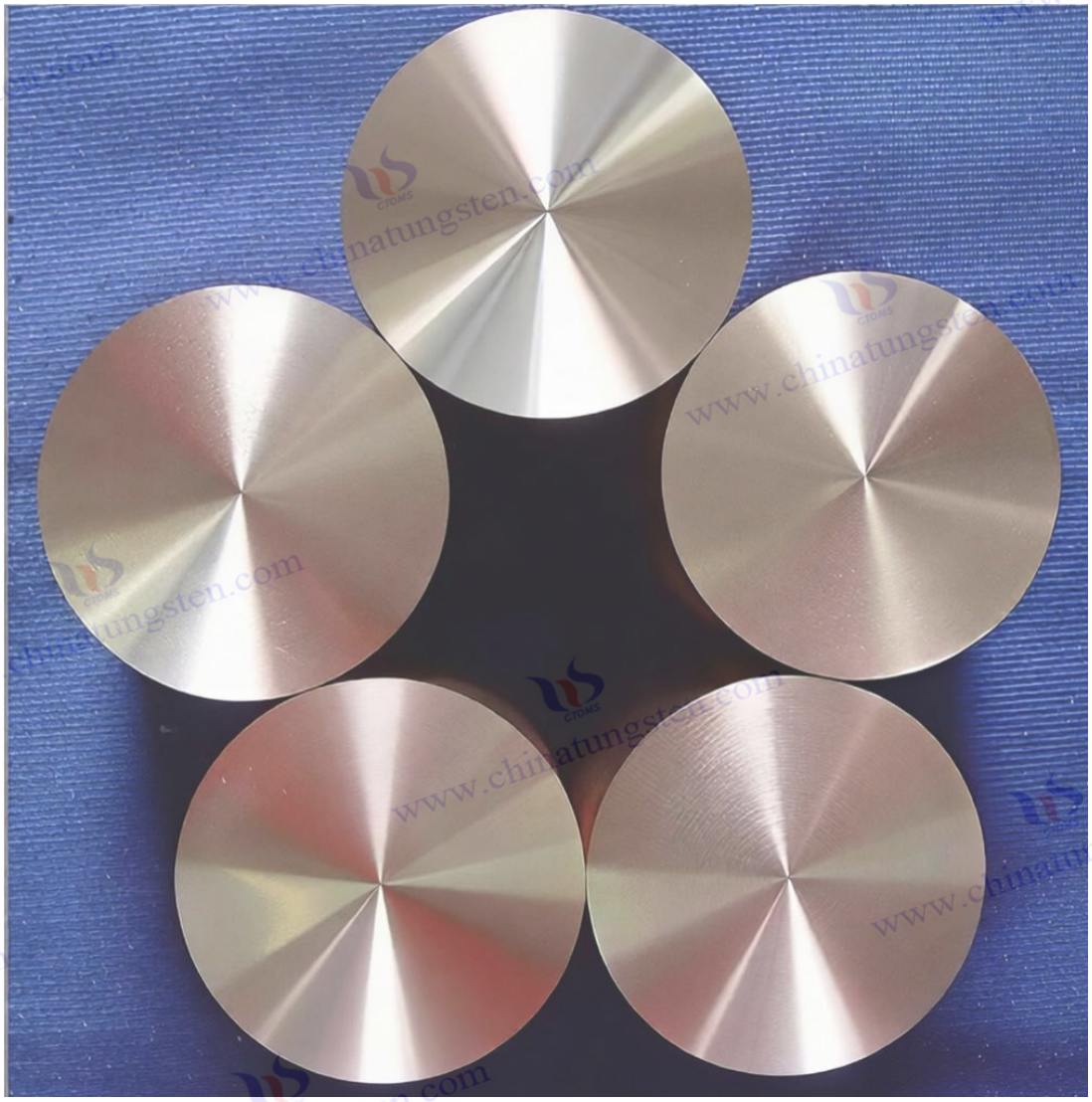
What do the three properties represent?

Hardness reflects the ability of a material to resist indentation, local plastic deformation, and surface wear; flexural strength reflects the ability of a specimen to withstand failure under bending load; tensile strength reflects the maximum engineering stress a material can withstand before fracture under tensile load. The three cannot replace each other, and high hardness does not necessarily mean that tensile strength or flexural strength is necessarily higher.

Tungsten-copper alloy is composed of a tungsten phase and a copper phase, and its properties are also affected by porosity, the bonding state between the two phases, copper phase distribution, and processing defects. As tungsten content increases, hardness and flexural strength usually show an upward trend, but actual results still depend on the material process, and tensile strength cannot be inferred solely from the grade.

If used for electrical contacts, resistance welding electrodes, or high-voltage switch contacts, focus should be placed on hardness, flexural strength, and arc erosion resistance; if used for precision electronic packaging or structural parts subjected to continuous tensile load, priority should be given to verifying tensile strength, yield strength, and elongation. Relevant materials and technical data from CTIA GROUP can also be consulted during material selection.

For formal procurement or design calculations, it is recommended to require suppliers to provide material reports for the corresponding grade, supply state, and test method, especially confirming whether the flexural strength and tensile strength come from specimens of the same batch.



Q23 What are the melting behavior, high-temperature resistance, and arc erosion resistance of tungsten-copper alloy?

Tungsten-copper alloy (W-Cu) combines the high melting point and high-temperature stability of tungsten with the excellent electrical and thermal conductivity of copper. It is a typical metal composite material widely used in fields such as high-voltage circuit breaker contacts, resistance welding electrodes, electrical discharge machining electrodes, and high-power electronic devices. Its melting behavior, high-temperature resistance, and arc erosion resistance are closely related to the tungsten-copper ratio, material density, microstructure, and actual working conditions.

I. Melting behavior of tungsten-copper alloy

Tungsten-copper alloy is different from a homogeneous metal alloy with a single melting point. Because the mutual solubility of tungsten and copper in the solid and liquid states is relatively low, common tungsten-copper materials usually have a composite microstructure in which the tungsten phase and copper phase are combined; therefore, when heated, the two components do not melt simultaneously at the same temperature.

Material	Ref.melting point	Main thermal behavior
Copper	Approx. 1084.6℃	Melts first, followed by possible flow, spattering, and evaporation
Tungsten	Approx. 3422℃	Usually remains solid when the copper phase melts, providing high-temperature skeleton support
W-Cu		As temperature rises, Cu & W phases soften, melt, or undergo other high-temperature changes in sequence

Tungsten-copper alloy is usually prepared by powder metallurgy (PM) processes, including pressing tungsten powder, sintering to form a porous tungsten skeleton, and then infiltrating liquid copper into the pores of the tungsten skeleton through a infiltration process. After proper control, the material can form a relatively dense and stable composite microstructure.

When the material is subjected to an arc or other localized high-temperature heat source, the copper phase usually heats up and melts first, and may then evaporate, spatter, or migrate; at the same time, the tungsten skeleton can still remain solid at higher temperatures, providing certain structural support for the material. If heat input continues to increase and a large amount of the copper phase is lost, the tungsten skeleton may also undergo local melting, deformation, cracking, or spalling, ultimately leading to material damage.

Therefore, the relatively high overall heat resistance of tungsten-copper alloy does not mean that the copper phase will not melt, nor does it mean that the material can work stably for a long time near the melting point of tungsten. Actual melting behavior also depends on the duration of the heat source, local temperature gradient, heat dissipation conditions, and internal microstructure of the material.

II. High-temperature resistance of tungsten-copper alloy

The high-temperature resistance of tungsten-copper alloy mainly comes from the high melting point and high-temperature stability of the tungsten phase, as well as the good thermal conductivity of the copper phase. The tungsten phase helps maintain the structural stability of the material under high thermal load, while the copper phase can conduct locally generated heat to the surrounding area and reduce local heat accumulation. The synergistic effect of the two components enables tungsten-copper alloy to adapt to high heat flux conditions that many ordinary copper materials cannot withstand for a long time.

However, the high-temperature resistance of tungsten-copper alloy cannot be judged only by the melting point of tungsten. For materials with higher tungsten content, even if the tungsten skeleton has not melted, the copper phase may already have softened, melted, or volatilized, causing changes in the internal microstructure of the material and further affecting dimensional stability, mechanical strength, and electrical conductivity. In oxygen-containing environments such as air, high-temperature tungsten may also oxidize, further affecting material life.

Actual high-temperature resistance is mainly affected by the following factors.

The first is the tungsten-copper ratio. Generally, grades with higher tungsten content have higher overall high-temperature stability and a lower coefficient of thermal expansion, but the reduction in copper content also changes the thermal conductivity, electrical conductivity, and heat diffusion ability of the material. Specific performance needs to be judged in combination with the grade and manufacturing process.

The second is material density and microstructure. Porosity, cracks, non-uniform tungsten skeleton distribution, and insufficient copper phase filling may all cause increased local thermal resistance, leading to temperature concentration when the material heats up rapidly and aggravating thermal stress and microstructural damage.

The third is thermal load and heat dissipation conditions. Short-term exposure to high-temperature impact and long-term exposure to a high-temperature environment are two different working states. For conditions such as pulse heating and arc impact, the material may temporarily withstand a higher thermal load by relying on relatively fast heat conduction; under continuous high temperature, problems such as copper phase loss, interface changes, and oxidation may gradually accumulate.

Therefore, tungsten-copper alloy is suitable for application scenarios such as high temperature, strong heat flux, and rapid thermal cycling, but the specific allowable working temperature should be determined according to duration, atmosphere, load, and cooling conditions; the melting point of tungsten should not be directly regarded as the maximum service temperature of tungsten-copper alloy.

III. Arc erosion resistance of tungsten-copper alloy

Tungsten-copper alloy has good arc erosion resistance and is widely used in components that need to withstand instantaneous high temperature and strong current, such as high-voltage

switch contacts, vacuum switch contacts, arc contacts, and EDM electrodes. During arc discharge, the arc channel and its attachment area generate highly concentrated heat, and the material surface may undergo local melting, evaporation, spattering, and material migration. Tungsten-copper alloy can resist this damage to a certain extent, mainly relying on the different thermophysical properties of the tungsten phase and the copper phase.

The tungsten phase has a high melting point and relatively high hardness and can usually maintain a solid structure better than the copper phase under arc action, helping to support the heated area and limit the development of local melting erosion. The copper phase has good electrical and thermal conductivity and can promote current transmission and heat diffusion. Under certain conditions, the material migration and heat consumption caused by melting and evaporation of the copper phase also affect the temperature distribution and erosion process in the arc area.

However, tungsten-copper alloy is not completely immune to arc erosion. As arc burning time lengthens, the number of breaking operations increases, or arc energy increases, the copper phase may gradually be lost, and pits, erosion grooves, or local protrusions may form on the surface. When copper phase loss is severe, the tungsten skeleton may be exposed, loosened, or even spalled, causing increased surface roughness and changes in effective contact area, which in turn affect contact resistance and switch performance. Arc erosion resistance mainly depends on the following aspects:

Influencing factor	Effect on arc erosion resistance
W-Cu ratio	Changes high-temperature skeleton stability, electrical and thermal conductivity, and copper phase loss characteristics
Material density	Dense and uniform microstructure is usually conducive to reducing the risk of local overheating and material spalling
W skeleton structure	Skeleton continuity, particle bonding state, and copper phase distribution affect microstructural stability after arc action
Arc energy	Current, voltage, arc burning time, and number of breaking operations affect the cumulative thermal load borne by the material
Working environment	Air, vacuum, and other atmospheres affect surface reactions, discharge state, and material loss
Cooling conditions	Heat dissipation capability affects temperature rise, temperature gradient, and thermal fatigue damage

For high-voltage switch contacts, in addition to arc erosion resistance, contact resistance, breaking capacity, mechanical strength, and electrical life also need to be considered; for EDM electrodes, attention should also be paid to electrode wear rate, machining efficiency, surface quality, and dimensional retention capability. Different applications have different performance requirements for tungsten-copper materials, and their comprehensive performance cannot be judged solely by the level of tungsten content.

IV. Application selection of different tungsten-copper grades

Common grades of tungsten-copper alloy include W70Cu30, W75Cu25, W80Cu20, and W90Cu10, among which the numbers usually represent the nominal mass percentages of

tungsten and copper. For example, W80Cu20 usually means tungsten accounts for approximately 80% and copper approximately 20%. Different grades differ in high-temperature stability, electrical and thermal conductivity, coefficient of thermal expansion, and mechanical properties.

grade	Main performance focus	Application directions that can be evaluated
W70Cu30	Balances electrical conductivity, thermal conductivity, and erosion resistance	Electrical contacts, resistance welding electrodes, some EDM electrodes
W75Cu25	Achieves a balance between thermal conductivity and thermal expansion matching	Electronic packaging, thermal management parts, and some electrodes
W80Cu20	Higher tungsten content, lower thermal expansion, and better dimensional stability	High-voltage switch contacts, precision electronic packaging, arc-resistant parts
W90Cu10	Lower thermal expansion, high tungsten content	Specific parts with high requirements for low thermal expansion and high dimensional stability

The above grades are for preliminary screening only, and specific performance also depends on powder particle size, tungsten skeleton preparation method, infiltration quality, final density, and subsequent processing state. For actual procurement, relevant tungsten-copper materials and technical data from CTIA GROUP can be consulted, and applicable specifications can be confirmed in combination with operating conditions.

V. How to evaluate the actual arc erosion resistance of tungsten-copper alloy?

In engineering applications, to judge the arc erosion resistance of tungsten-copper alloy, priority should be given to actual test results under specified test conditions rather than merely comparing melting points or tungsten content. Commonly used evaluation indicators include mass loss, volume loss, erosion depth, surface morphology changes, contact resistance changes, and structural integrity after multiple arc actions. Among them, mass loss reflects the change in material mass before and after the test; volume loss can more intuitively measure the degree to which the material is eroded; erosion depth is used to judge the degree of local damage; contact resistance change helps evaluate the electrical contact stability of electrical contacts after repeated operation. When comparing grades, it should also be ensured that test current, voltage, arc burning time, number of breaking operations, atmosphere, and cooling conditions are basically consistent; otherwise, different test results may lack comparability.

In short, the high-temperature resistance and arc erosion resistance of tungsten-copper alloy come from the synergistic cooperation between the structural support of the high-melting-point tungsten phase and the electrical and thermal conductivity of the copper phase. Only by reasonably selecting the tungsten-copper ratio, controlling material density and microstructure, and conducting verification according to real thermal load and arc working conditions can its material advantages be more accurately brought into play and the service life of components be extended.



Q24 Why are the density, electrical conductivity, and thermal conductivity of tungsten-copper alloy affected by porosity and manufacturing process?

The density, electrical conductivity, and thermal conductivity of tungsten-copper alloy (W-Cu) depend not only on the ratio of tungsten to copper, but are also affected by porosity, powder particle size, sintering temperature, infiltration effect, and subsequent processing. The fundamental reason is that tungsten-copper alloy is usually prepared by powder metallurgy and infiltration processes, and the final performance depends on the distribution and bonding state of the tungsten skeleton and copper phase, as well as whether pores and defects exist inside the material.

I. Why does porosity affect the three properties?

Porosity is the proportion of pore volume inside the material to the total volume. Pores in tungsten-copper alloy may come from insufficient powder pressing, uneven sintering shrinkage, incomplete copper infiltration, or microcracks formed during subsequent processing.

Effect on density

Pores contribute almost no mass but occupy material volume. Therefore, when the tungsten-copper ratio is unchanged, the higher the porosity, the lower the actual density is usually. The fewer the pores and the higher the material density, the closer the measured density is to the theoretical density corresponding to that ratio.

Effect on electrical conductivity

Pores reduce the effective conductive cross-sectional area and make the current path more tortuous; if pores are concentrated at the interface between tungsten particles and the copper phase, they may also increase interfacial contact resistance. Therefore, an increase in porosity usually reduces electrical conductivity and makes the conductive performance at different locations more uneven.

Effect on thermal conductivity

The gas in pores usually has much lower thermal conductivity than metal, and some pores approximately form obstacles to heat conduction. Heat needs to bypass the pores, the path becomes longer, and local thermal resistance increases, so thermal conductivity usually decreases as porosity increases. The shape, size, and distribution of pores also affect the actual degree of reduction.

II. How does the manufacturing process change the properties of tungsten-copper alloy?

Manufacturing stage	Effect on material microstructure	Effect on final performance
Powder particle size & mixing	Affects particle packing, tungsten phase uniformity, and pore distribution	Indirectly affects density, electrical conductivity, and thermal conductivity
Pressing and forming	Determines compact density and density distribution	Uneven pressing easily causes residual porosity and performance differences
Sintering process	Affects tungsten skeleton formation, particle bonding, and shrinkage uniformity	Skeleton quality affects material density and heat and electrical transmission paths
Copper infiltration process	Determines whether liquid copper can fully fill the pores of the tungsten skeleton	Insufficient infiltration leaves pores and reduces density and transmission performance
Subsequent heat treatment & processing	May change residual stress, microstructural state, and surface integrity	Affects dimensional stability, local electrical conductivity, and test results

Among these, copper infiltration is a key step affecting the performance of many tungsten-copper composite materials. If the pore distribution of the tungsten skeleton is reasonable and the liquid copper can fully enter the interior, it is usually conducive to forming a dense composite structure; if the skeleton pores are too small, closed pores exist, or the infiltration temperature, time, and wetting conditions are unsuitable, problems such as local copper deficiency, residual porosity, and microstructural non-uniformity may occur. In addition, the manufacturing process not only changes porosity but also affects the spatial distribution of the tungsten phase and copper phase, interfacial contact conditions, and impurity content. These factors jointly determine the transmission efficiency of electrons and heat inside the material; therefore, even if two products have the same nominal grade, they may exhibit different electrical conductivity and thermal conductivity.

III. What is the relationship among the three properties?

All three properties are related to material density, but their variation patterns are not completely the same.

Performance	Change when porosity increases	Main reason
Density	Decreases	Metal mass per unit total volume decreases
Electrical conductivity	Decreases	Effective conductive cross-sectional area decreases, and current path and interface resistance increase
Thermal conductivity	Decreases	Heat conduction path is obstructed, and equivalent thermal resistance increases

The relationship between density and porosity can be approximately expressed as: ρ_measured ≈ ρ_theoretical × (1 – P). Here, ρ_measured is the measured density of the material, ρ_theoretical is the theoretical density of the pore-free material, and P is porosity expressed as a volume fraction. This formula applies to approximate situations where the pore mass is negligible and the theoretical density calculation is reasonable; if there is obvious composition deviation or internal defects, analysis combined with the actual material composition is still needed. Electrical conductivity and thermal conductivity cannot be directly converted based only on density. They are also affected by the tungsten-copper ratio, interface quality, impurity content, and microstructure. For example, at the same porosity, a material with a more continuous copper phase distribution and better interfacial bonding may have better electrical and thermal conductivity.

IV. How to judge the quality of tungsten-copper alloy through testing?

Actual quality evaluation should combine density, electrical conductivity, and thermal conductivity rather than checking only one of them. Density testing can determine the overall density of the material; metallographic examination can observe pores, the tungsten skeleton, and copper phase distribution; electrical conductivity testing is used to evaluate current transmission capability; thermal conductivity testing reflects the heat transfer performance of the material. If the product density is lower than expected, the tungsten-copper ratio, residual porosity, and infiltration integrity should be further checked; if the density meets the requirements but the electrical conductivity or thermal conductivity is low, factors such as copper phase continuity, interfacial contact, impurities, and test methods should also be investigated. For electrical contacts, electrodes, and electronic heat-dissipating parts, it is recommended to specify in the procurement technical conditions the grade, lower density limit, electrical conductivity or thermal conductivity requirements, as well as the corresponding test methods and temperature conditions. Relevant materials and technical information from CTIA GROUP can also serve as a reference for specification comparison and material selection of tungsten-copper alloy: https://www.ctia.com.cn.

In summary, porosity mainly affects the performance of tungsten-copper alloy by reducing the effective metal volume and hindering current and heat transmission, while the manufacturing process determines whether these pores form, whether the copper phase can fully fill them, and whether the tungsten and copper phases can form a uniform and dense composite

structure. Only by combining composition control, densification process, and performance testing can tungsten-copper alloy materials meeting application requirements be stably obtained.

Q25 How to correctly compare the performance data of tungsten-copper alloy provided by different manufacturers?

When comparing the performance data of tungsten-copper alloy (W-Cu) provided by different manufacturers, it is not enough to look only at the grade and parameter values; it is also necessary to confirm whether the material composition, manufacturing process, testing conditions, test methods, and the product state corresponding to the data are consistent. Materials also marked as W80Cu20 may have different actual performance from different manufacturers, so comparison conditions should be unified first, and then whether the data are comparable should be judged.

I. First confirm whether the grade and actual composition are consistent

The numbers in tungsten-copper alloy grades usually indicate the nominal mass percentages of tungsten and copper. For example, W80Cu20 usually means tungsten accounts for approximately 80% and copper approximately 20%. However, the nominal ratio does not equal the actual test result; factors such as raw material purity, batching accuracy, copper infiltration loss, and impurity content may all cause differences in actual composition. When comparing products, the following information should be checked first: actual content of tungsten and copper, impurity control requirements, composition testing methods, and the standard or manufacturer internal specification adopted for the grade. If one manufacturer's data correspond to nominal composition while another provides measured composition, the two should not be directly regarded as completely identical.

II. Unify the main performance indicators and units

Common performance indicators of tungsten-copper alloy include density, electrical conductivity, thermal conductivity, coefficient of thermal expansion, hardness, bending strength, and tensile strength. The comparison methods for each indicator are not the same.

Performance indicator	What should be confirmed during comparison	Common problems
Density	Unit, measured value or theoretical value, specimen state	Directly comparing theoretical density with actual density
Electrical conductivity	Conductivity or resistivity, test temperature, unit and reference	Directly comparing percentage conductivity on different bases
Thermal conductivity	Test temperature, test method, unit	Mixing room-temperature data with high-temperature data
Coefficient of thermal expansion	Temperature range, average value or instantaneous value	Ignoring differences caused by different temperature ranges
Hardness	Brinell (HB), Vickers (HV), or Rockwell (HR) test conditions	Directly comparing values on different hardness scales
Bending strength	Specimen dimensions, support span, loading method, and test standard	Treating results under different test conditions as equivalent
Tensile strength	Specimen shape, processing state, test standard, and sampling direction	Directly comparing specimen data in different states

For example, electrical conductivity may be expressed as Sigma conductivity (Electrical Conductivity, usually in megasiemens per meter, MS/m) or as a percentage of the International Annealed Copper Standard (IACS). The two can be converted, but it must be confirmed that the reference temperature and standard basis are consistent. Similarly, the unit of thermal conductivity is usually watts per meter-kelvin [W/(m·K)]. The higher the value, the stronger the heat transfer capability of the material is usually, but such numerical comparison is meaningful only when the test temperature and test method are comparable.

III. Check the manufacturing process and material density

Even if two manufacturers use the same tungsten-copper ratio, different manufacturing processes may form different microstructures and properties.

Influencing factor	Potential impact on performance data
Powder particle size & mixing uniformity	Affects tungsten particle distribution, pore formation, and microstructural uniformity
Pressing and sintering process	Affects tungsten skeleton strength, porosity, and dimensional stability
Copper infiltration quality	Affects copper phase filling degree, material density, and thermal and electrical conductivity
Impurities and interface state	Affects electron transmission, heat conduction, and high-temperature stability
Subsequent heat treatment & processing	May change residual stress, defect state, and final test results

Therefore, when comparing performance data, the material density and its allowable deviation should also be checked. Density can serve as an important clue for judging the degree of density, but it cannot alone prove that the material quality is better, nor can it completely replace porosity, metallographic structure, and electrothermal performance testing.

IV. Distinguish among typical values, guaranteed values, and measured values

Data sheets from different manufacturers may use different ways of expressing data, and the following three categories especially need to be distinguished during procurement comparison.

Data type	Meaning	Applicable use
Typical value	Represents common products or test results, not necessarily a value that every batch of products can achieve	Preliminary material selection and technical reference
Guaranteed value or specification limit	The minimum value, maximum value, or allowable range that the manufacturer promises to meet	Technical agreement and acceptance basis
Batch measured value	Data actually measured for a specific batch or specimen	Incoming inspection, batch comparison, and quality traceability

For example, Manufacturer A publishes a thermal conductivity of 220 W/(m·K), and Manufacturer B publishes a minimum guaranteed value of 210 W/(m·K). It cannot be concluded solely from this that Manufacturer A's product is definitely better than Manufacturer B's, because what A provides may be a typical value, while B explicitly promises a minimum limit. A more reasonable approach is to require both parties to provide typical values, specification ranges, and batch measured results for the same grade under the same test conditions.

V. Check the testing standards and test conditions

Performance data are strongly comparable only when the test conditions are sufficiently close. For tungsten-copper alloy, at least the test standard and version, specimen dimensions, test temperature, specimen processing state, sampling location, and testing equipment should be confirmed. Among these, density testing should clarify which measurement method is used; electrical conductivity and thermal conductivity testing should clarify the temperature conditions and corresponding standards; hardness and strength testing should clarify the specimen state and loading conditions. For applications such as high-voltage switch contacts, conventional material performance testing should also be distinguished from actual arc erosion testing, because the former cannot directly replace the latter. If two manufacturers use different standards, it should first be determined whether an acceptable equivalence relationship exists between the standards. When equivalence cannot be confirmed, it is best to require both parties to retest according to the same standard, or entrust a third-party testing institution with the corresponding capability to conduct the comparison.

VI. Establish a unified supplier comparison table

During actual procurement, the data of all candidate manufacturers can be placed in the same technical comparison table to avoid making decisions based only on one outstanding parameter.

Comparison item	Manufacturer A	Manufacturer B	Manufacturer C
Grade and actual composition			
Density and allowable deviation			
Electrical conductivity and test conditions			
Thermal conductivity and test temperature			
Coefficient of thermal expansion & temperature range			
Hardness and scale			
Bending strength, tensile strength			
Testing standards and reports			
Typical value, guaranteed value, or measured value			

If used for electrical contacts, the weight of indicators such as electrical conductivity, arc erosion resistance, contact resistance, and electrical life should be increased; if used for electronic packaging, thermal conductivity, coefficient of thermal expansion, density, and dimensional stability should be mainly examined; if used for load-bearing parts, strength, hardness, defects, and fatigue-related performance should be mainly checked.

VII. How to judge whether the data are credible?

Whether manufacturer data are reliable can be judged from three aspects: data completeness, test traceability, and batch stability. Technical data should clearly specify the product grade, test method, unit, test conditions, and data type; test reports should correspond to specific products or batches; for critical applications, multi-batch testing should also be used to confirm whether performance fluctuations are within the agreed range.

If the parameters of a certain product are obviously higher than those of other manufacturers, first check whether the composition is the same, whether the density is close, whether the test temperature is consistent, and whether the data are typical values or special customized samples, rather than immediately regarding them as a performance advantage. For high-requirement applications, suppliers can be required to provide material quality certificates, batch inspection reports, and necessary third-party test results. Relevant products and technical information from CTIA GROUP can also serve as one of the references for verifying supplier technical information: https://www.ctia.com.cn.

In one sentence, to correctly compare tungsten-copper alloy from different manufacturers, the principles of same grade, same composition basis, same test conditions, and same data basis should be followed, and judgment should be made in combination with the manufacturing process, batch stability, and actual service conditions. Only by unifying the measurement conditions and guarantee ranges of the data can the differences in material performance be truly distinguished, rather than merely comparing the numbers on technical tables.





D. Manufacturing Processes of Tungsten-Copper Alloy

Q26 What are the main manufacturing processes for tungsten-copper alloy?

Tungsten-copper alloy (W-Cu) is a metal composite material composed of a tungsten phase and a copper phase. Because the melting points of tungsten and copper differ greatly and their mutual solubility in the solid state is very low, conventional melting makes it difficult to directly prepare tungsten-copper materials with uniform microstructure and high density. Therefore, industrial production mainly adopts the powder metallurgy route, including the tungsten skeleton infiltration method, mixed powder pressing and sintering method, activated liquid-phase sintering method, as well as injection molding and additive manufacturing processes applied to specific products in recent years.

I. Main manufacturing processes for tungsten-copper alloy

The tungsten skeleton infiltration method is the mainstream process

Tungsten powder is first pressed and formed and then sintered to produce a porous tungsten skeleton with a certain porosity. Copper is then heated to a molten state so that liquid copper enters the skeleton pores under capillary action, and after cooling a tungsten-copper composite material is formed. This process is suitable for products with high requirements for high density, high electrical and thermal conductivity, and microstructural stability, and is often used for electrical contacts, electrodes, and electronic packaging materials.

Mixed powder pressing and sintering method

Tungsten powder and copper powder are mixed according to the ratio, then formed into compacts by die pressing or cold isostatic pressing, followed by sintering. The process flow is relatively direct, but because the sintering behaviors of tungsten and copper differ greatly, the material is prone to problems such as insufficient densification, residual porosity, or microstructural non-uniformity. This method usually needs to be optimized in combination with powder particle size, pressing pressure, and sintering schedule.

Activated liquid-phase sintering method

By optimizing powder composition, adding appropriate sintering aids, or adjusting process conditions, particle rearrangement, interfacial bonding, and densification are promoted. This method can be used to improve the microstructure and properties of some tungsten-copper materials, but the process window is relatively narrow, and residual aids and composition changes may also affect electrical conductivity, thermal conductivity, and high-temperature performance.

Powder injection molding method

Metal powder is mixed with an organic binder to make a feedstock, complex-shaped blanks are obtained by injection molding, and then degreasing, sintering, and necessary subsequent processing are carried out. Its advantage is that it is suitable for batch production of small, complex-structured parts, but problems such as degreasing deformation, shrinkage control, residual porosity, and copper phase distribution need to be solved.

Additive manufacturing and composite forming technologies

Tungsten-copper parts with complex geometric shapes are manufactured through routes such as laser powder bed fusion, binder jetting combined with subsequent sintering or infiltration. Such processes are conducive to realizing internal flow channels and complex structures that are difficult to complete with traditional molds, but the two phases of tungsten and copper differ significantly in melting point, thermal conductivity, and thermal expansion, making cracks, composition segregation, and residual porosity prone to occur; process development for specific material systems is usually required.

II. Typical production flow of the tungsten skeleton infiltration method

For many traditional tungsten-copper electrical contacts and high-performance composite materials, the tungsten skeleton infiltration method has relatively high practical value. Its typical flow is as follows: tungsten powder screening and batching → pressing and forming → high-temperature sintering to form a porous tungsten skeleton → copper material assembly and infiltration → cooling and necessary heat treatment → machining, finishing, and performance testing. The control focus of each process differs. Tungsten powder particle size and pressing conditions affect the skeleton pore structure; the sintering process determines the degree of bonding between tungsten particles and the skeleton strength; the infiltration stage needs to ensure that liquid copper can fully fill the open pores while avoiding copper liquid loss or residual voids. Finally, through machining, dimensional inspection, density testing, and necessary electrothermal performance testing, it is confirmed whether the product meets the use requirements.

III. Comparison of different manufacturing processes

Manufacturing process	Main advantages	Main difficulties	Typical application directions
Tungsten skeleton infiltration method	Relatively high density, suitable for controlling tungsten-copper ratio & microstructure	Control of skeleton pores & infiltration integrity	Electrical contacts, welding electrodes, electronic packaging
Mixed powder pressing & sintering method	Relatively direct process flow, flexible batching	Control of densification & microstructural uniformity	Specific grades and structural parts
Activated liquid-phase sintering method	Can improve densification of specific systems	Residual aids & performance stability	Composite materials with specific formulations
Powder injection molding method	Suitable for complex shapes & batch production	Control of degreasing, shrinkage, and defects	Small precision parts
Additive manufacturing and composite forming	Suitable for complex structures and functional integration	Cracks, segregation, porosity, and process repeatability	R&D, specific customized parts

It should be distinguished that powder metallurgy is a process category; both the tungsten skeleton infiltration method and the mixed powder pressing and sintering method belong to the powder metallurgy route; infiltration is one specific densification method among them, not an independent category completely parallel to powder metallurgy.

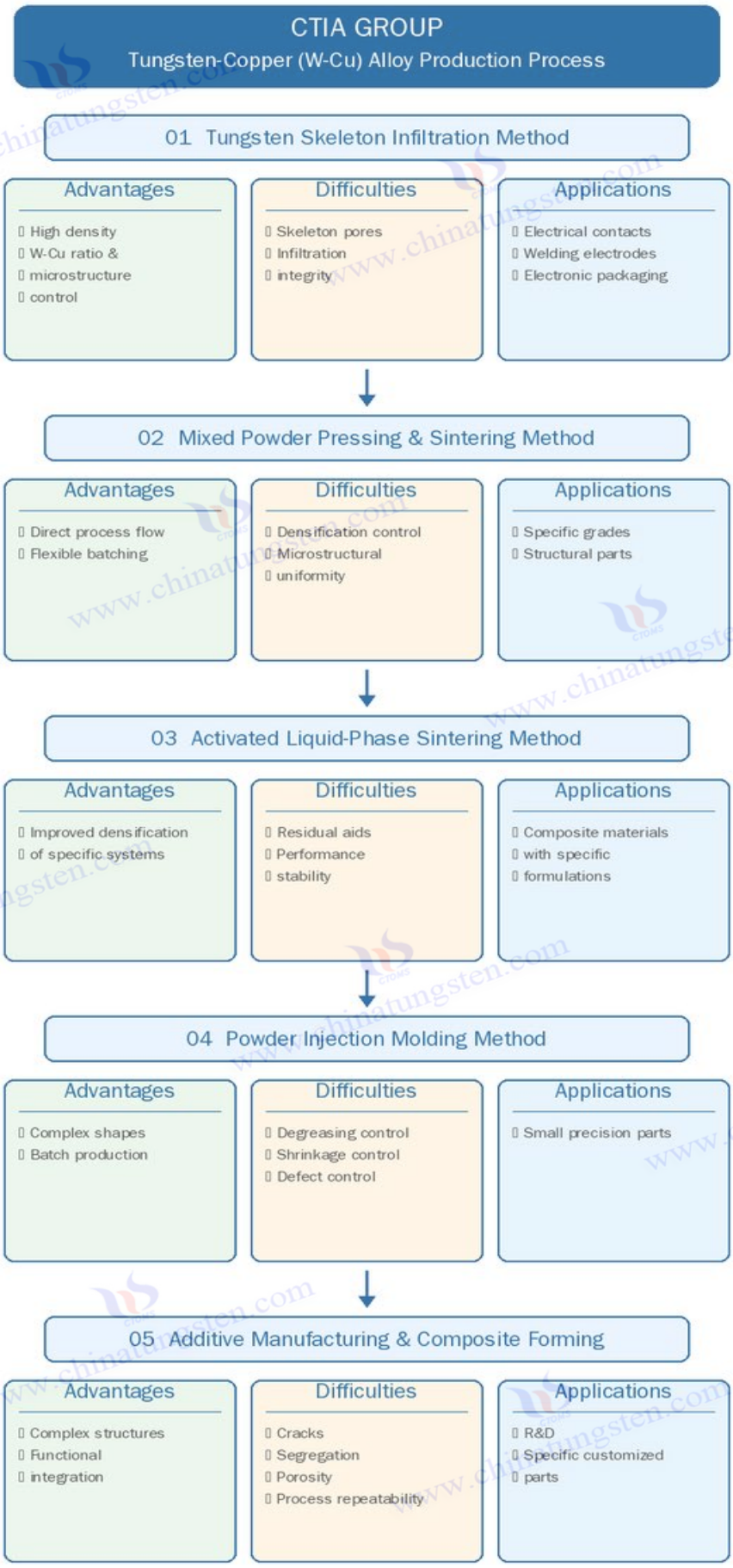
IV. How does the manufacturing process affect final performance?

The manufacturing process of tungsten-copper alloy directly affects density, electrical conductivity, thermal conductivity, coefficient of thermal expansion, hardness, and arc erosion resistance. First, porosity determines the actual density of the material. The more residual pores, the lower the measured density of the material is usually, and the more easily current and heat transmission paths are obstructed. Second, the distribution of the tungsten skeleton and copper phase affects the transmission efficiency of heat and current between the two phases. If the copper phase filling is insufficient or the distribution is uneven, problems such as locally high resistance, uneven thermal conductivity, and local overheating may occur. Third, powder impurities, interface state, and subsequent processing defects may also affect the strength, dimensional stability, and long-term service performance of the material.

For example, electrical contacts usually need to comprehensively consider electrical conductivity, arc erosion resistance, and mechanical strength; electronic packaging materials pay more attention to thermal conductivity, coefficient of thermal expansion, and dimensional stability; small parts with complex shapes may place more importance on forming accuracy, shrinkage control, and batch consistency. Therefore, the choice of manufacturing process should be comprehensively determined according to product application, size and shape, target performance, and cost requirements. For actual material selection, relevant tungsten-copper materials and technical information from CTIA GROUP can be consulted, and suppliers should be required to explain the specific manufacturing route, material density, testing standards, and batch performance data.

In one sentence, tungsten-copper alloy is mainly manufactured on the basis of powder metallurgy, among which the tungsten skeleton infiltration method is suitable for many high-performance traditional products, while mixed powder sintering, powder injection molding, and additive manufacturing serve different material systems, part shapes, and production needs respectively. What truly determines product quality is not only the name of the process adopted, but also whether powder control, sintering and infiltration parameters, microstructural density, and final testing are stable and reliable.




CTIA GROUP
Tungsten-Copper (W-Cu) Alloy Production Process
01 Tungsten Skeleton Infiltration Method
Advantages
High density
W-Cu ratio &
microstructure
control
Difficulties
Skeleton pores
Infiltration
integrity
Applications
Electrical contacts
Welding electrodes
Electronic packaging
02 Mixed Powder Pressing & Sintering Method
Advantages
Direct process flow
Flexible batching
Difficulties
Densification control
Microstructural
uniformity
Applications
Specific grades
Structural parts
03 Activated Liquid-Phase Sintering Method
Advantages
Improved densification
of specific systems
Difficulties
Residual aids
Performance
stability
Applications
Composite materials
with specific
formulations
04 Powder Injection Molding Method
Advantages
Complex shapes
Batch production
Difficulties
Degreasing control
Shrinkage control
Defect control
Applications
Small precision parts
05 Additive Manufacturing & Composite Forming
Advantages
Complex structures
Functional
integration
Difficulties
Cracks
Segregation
Porosity
Process repeatability
Applications
R&D
Specific customized
parts

Q27 What is the tungsten-copper alloy infiltration method? What is its basic process flow?

The tungsten-copper alloy infiltration process (Tungsten-Copper Infiltration Process) is a typical powder metallurgy preparation process, which mainly prepares a porous tungsten skeleton first and then infiltrates molten copper into the pores inside the skeleton, so that the tungsten phase and copper phase form a dense composite material. This process can relatively well control the tungsten-copper ratio, material density, and microstructure, and is widely used in fields such as high-voltage electrical contacts, resistance welding electrodes, electrical discharge machining electrodes, and electronic packaging.

I. Basic principle of the tungsten-copper alloy infiltration method

The tungsten-copper alloy infiltration method uses the large difference in melting point between tungsten and copper for preparation. The melting point of tungsten is approximately 3422℃, and the melting point of copper is approximately 1084.6℃. During manufacturing, tungsten powder is first pressed and formed and sintered, so that tungsten particles form a skeleton with a certain strength and interconnected pores; then copper is heated to a molten state, and under capillary action and appropriate process conditions, liquid copper enters the pores of the tungsten skeleton, and after cooling a composite structure in which the tungsten phase and copper phase are bonded to each other is formed. The key to this process is that the tungsten skeleton must have sufficient strength while retaining a suitable pore structure so that liquid copper can fully infiltrate. If the skeleton has too few pores or too many closed pores, it is difficult for liquid copper to completely fill them; if the skeleton strength is insufficient, deformation may occur during infiltration, affecting the final dimensions and performance.

II. Basic process flow of the tungsten-copper alloy infiltration method

Sequence	Stage	Basic task
1	W powder preparation and batching	Control powder particle size, purity, and batch consistency
2	Pressing and forming	Press tungsten powder into a compact of the required shape
3	High-temperature sintering	Form a tungsten skeleton with a certain strength and porosity
4	Copper material assembly and infiltration	Heat and melt the copper material so that liquid copper fills the skeleton pores
5	Cooling and post-treatment	After cooling, perform necessary heat treatment, machining, and finishing
6	Quality inspection	Inspect density, dimensions, microstructure, and related performance

Tungsten powder preparation and batching

Select suitable tungsten powder according to the target tungsten-copper grade, control powder particle size distribution, purity, and oxygen content, and check the consistency of raw material batches. Tungsten powder characteristics affect compact density, sintering shrinkage, skeleton pore distribution, and final material performance.

Pressing and forming

By means such as die pressing or cold isostatic pressing, tungsten powder is pressed into blanks of the required shape. Pressing pressure and powder filling uniformity affect compact density and its distribution. If the local density difference is too large, problems such as uneven pore

distribution, dimensional deviation, or local insufficient infiltration may form after sintering.

High-temperature sintering to form a porous tungsten skeleton

The compact is placed in an appropriate protective atmosphere or vacuum environment for high-temperature sintering, so that strong bonding forms between tungsten particles while retaining a pore structure suitable for subsequent infiltration. This step is one of the key links of the infiltration method. Insufficient sintering leads to low skeleton strength; excessive sintering may cause excessive pore shrinkage and reduced connectivity, reducing the ability of liquid copper to enter the interior of the skeleton.

Copper material assembly and infiltration

The copper material is placed above the porous tungsten skeleton or at a specified position, and then the infiltration temperature, holding time, and atmosphere conditions are set according to the material system, so that copper melts and enters the pores of the tungsten skeleton. Whether liquid copper can fully fill depends on the size and connectivity of the skeleton pores, the wetting behavior of liquid copper on the tungsten skeleton, temperature, holding time, and surface cleanliness. If infiltration is insufficient, pores may remain inside the material; if the amount of liquid copper or process control is improper, problems such as residual copper on the surface and local copper content deviation may also occur.

Cooling and post-treatment

After infiltration is completed, cooling is carried out according to process requirements. Depending on the application of the part, processes such as heat treatment, cutting, grinding, and surface finishing may also be required to achieve the specified dimensional accuracy, surface quality, and use requirements. The cooling rate and temperature gradient need to be reasonably controlled because tungsten and copper have different thermal expansion behaviors, and temperature changes may generate residual stress at the two-phase interface and inside the material.

Quality inspection

Finished products usually need to be inspected for dimensions, density, appearance, and internal microstructure, and according to the application, electrical conductivity, thermal conductivity, hardness, bending strength, or arc erosion resistance should be tested. For high-requirement parts, residual porosity, copper phase distribution, and batch performance stability should also be checked to ensure that the material meets technical specifications.

III. Main process control points of the infiltration method

Control link	Key control content	Possible problems
W powder quality	Particle size, purity, oxygen content, batch consistency	Uneven skeleton formation, performance fluctuation
Pressing and forming	Pressing pressure, compact density and uniformity	Local density difference, dimensional deviation
W skeleton sintering	Sintering temperature, time, atmosphere, structure	Insufficient skeleton strength or reduced pore connectivity
Cu infiltration	Amount of Cu, wettability, temperature, holding time	Incomplete infiltration, residual porosity, residual copper
Cooling & processing	Cooling conditions, machining allowance	Residual stress, cracks, or dimensional deviation
Finished inspection	Density, metallography, dimensions, electrothermal	Defects not identified in time, batch differences

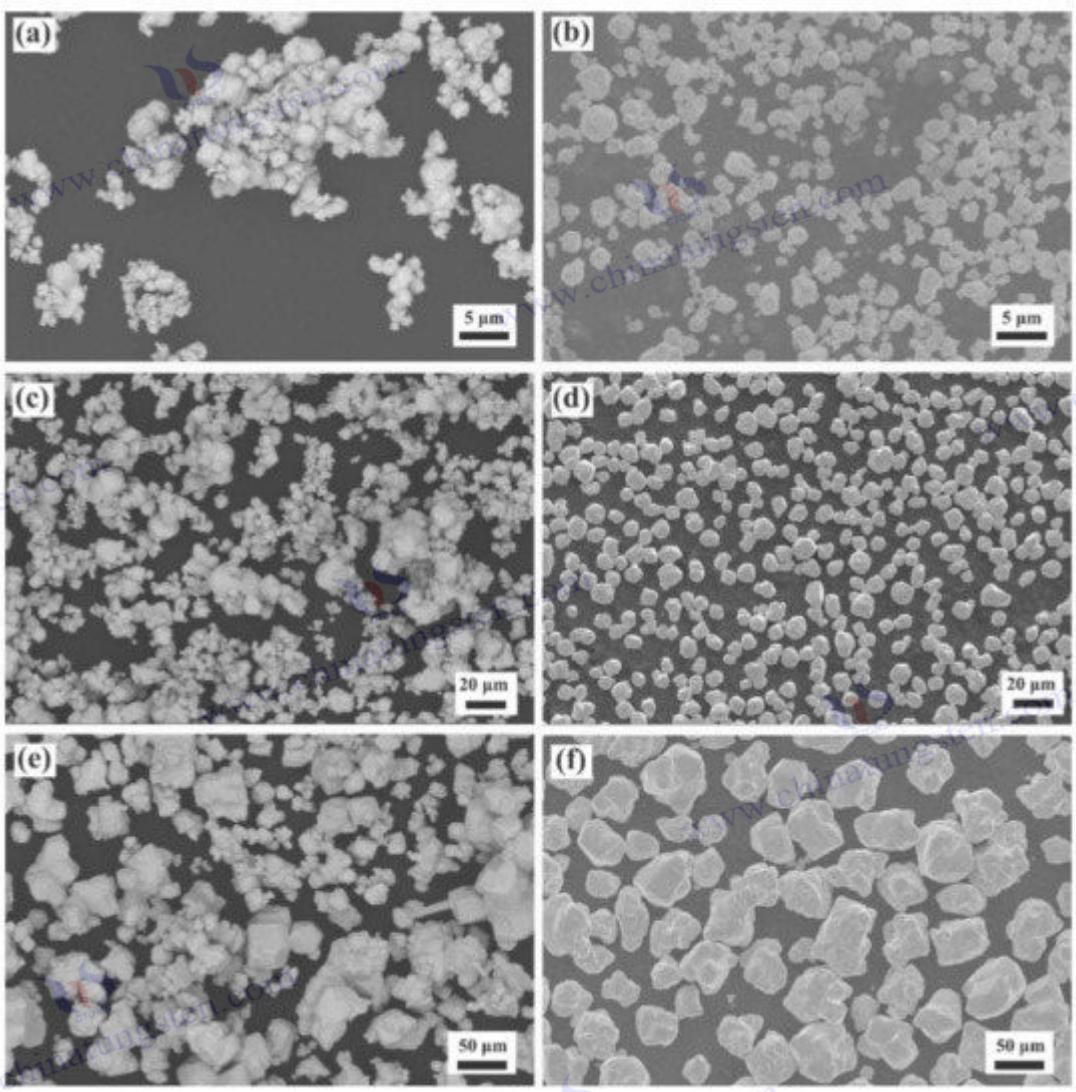
IV. Main advantages and limitations of the infiltration method

The advantage of the infiltration method lies in its ability to use the tungsten skeleton to provide structural support and to improve the electrical and thermal conductivity of the material through copper phase filling. After reasonable process control, relatively high density and good microstructural stability can usually be obtained, making it suitable for manufacturing tungsten-copper parts with high requirements for electrothermal performance and dimensional stability.

Its limitation mainly lies in the strong correlation among process parameters: the pore structure of the tungsten skeleton must be suitable for liquid copper to enter, the amount of liquid copper needs to match the pore volume of the skeleton, and the sintering and infiltration processes also need stable control. In addition, for complex-shaped parts, the internal infiltration uniformity, final dimensions, and local microstructural consistency are often more difficult to control than for simple-shaped parts.

For electrical contacts and electrodes, the infiltration method helps to balance electrical conductivity, thermal conductivity, and arc erosion resistance; for electronic packaging materials, further attention needs to be paid to the coefficient of thermal expansion, thermal conductivity, and dimensional accuracy. During actual material selection, relevant products and technical information from CTIA GROUP can be consulted, and suppliers should be required to provide density, composition, and performance inspection reports corresponding to specific grades.

In short, the core of the tungsten-copper alloy infiltration method is to first construct a porous tungsten skeleton, then use molten copper to fill the skeleton pores, and finally obtain a composite material meeting use requirements through post-treatment and testing. The final quality depends not only on the tungsten-copper ratio, but also on the tungsten skeleton quality, the degree of copper liquid filling, and the process stability of the entire process.



Q28 What is the difference between the infiltration method and the mixed-powder sintering method?

The infiltration method and the mixed-powder sintering method for tungsten-copper alloy both belong to powder metallurgy processes. The main difference lies in how tungsten powder and copper are combined: the infiltration method first prepares a porous tungsten skeleton and then allows molten copper to fill the pores; the mixed-powder sintering method mixes tungsten powder and copper powder in proportion, presses them, and then forms a composite material through sintering. Both methods affect the density, electrical conductivity, thermal conductivity, mechanical properties, and arc erosion resistance of tungsten-copper alloy, and the specific choice depends on product composition, dimensions, performance indicators, and production cost.

I. Core differences between the two processes

Infiltration method: first prepare a tungsten skeleton, then fill it with copper.

Mixed-powder sintering method: mix tungsten powder and copper powder, then press and

sinter.

Comparison item	Infiltration method	Mixed-powder sintering method
material preparation	process W powder 1st to prepare porous W skeleton	Mix W powder & Cu powder in proportion
Basic process	pressing → skeleton sintering → copper infiltration	Powder mixing → pressing → sintering
Way Cu introduced	Molten Cu enters the pores of the W skeleton	Cu & W powder participate in sintering together
Densification mechanism	Capillary action, wetting, and external process conditions jointly promote copper pore filling	Particle contact, sintering shrinkage, and liquid phase formation jointly act
Density & porosity	High density is relatively easy to obtain when the process is appropriate	Depends on powder mixing uniformity, compact density, and sintering schedule
Composition uniformity	Depends on skeleton pore distribution, copper liquid flow, and filling degree	Depends on powder mixing uniformity and component distribution during sintering
Size & shape	Suitable for skeletons of moderate complexity and common block parts, but limited by infiltration paths	Suitable for various press-formed parts; complex shapes are also limited by molds and sintering shrinkage
Process difficulties	Skeleton pore control, copper liquid wetting, infiltration temperature and time	Powder mixing uniformity, compact density, sintering shrinkage, and pore control
Production cost	More process steps, higher requirements for equipment and process control	Process may be simpler, but still depends on formulation, sintering schedule, and post-processing
Typical applications	High-voltage electrical contacts, EDM electrodes, arc erosion-resistant parts	General electrical contact materials, tungsten-copper parts of specific compositions, and powder metallurgy products

II. Why is the infiltration method more likely to achieve high density?

The key to the infiltration method is to pre-build a tungsten skeleton with interconnected pores. After the skeleton is sintered, molten copper enters the pores when wetting conditions are appropriate, filling the spaces between tungsten particles and thereby increasing the density of the material.

The mixed-powder sintering method requires tungsten powder and copper powder to form a relatively uniform and dense structure during pressing and sintering. Because the melting points of tungsten and copper differ greatly and their mutual solubility is limited, densification and microstructural uniformity during sintering need to be controlled through reasonable powder particle size, pressing pressure, sintering temperature, and holding time.

However, the infiltration method does not mean that there will definitely be no pores. If the tungsten skeleton channels are not interconnected, the wettability of the copper liquid is insufficient, the infiltration time is insufficient, or the amount of copper material is unreasonable, problems such as residual porosity, local copper deficiency, or free copper may still occur.

III. What impact does it have on electrical conductivity, thermal conductivity, and arc

resistance?

For applications such as high-voltage electrical contacts and resistance welding electrodes, the difference between the two processes must ultimately be reflected in actual performance.

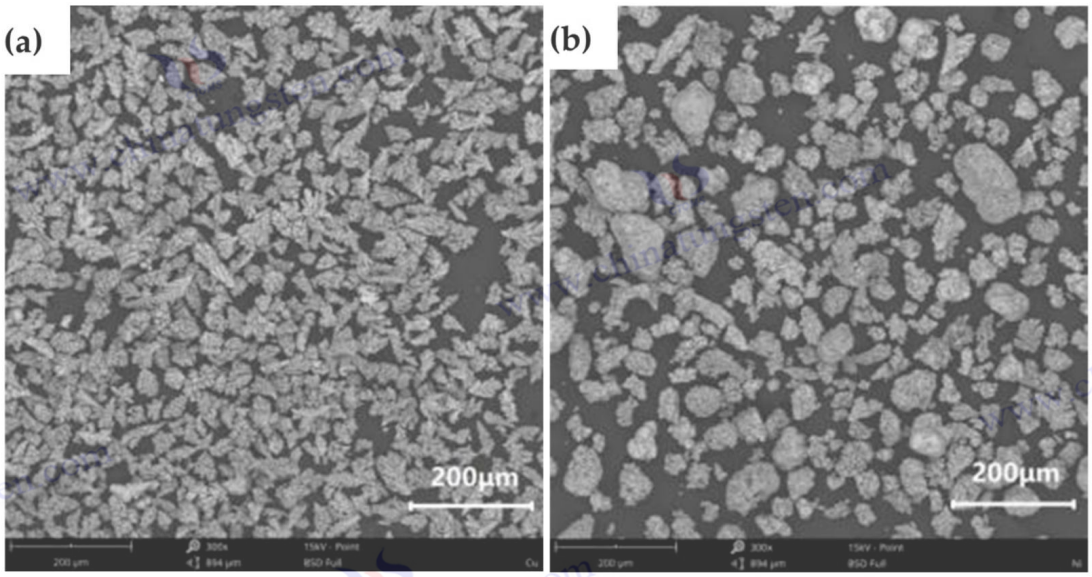
Performance indicator	Main influencing factors
Electrical conductivity	Copper content, porosity, impurities, copper phase continuity, and interfacial contact conditions
Thermal conductivity	Copper phase distribution, tungsten skeleton continuity, pores, and interfacial thermal resistance
Coefficient thermal expansion	Tungsten-copper ratio, two-phase microstructure, porosity, and test temperature
Bending strength	Tungsten skeleton strength, particle bonding state, defects, and residual stress
Arc erosion resistance	W phase distribution, Cu replenishment & evaporation behavior, density, & actual arc conditions

For tungsten-copper alloy of the same nominal composition, it cannot be judged which process provides better performance solely by the process name. A more reliable approach is to compare measured density, electrical conductivity, thermal conductivity, mechanical properties, and arc erosion results under the same test conditions.

IV. How to choose in actual production?

If the product mainly requires high density, stable electrothermal performance, and good arc erosion resistance, the infiltration method can be evaluated first, especially for important electrical contact parts such as high-voltage electrical contacts. If the product structure is suitable for press forming and mixed-powder sintering can meet the target density, composition uniformity, and performance requirements, the mixed-powder sintering method can be evaluated to comprehensively compare production efficiency, processing cost, and batch stability. Tungsten-copper material selection and process parameter evaluation can also refer to relevant product and material information from CTIA GROUP; the actual plan should still be based on the specific grade, product dimensions, and test data.

In short, the core of the infiltration method is to first form a tungsten skeleton and then fill it with copper, while the core of the mixed-powder sintering method is to mix tungsten powder and copper powder and then form and sinter them together. The former emphasizes skeleton pores and infiltration control, while the latter emphasizes powder mixing uniformity and sintering densification.



Q29 Why does tungsten-copper alloy need to prepare a porous tungsten skeleton?

The core reason why the infiltration method for tungsten-copper alloy needs to first prepare a porous tungsten skeleton is that the melting points of tungsten and copper differ greatly and their mutual solid solubility is relatively low, making it difficult to directly obtain a tungsten-copper composite material with uniform microstructure, high density, and stable performance through ordinary melting. Therefore, tungsten powder is first pressed and sintered to form a tungsten skeleton with certain strength and interconnected pores, and then molten copper is infiltrated into the pores, which can combine the high-temperature resistance of tungsten with the electrical and thermal conductivity of copper.

Main functions of the porous tungsten skeleton

Provide infiltration channels for molten copper

The sintered tungsten skeleton has interconnected pores inside. Molten copper enters these pores under the influence of capillary action, wettability, and process pressure, and after cooling forms a composite structure in which the tungsten phase and copper phase are bonded to each other. If the skeleton pores are not interconnected or are closed, it is difficult for the copper liquid to fully enter the interior, and non-infiltrated areas and residual voids are likely to occur, reducing the density and performance stability of the material.

Maintain the skeleton structure of the tungsten phase

The melting point of tungsten is approximately 3422°C, and the melting point of copper is approximately 1084.6°C. During infiltration, the copper liquid is in a molten state, while the tungsten skeleton usually remains solid, so the tungsten skeleton can maintain the basic shape of the material and provide high-temperature support for the composite material. The strength, pore distribution, and continuity of the tungsten skeleton affect the mechanical properties, arc erosion resistance, and high-temperature service stability of the finished product.

Adjust the tungsten-copper ratio and material properties

The pore volume of the porous tungsten skeleton determines the volume of copper liquid that can theoretically be accommodated. By adjusting the tungsten powder pressing density, sintering temperature, and holding time, the porosity of the skeleton can be controlled, thereby adjusting the composition ratio of the final tungsten-copper material.

Skeleton state	Effect on the infiltration process	Possible result
Too few pores	Less Cu liquid can be accommodated	W content is too high, Cu phase is insufficient
Moderate & interconnected pores	Cu liquid can more easily infiltrate fully	Conducive to obtaining a dense and uniform microstructure
Too many pores or insufficient skeleton strength	Skeleton is prone to deformation or local damage	Dimensional accuracy and mechanical properties may decrease
Closed pores or poor connectivity	Copper liquid is difficult to enter the interior	Residual voids are likely, reducing density

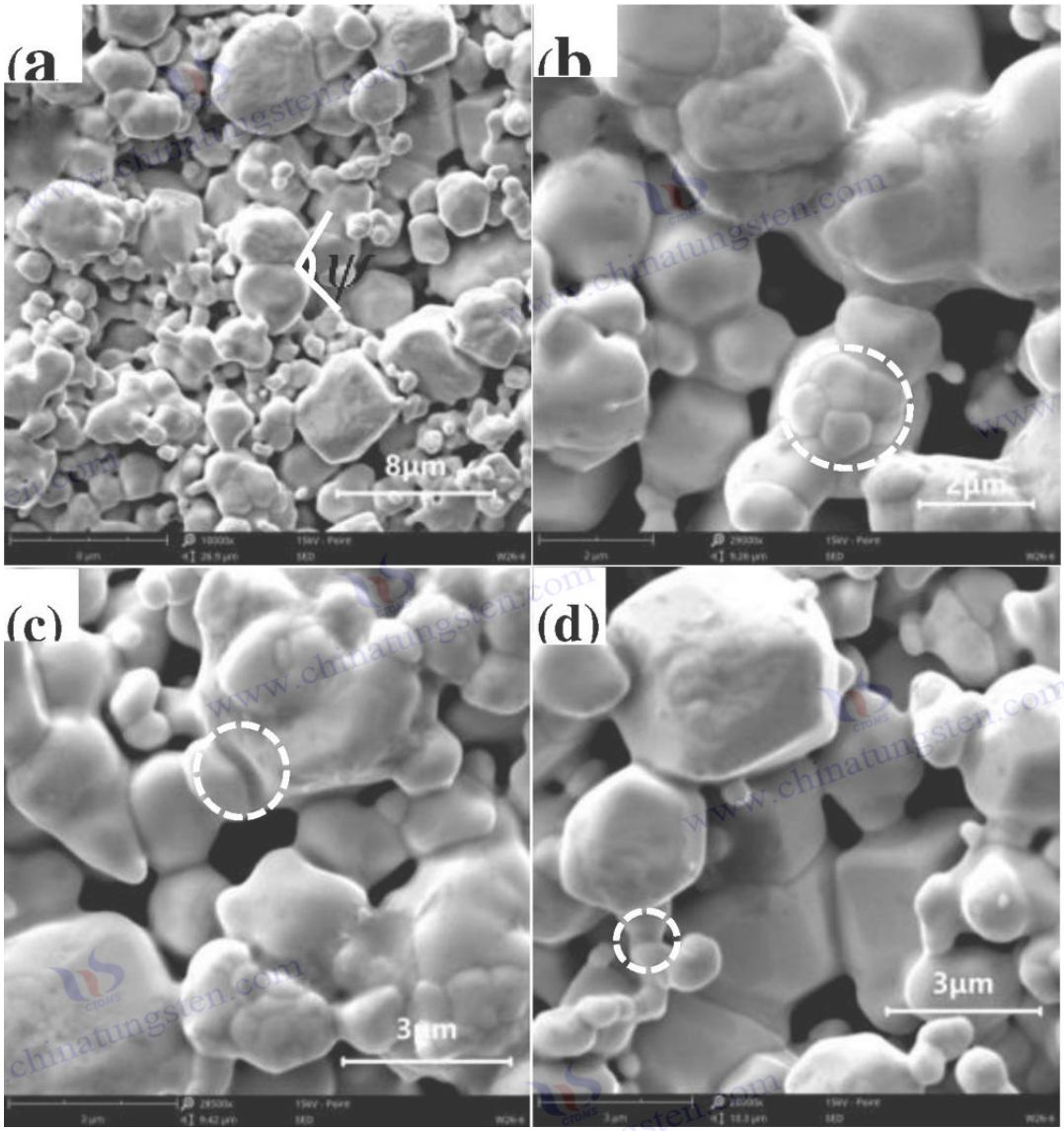
Establish continuous electrical and thermal conduction paths

The tungsten and copper phases respectively undertake different functions: the tungsten phase mainly provides high-temperature resistance, arc erosion resistance, and structural support, while the copper phase mainly provides relatively high electrical and thermal conductivity. A reasonable skeleton structure and degree of copper liquid filling help form a stable composite microstructure and reduce the obstruction of current transmission and heat transfer by voids and interface defects. For example, products such as high-voltage electrical contacts, resistance welding electrodes, and EDM electrodes all need to balance electrical conductivity, thermal conductivity, arc erosion resistance, and mechanical properties according to service conditions. When selecting or customizing tungsten-copper materials, relevant material information from CTIA GROUP can also be consulted.

Why can't copper and tungsten powder be directly mixed and then melted?

This is mainly because copper melts before tungsten, while the melting point of tungsten is extremely high; at the same time, the mutual solid solubility of tungsten and copper is relatively low, and ordinary melting makes it difficult to simultaneously achieve full melting of tungsten, uniform distribution, and material densification. The infiltration method avoids the requirement of heating the entire material above the melting point of tungsten by first forming a solid tungsten skeleton and then allowing liquid copper to fill the pores. It should be noted that the porous tungsten skeleton is not a void structure that needs to be retained in the final product, but an intermediate structure in the infiltration stage. Ideally, most of the interconnected pores are occupied after filling with copper liquid, ultimately obtaining a dense tungsten-copper composite material; the actual effect depends on the skeleton pore structure, copper liquid wettability, infiltration temperature, holding time, and process control level.





Q30 How do tungsten powder particle size, copper powder particle size, and mixing uniformity affect product performance?

Tungsten powder particle size, copper powder particle size, and mixing uniformity directly affect the press forming, sintering densification, copper liquid infiltration, microstructural uniformity, and ultimately the electrical conductivity, thermal conductivity, mechanical properties, and arc erosion resistance of tungsten-copper alloy. The three are not isolated factors but jointly determine the powder packing state, pore structure, and distribution of the tungsten and copper phases.

I. How does tungsten powder particle size affect product performance?

Tungsten powder is the main skeleton material of tungsten-copper alloy, and its particle size and particle size distribution affect compact density, sintering behavior, skeleton strength, and infiltration channels.

When tungsten powder is finer, the specific surface area increases, and the sintering driving

force is usually stronger, which is conducive to particle bonding and skeleton homogenization, but the powder is also more prone to agglomeration, and friction and forming resistance during pressing may increase. If the sintering temperature or holding time is too high, the pores may shrink excessively or even become locally closed, making it difficult for subsequent copper liquid to fully infiltrate.

When tungsten powder is coarser, powder flowability and pressing performance under certain conditions may be better, but there are fewer contact points between particles, and the sintered skeleton may have larger pores or insufficient local bonding. If the particle size distribution is unreasonable, pores with obvious size differences may also form, causing uneven copper liquid flow.

Effect of tungsten powder particle size on the performance of tungsten-copper alloy

Tungsten powder characteristics	Main effect on the process	Possible effect on finished product performance
Finer particle size	Higher sintering activity, pores tend to shrink	Skeleton strength may increase, but infiltration channels may decrease
Coarser particle size	Slower sintering densification, relatively larger pores	Insufficient skeleton bonding or microstructure coarsening may occur
Reasonable particle size distribution	Conducive to powder packing and skeleton structure control	Helps balance skeleton strength and copper liquid permeability
Too wide or unstable particle size distribution	Local packing and pore structure differences increase	May cause performance fluctuations and batch differences

Therefore, tungsten powder is not better the finer it is; rather, the appropriate particle size range should be determined according to the target tungsten content, skeleton sintering process, required porosity, and product dimensions.

II. How does copper powder particle size affect product performance?

The effect of copper powder depends on the specific manufacturing route. For the process of first preparing a tungsten skeleton and then using molten copper for infiltration, copper is usually added as blocks, sheets, or other preformed copper materials, and copper powder particle size is not the core parameter of all infiltration processes; however, in the direct pressing and sintering of tungsten-copper mixed powder or other powder composite processes, copper powder particle size has an important effect.

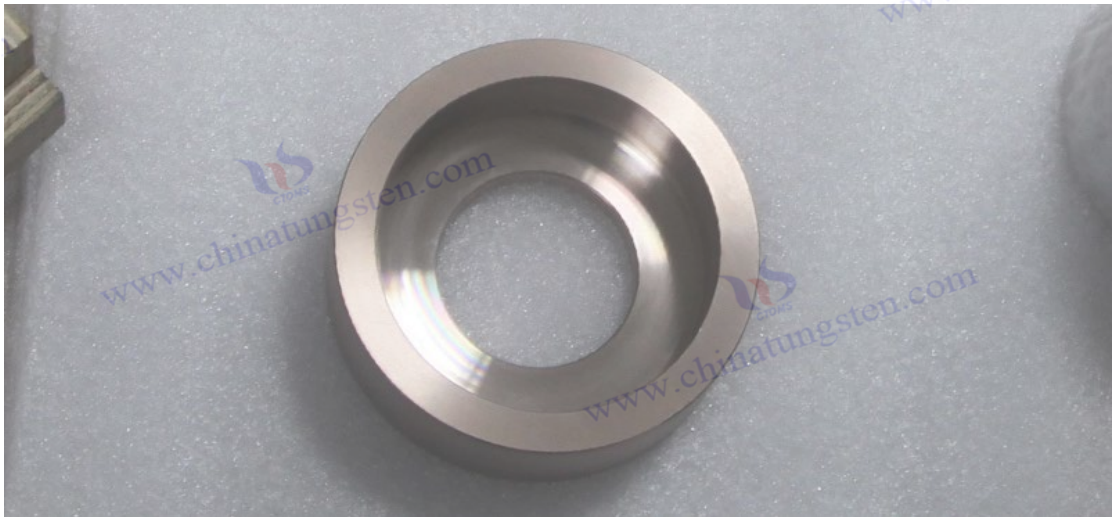
When using the tungsten-copper mixed powder process, finer copper powder can increase the contact area with tungsten powder and is conducive to copper phase dispersion, but it is also more prone to oxidation, agglomeration, and local enrichment. When copper powder is coarser, local composition segregation may occur during powder mixing and pressing, and uneven copper phase distribution may also occur during subsequent sintering or liquid phase formation.

Copper powder characteristics	Main process effect	Potential performance effect
Finer particle size	Large contact area, high dispersion requirements	Conducive to uniform distribution, but oxidation and agglomeration need to be controlled
Coarser particle size	Local contact and distribution uniformity are harder to control	Copper-rich regions or local performance differences may form
Particle size matched with tungsten powder	Conducive to forming a relatively uniform mixed system	Helps improve microstructural consistency
Severe surface oxidation	Deterioration of particle interface state	May affect wetting, sintering, and electrical conductivity

In the infiltration method, more attention should be paid to the amount of copper material, the wettability between copper liquid and the tungsten skeleton, pore connectivity, infiltration temperature, and holding time, rather than judging infiltration quality solely by copper material particle size.

III. Why is mixing uniformity so important?

Mixing uniformity determines the spatial distribution of the tungsten phase and copper phase. If mixing is insufficient, even if the average ratio of tungsten powder and copper powder is accurate, regions with locally high tungsten content or high copper content may appear. Regions with high tungsten content are usually harder and have a lower tendency toward thermal expansion, but insufficient copper phase may affect local electrical and thermal conductivity; regions with high copper content usually have better electrical and thermal conductivity, but high-temperature structural support and arc erosion resistance may be inconsistent with surrounding regions. Uneven two-phase distribution may also lead to local thermal stress concentration, crack initiation, and fluctuations in processing performance. Common causes of insufficient mixing uniformity include excessive differences in powder particle size, segregation caused by differences in particle density, unreasonable mixing time or charging ratio, powder agglomeration, and re-layering during transfer and pressing after mixing. For the infiltration method, although it is not necessarily required to pre-mix tungsten powder and copper powder, the uniformity of the tungsten powder itself, the compact density distribution, and the skeleton pore uniformity are equally critical. They determine whether the copper liquid can uniformly penetrate along the interior of the skeleton.



IV. How do the three factors jointly affect key properties?

Performance indicator	Main mechanism of particle size and mixing state	Typical risk
Density	Affects powder packing, compact density, sintering shrinkage, and pore filling	Residual porosity, insufficient local density
Electrical conductivity	Affects Cu phase continuity, number of voids, & interfacial contact	Increased resistance, local heating
Thermal conductivity	Affects continuity of heat conduction paths and pore distribution	Increased thermal resistance, uneven temperature distribution
Coefficient of thermal expansion	Mainly affected by tungsten-copper ratio, phase distribution, and porosity	Increased local thermal deformation and thermal stress
Hardness and strength	Affected by skeleton strength, particle bonding, phase distribution, and defect control	Strength dispersion, cracks, or local weakness
Arc erosion resistance	Affected by tungsten skeleton continuity, copper phase distribution, and pore defects	Local erosion, material spatter, or contact performance degradation

These relationships are not simple monotonic relationships. For example, reducing tungsten powder particle size may promote sintering, but may also cause excessive pore shrinkage; increasing compact density may strengthen the skeleton, but may also reduce the interconnected porosity required for infiltration. Therefore, judgment needs to be made in combination with the specific process, and finished product performance cannot be predicted based on a single powder parameter alone.

V. How to control and verify in production?

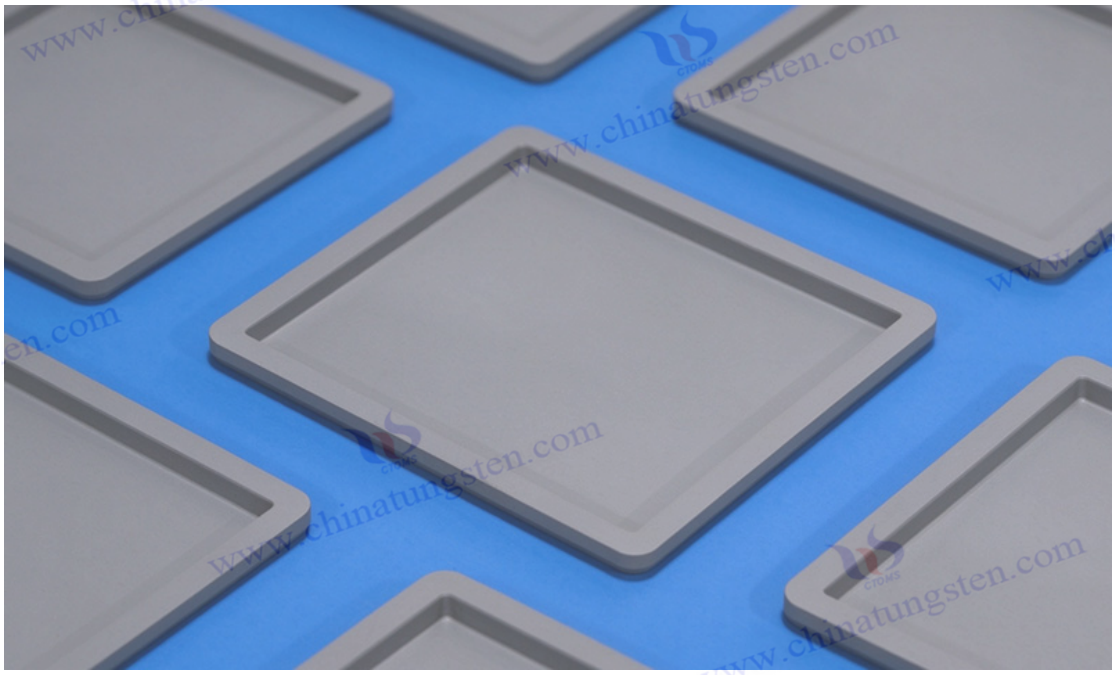
In actual production, it is recommended to establish a corresponding relationship among powder quality, mixing quality, and finished product performance. Tungsten powder and copper powder should be separately tested for particle size distribution, purity, oxygen content, and powder morphology; for the mixed powder process, mixing uniformity should also be verified, and attention should be paid to segregation caused by transfer after mixing. For the infiltration method, the compact density, sintering shrinkage, porosity, and pore connectivity of the tungsten skeleton should be mainly tested.

At the finished product stage, density measurement, metallographic structure analysis, microhardness testing, electrical conductivity, and thermal conductivity testing can be combined to determine whether the powder parameters have truly translated into stable material performance. For applications such as high-voltage electrical contacts, resistance welding electrodes, and electronic packaging materials, the particle size window and acceptance indicators should be determined according to the technical specifications of the specific product.

When selecting tungsten-copper materials or evaluating process parameters, relevant material information from CTIA GROUP can also be consulted, and the specific grade, manufacturing process, and test data should be used as the final basis for judgment.

Tungsten powder particle size mainly affects tungsten skeleton formation and pore structure, copper powder particle size mainly affects copper phase distribution in the mixed powder

process, and mixing uniformity determines whether the local composition and microstructure are consistent. The three need to be collaboratively optimized with pressing, sintering, or infiltration conditions to balance density, electrical and thermal conductivity, strength, and arc erosion resistance.



Q31 How do the sintering temperature, time, and atmosphere of tungsten-copper alloy affect the material microstructure?

The sintering temperature, holding time, and sintering atmosphere of tungsten-copper alloy jointly determine the degree of bonding between powder particles, the pore structure, the strength of the tungsten skeleton, the distribution of the copper phase, and the subsequent infiltration effect. The three are interrelated and must be optimized in combination with the specific manufacturing process; it cannot simply be assumed that the higher the temperature and the longer the time, the better the material performance.

For tungsten-copper alloy prepared by the infiltration method, the primary task of the sintering stage is to obtain a porous tungsten skeleton with sufficient strength and suitable interconnected pores, creating conditions for the subsequent filling of molten copper; for the process of directly sintering mixed tungsten-copper powder, further consideration must be given to the softening, melting, migration, and redistribution of the copper phase during sintering.

I. Effect of sintering temperature on material microstructure

The melting point of tungsten is approximately 3422℃, and the melting point of copper is approximately 1084.6℃. In a typical infiltration process, tungsten powder is first pressed into shape, and then high-temperature sintering is used to make the tungsten particles form a mutually bonded skeleton. At this time, the sintering temperature needs to be controlled so that the particles fully bond while avoiding excessive pore shrinkage or closure.

Sintering temperature mainly changes the material microstructure by affecting the atomic diffusion rate, sintering neck growth, grain growth, and pore evolution.

Sintering temperature state	Effect on material microstructure	Effect on subsequent process and performance
Too low	Insufficient diffusion between W particles, inadequate sintering neck development	Low skeleton strength; damage or deformation may occur during infiltration
Appropriate	Enhanced particle bonding, forming a porous skeleton with certain strength	Conducive to balancing skeleton strength and copper liquid permeability
Too high	Grain growth, pore shrinkage, some pore channels may close	Cur liquid penetration is obstructed; microstructural uniformity and finished product performance may decrease

Increasing temperature can usually promote diffusion and bonding between tungsten particles, but it also accelerates the densification process. For the infiltration method, the tungsten skeleton is not better the denser it is; rather, a balance needs to be achieved between skeleton strength and pore connectivity. If the pores shrink or close prematurely, even if the skeleton itself is relatively strong, molten copper may not be able to fully enter the interior, resulting in residual voids and insufficient local copper content.

For the mixed tungsten-copper powder sintering process, temperature control also needs to

consider the state changes of the copper phase. If the temperature exceeds the melting point of copper, liquid copper may migrate, aggregate, or locally flow away; therefore, the temperature schedule must be determined according to the specific process route, tungsten-copper ratio, and product structure, and the sintering parameters for the tungsten skeleton cannot be directly applied.

II. Effect of holding time on material microstructure

Holding time determines the degree to which the material continues to undergo diffusion, particle bonding, and pore evolution at the set temperature. Temperature and time have a synergistic effect: when the temperature is higher, the time required to reach the same degree of sintering is usually shorter, but the combination of excessively high temperature and excessively long holding time may cause grain coarsening and deterioration of the pore structure.

Holding time state	Main microstructural change	Potential problem
Too short	Insufficient sintering neck formation, insufficient bonding between particles	Low skeleton strength, locally loose structure
Appropriate	Relatively sufficient particle bonding, pore structure maintained within the target range	Conducive to subsequent infiltration and microstructural stability
Too long	Grains continue to grow, pores may further shrink or change morphology	Interconnected pores decrease, infiltration uniformity decreases

In the preparation of porous tungsten skeletons, the holding time should aim to form sufficient strength while retaining suitable interconnected pores. If the time is insufficient, the skeleton may be difficult to withstand the thermal shock and local stress during the subsequent copper liquid infiltration process; if the time is too long, the degree of skeleton densification may be too high, reducing the pore volume into which the copper liquid can enter and changing the size and distribution of pore channels.

The holding time should also be determined in combination with the heating rate, compact dimensions, furnace load, and temperature uniformity inside the furnace. Large or thick-walled blanks require a certain time for the interior to reach the target temperature, so it cannot be judged that the workpiece has completed uniform heating solely based on the moment when the furnace temperature reaches the set value. In actual production, the reasonable holding range should be verified through trial firing, dimensional shrinkage measurement, metallographic observation, and infiltration results.

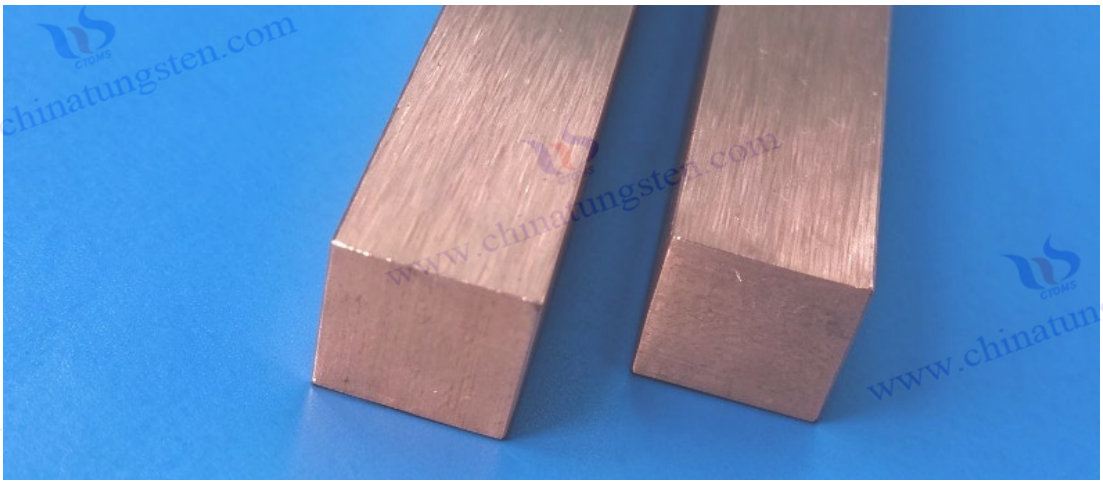
III. Effect of sintering atmosphere on material microstructure

The sintering atmosphere mainly affects the oxidation state of the powder surface, impurity content, particle interface bonding, and the subsequent wetting and filling effect of the copper liquid. For tungsten-copper alloy, surface oxides on both tungsten powder and copper powder may interfere with particle contact and interface bonding, so atmosphere purity, residual oxygen content, and dew point control are very important.

Sintering atmosphere	Main function	Key control factors
Hydrogen atmosphere	Under appropriate conditions, reduces some metal oxides and helps improve powder surface state	Hydrogen purity, dew point, flow rate, temperature, and safety measures
Vacuum atmosphere	Reduces gas partial pressure and decreases some gas contamination	Vacuum degree, residual gas, equipment cleanliness, and volatilization behavior
Inert gas atmosphere	Reduces external oxidation and contamination	Gas purity, residual oxygen content, dew point, and gas flow state
Improper atmosphere control	May cause oxidation, residual impurities, or interface contamination	Poor particle bonding, decreased infiltration wettability, and performance fluctuation

When the surface oxygen content of tungsten powder is relatively high, oxides may hinder the formation of effective bonding between particles and reduce the integrity of the tungsten skeleton; oxidation of copper powder may affect the sintering, flow, and interface contact of the copper phase. During the infiltration process, if the surface state of the tungsten skeleton is poor, or if contaminants unfavorable to the entry of copper liquid exist in the pores, local non-infiltration and residual voids may also result.

Different atmospheres cannot be arbitrarily interchanged. The reducing effect of hydrogen depends on the type of oxide, temperature, and gas conditions; vacuum sintering does not mean that all oxides can be automatically removed; the protective effect of an inert atmosphere depends on gas purity and system sealing. In addition, hydrogen is flammable, and when hydrogen is used for sintering, gas supply, exhaust, sealing, and safety interlock systems meeting the requirements must be provided.



IV. Synergistic effect of temperature, time, and atmosphere

Sintering temperature, holding time, and atmosphere are not three independent parameters; they jointly affect tungsten particle bonding, grain size, pore structure, and impurity state. For example, extending the holding time at a lower temperature may improve particle bonding, but may not necessarily achieve the same microstructural state as after increasing the temperature; increasing the temperature and extending the time may cause excessive pore shrinkage while strengthening the skeleton. The effects of the three parameters on final performance are mainly reflected in the following aspects.

Performance indicator	Main microstructural influencing factors	Possible problems
Density	Skeleton porosity, Cu liquid filling degree, residual voids	Insufficient finished product density or batch differences
Electrical conductivity	Cur phase continuity, number of pores, interface defects, & impurity	Increased resistance, local heating
Thermal conductivity	Cu phase distribution, pore structure, contact state between tungsten and copper phases	Heat conduction path obstructed
Mechanical properties	W particle bonding degree, skeleton strength, grain size, and defects	Insufficient strength, cracks, weakness
Arc erosion resistance	W skeleton continuity, Cu phase distribution, & microstructural	Increased local ablation, increased material loss
Dimensional stability	Sintering shrinkage, temperature uniformity, cooling stress	Deformation, dimensional deviation

A particular distinction needs to be made between the pore requirements of the sintering stage and the final infiltration stage. For the infiltration method, retaining an appropriate amount of interconnected pores after sintering is a necessary condition and does not mean that the skeleton quality is unqualified; what really needs to be controlled is whether the pore structure is suitable for the copper liquid to enter and whether excessive residual voids still exist after infiltration. The latter may adversely affect density, electrical conductivity, thermal conductivity, and mechanical properties.

V. How to determine a reasonable sintering process window?

In actual production, process parameters should be determined according to tungsten powder particle size, compact density, product dimensions, target tungsten content, and furnace characteristics, rather than directly adopting universal fixed temperatures and holding times. A reasonable verification process is to first determine the test range of temperature, time, and atmosphere, then compare the dimensional shrinkage, density, porosity, pore connectivity, and microstructure of the tungsten skeleton after sintering, and subsequently check the copper liquid filling degree and final performance through infiltration tests.

For products such as tungsten-copper electrical contacts, welding electrodes, and electronic packaging materials, the finished product density, tungsten-copper distribution, electrical conductivity, thermal conductivity, hardness, and necessary mechanical properties should also be tested according to application requirements. If a certain batch shows insufficient infiltration, it cannot be solved only by increasing the sintering temperature or extending the holding time; it should also be checked whether the pores are closed, whether there is contamination on the skeleton surface, whether the wettability of the copper liquid is suitable, and whether the infiltration temperature and holding time meet the requirements. When selecting tungsten-copper materials or evaluating processes, relevant material information from CTIA GROUP can also be consulted, and the applicable parameters should be determined in combination with the specific grade, manufacturing route, and test results.

In summary, sintering temperature mainly controls the diffusion rate, particle bonding, and pore evolution; holding time determines the degree of microstructural change; and sintering

atmosphere affects oxidation, impurities, and interface state. The core goal of synergistic optimization of the three is to retain suitable interconnected pores while obtaining sufficient skeleton strength, creating conditions for full infiltration of the copper liquid and stable final performance.

Q32 How to improve the density of tungsten-copper alloy and reduce porosity?

Improving the density and reducing the porosity of tungsten-copper alloy requires coordinated optimization of raw powder materials, pressing and forming, sintering schedule, copper liquid infiltration, and quality testing. The control priorities differ among different manufacturing processes: for the infiltration method, the forming quality of the tungsten skeleton and the copper liquid filling rate need to be improved while retaining suitable interconnected pores; for the mixed tungsten-copper powder sintering method, the focus should be on improving powder packing, particle bonding, and copper phase distribution.

I. Clarify the relationship between density and porosity

The density of tungsten-copper alloy is usually evaluated by comparing the measured density with the theoretical density. The relative density is calculated as follows:

Relative density (%) = measured density ÷ theoretical density × 100%. Here, the measured density is the actual density of the material obtained through density testing, and the theoretical density is calculated according to the tungsten-copper ratio of the material and the densities of each component. When the composition is accurate, the pore mass can be ignored, and pores are the main defects, the total porosity can be approximately calculated as: total porosity (%) ≈ 100% – relative density (%). For example, if the measured density of a tungsten-copper alloy is 15.2 g/cm³ and the theoretical density is 15.8 g/cm³, then the relative density is approximately 96.2%, and the corresponding total porosity is approximately 3.8%. This result is an approximate estimate; actual testing should also consider the effects of composition deviation, oxides, and other second phases. For two-phase tungsten-copper materials, the theoretical density should be calculated based on the actual tungsten-copper mass ratio. If the mass fractions of tungsten and copper and their respective densities are known, the volumes occupied by tungsten and copper per unit mass of material can first be calculated, and then the theoretical density can be obtained by dividing the total mass by the total volume. This is more accurate than directly applying the density of pure tungsten or pure copper.

II. Optimize powder raw materials and particle size distribution

Powder particle size, particle morphology, purity, and oxygen content affect powder packing, pressing and forming, and subsequent sintering behavior. Reasonable particle size matching helps improve the particle filling state and reduce large initial pores, but the finer the powder, the better. Tungsten powder that is too fine easily agglomerates, which may cause local density non-uniformity and make the pore structure after sintering difficult to control. In actual production, the consistency of tungsten powder particle size and particle size distribution should be controlled to avoid excessive differences between batches of raw materials. For the mixed tungsten-copper powder sintering process, attention should also be paid to copper powder particle size, oxidation degree, and mixing uniformity; for the tungsten skeleton infiltration method, the focus should be on controlling the uniformity of tungsten powder and the pore size and connectivity formed by powder packing.

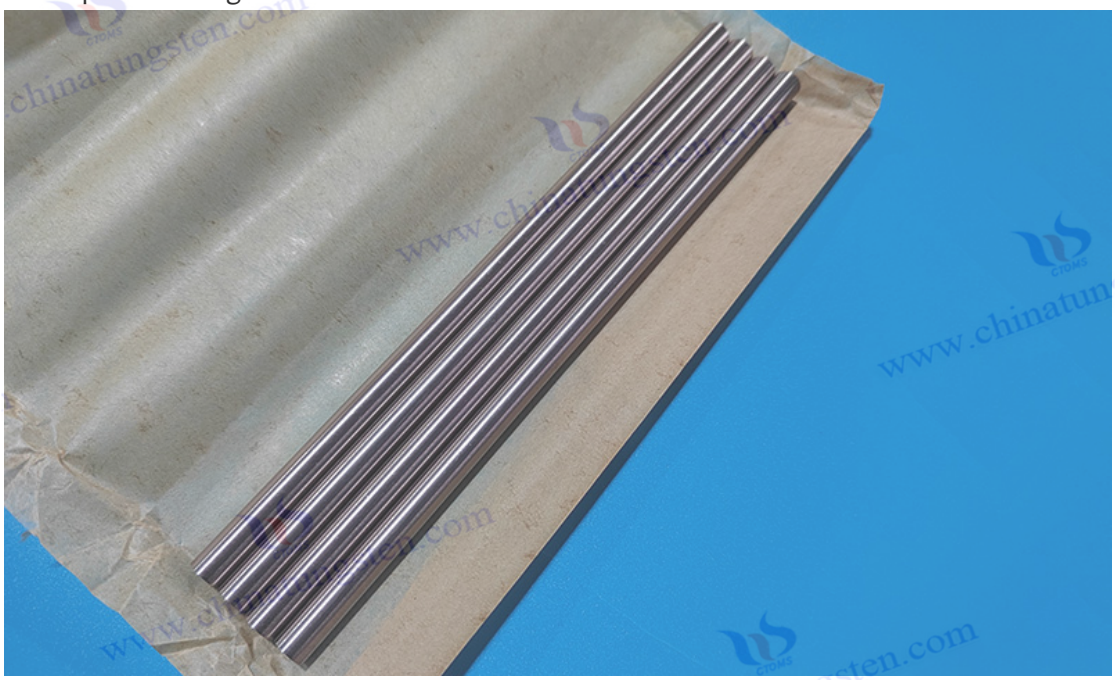
III. Optimize pressing and forming to improve compact uniformity

Insufficient pressing pressure, uneven powder filling, or uneven mold force may cause low

compact density, local looseness, or large density differences in different regions. During subsequent sintering, these differences may turn into uneven shrinkage, cracks, or local pore accumulation. Improving compact quality can start from aspects such as mold structure, pressing method, powder filling uniformity, and lubrication conditions. For products with complex shapes or large dimensions, the density differences at corners, central regions, and positions with thickness changes should be especially checked. When necessary, forming methods such as cold isostatic pressing can be evaluated to improve the density distribution inside the compact, but the specific solution still needs to be determined in combination with product shape, dimensions, and cost requirements.

IV. Reasonably control sintering temperature, time, and atmosphere

Sintering temperature and holding time affect the diffusion and bonding between tungsten particles, while the sintering atmosphere affects the oxidation state of the powder surface and interface quality. Too low a temperature or insufficient holding may lead to insufficient skeleton strength; too high a temperature or too long a holding time may cause grain coarsening, pore shrinkage, or local closure. For the infiltration method, the goal is not to sinter the tungsten skeleton to full density, but to give it sufficient mechanical strength while retaining interconnected pores into which the copper liquid can enter. After sintering, the skeleton density, porosity, and pore connectivity should be tested, and then the temperature and holding time should be adjusted according to the test results. Regarding the atmosphere, a suitable hydrogen, vacuum, or inert gas process can be selected according to the powder state and equipment conditions, and the gas purity, residual oxygen content, and dew point should be controlled to reduce the effects of oxides and impurities on particle bonding and subsequent wetting.



V. Optimize copper liquid infiltration to improve pore filling rate

For the tungsten-copper alloy infiltration method, the final density depends to a large extent on whether the molten copper can fully fill the pores inside the tungsten skeleton. Even if the

pore structure of the tungsten skeleton is reasonable, if the wettability of the copper liquid is insufficient, the infiltration temperature is unsuitable, or the holding time is insufficient, residual voids may still remain.

Key factor	Optimization direction	Risk of improper control
W skeleton pore structure	Maintain suitable pore size & connectivity	Pore channels closed, copper liquid difficult to enter
Cu material amount	Reasonably batch according to skeleton pore volume and target composition	Insufficient copper leads to incomplete filling; excess may cause local copper enrichment
Infiltration temperature	Ensure the copper liquid has suitable fluidity and wetting conditions	Insufficient temperature may cause incomplete filling; high temperature may cause other microstructural problems
Holding time	Provide sufficient time for the copper liquid to penetrate into the skeleton interior	Internal residual voids increase
Surface cleanliness	Reduce oxides and contaminants	Poor wetting, local non-infiltration
Cooling process	Control temperature gradient and thermal stress	Cracks, deformation, or interface defects

For skeletons with finer pores and greater penetration resistance, process solutions such as vacuum-assisted infiltration can be evaluated in combination with the material system, but it cannot be assumed that applying a vacuum will definitely eliminate all pores. The final effect still depends on pore connectivity, copper liquid wettability, gas discharge paths, and process parameters.

VI. Targeted improvement according to pore types

Reducing porosity cannot rely only on a single process parameter. Different pores have different causes; the defect type should first be determined through metallographic analysis, microscopic observation, or applicable non-destructive testing, and then the corresponding improvement measures should be selected.

Defect type	Common cause	Improvement direction
Excessive initial compact porosity	Poor powder packing, insufficient pressing, or uneven density	Optimize powder particle size matching, powder filling, and pressing schedule
Insufficient skeleton bonding after sintering	Too low temperature, insufficient holding, or powder surface contamination	Adjust the sintering schedule and control raw material purity and atmosphere
Residual voids after infiltration	Insufficient copper liquid filling, disconnected pores, or poor wettability	Improve skeleton pore structure, material ratio, and infiltration conditions
Local copper enrichment or uneven copper phase distribution	Improper batching, mixing segregation, or copper liquid migration	Optimize batching, mixing, and infiltration process
Cracks or interface defects after cooling	Large temperature gradient, thermal stress, or poor interface bonding	Optimize the cooling schedule and check the compatibility between material and process

VII. Establish a testing closed loop between density and performance

In production, powder testing, compact testing, sintered skeleton testing, and finished product testing should be combined, rather than relying only on final density to judge whether the process is qualified. At the raw material stage, focus on checking particle size, purity, and oxygen content; after pressing, check the compact density distribution; after tungsten skeleton sintering, check porosity, pore connectivity, and skeleton strength; after infiltration, focus on testing finished product density, residual voids, tungsten-copper phase distribution, and properties such as electrical conductivity and thermal conductivity.

For products such as high-voltage electrical contacts, welding electrodes, and electronic packaging materials, density indicators should match the actual application. Improving density usually helps reduce the obstruction of pores to current and heat transmission, but the final performance is still jointly affected by the tungsten-copper ratio, microstructural distribution, interface state, and processing quality. When selecting materials or evaluating processes, relevant material information from CTIA GROUP can also be consulted, and the specific grade, manufacturing route, and test data should be used as the basis for judgment.

In short, the key to improving the density of tungsten-copper alloy is to improve powder packing and compact uniformity, establish a reasonable sintered microstructure, and optimize the copper phase distribution or copper liquid infiltration according to the manufacturing route. For the infiltration method, especially, it is necessary to avoid prematurely closing the pores of the tungsten skeleton in pursuit of high density; only by balancing skeleton strength, pore connectivity, and copper liquid filling rate can the final residual porosity be effectively reduced and the stability of material performance be improved.



Q33 Why does tungsten-copper alloy exhibit uneven copper phase distribution, voids, cracks, or delamination?

Uneven copper phase distribution, voids, cracks, or delamination in tungsten-copper alloy are usually related to links such as powder raw materials, pressing and forming, sintering schedule, copper liquid infiltration, and cooling and processing. These defects may form during manufacturing or gradually become exposed during subsequent heat treatment, mechanical processing, or service. Tungsten-copper alloy is a composite material composed of a tungsten phase and a copper phase; tungsten has a high melting point and relatively high high-temperature structural stability, while copper has good electrical and thermal conductivity. Because the melting points of the two differ greatly and their mutual solid solubility is low, the microstructural uniformity of the material depends to a large extent on powder distribution, tungsten skeleton structure, and copper phase filling state.

I. Uneven copper phase distribution: why does local copper enrichment or copper deficiency occur?

Uneven copper phase distribution means that there are obvious differences in copper content or spatial distribution of the copper phase inside the material, manifested as local copper enrichment, local copper deficiency, or inconsistent copper phase continuity. Its causes are closely related to the specific manufacturing process. For the mixed tungsten-copper powder process, if the particle size, density, and flowability of tungsten powder and copper powder differ greatly, agglomeration or segregation is likely to occur during mixing. During pressing, uneven powder flow and force may also cause local composition changes; during sintering, copper phase migration or aggregation may further expand the original microstructural differences. For the tungsten skeleton infiltration method, uneven copper phase distribution is usually related to the skeleton pore structure and the copper liquid penetration process. If the pore sizes of the tungsten skeleton differ greatly, some pore channels are disconnected, or the wettability of the copper liquid is insufficient, there may be sufficient copper liquid filling in some areas and insufficient filling in others.

Main cause	Formation mechanism	Possible impact
Uneven powder mixing	Local segregation or agglomeration of tungsten powder and copper powder	Local composition deviation, inconsistent performance
Unreasonable particle size distribution	Large differences in powder packing state and particle contact	Uneven copper phase distribution
Obvious differences in W skeleton pores	Different flow resistance of copper liquid in different regions	Local copper enrichment or copper deficiency
Insufficient Cu liquid wettability	Copper liquid difficult to fully spread and fill pores	Local non-infiltration, residual voids
Unreasonable Cul amount or infiltration parameters	Copper liquid supply does not match skeleton pore demand	Insufficient local filling or excessive residual copper

To improve copper phase distribution, different measures should be taken according to the process route: the mixed powder process should focus on controlling batching, mixing

uniformity, and compact density distribution; the infiltration process should focus on controlling tungsten skeleton pore connectivity, copper material amount, infiltration temperature, holding time, and surface cleanliness.

II. Voids: why do gaps remain inside the material?

Voids in tungsten-copper alloy can be divided into original pores, residual pores after sintering, voids formed by insufficient infiltration, and damage voids generated during processing or service. When judging the cause of voids, it is not enough to look only at the number; attention should also be paid to the size, shape, distribution position, and whether they are interconnected. For the infiltration method, the tungsten skeleton needs to retain suitable interconnected pores so that molten copper can enter. However, if the pore channels are too narrow, locally closed, or the skeleton surface is contaminated, the copper liquid may not be able to fully fill them, ultimately leaving residual voids inside the finished product. For the mixed powder sintering method, voids may come from insufficient compact density, powder agglomeration, insufficient particle bonding, or gas residue during sintering. If the raw material oxygen content is relatively high and the powder surface oxides are not effectively controlled, particle bonding and interface quality may also be affected.

Common causes and improvement directions of voids in tungsten-copper alloy

Cause of void	Typical manifestation	Improvement measure
Insufficient compact density	Voids widely distributed, local looseness	Optimize powder filling, pressing pressure, and forming method
Insufficient sintering	Weak particle bonding, more residual pores	Adjust sintering temperature, holding time, and atmosphere
Disconnected skeleton pores	Regions inside that copper liquid is difficult to reach	Optimize tungsten powder particle size, compact density, and skeleton sintering schedule
Insufficient Cu liquid filling	Unfilled voids still present after infiltration	Check copper material amount, wettability, and infiltration parameters
Residual gas or contaminants	Irregular voids or interface defects locally	Improve raw material cleanliness, degassing, and atmosphere control

Voids reduce the effective load-bearing area and destroy current and heat transmission paths, usually reducing the effective electrical conductivity, thermal conductivity, and mechanical properties of the material. However, for the infiltration method, the presence of pores in the tungsten skeleton after sintering is a necessary intermediate state; what really needs to be controlled is the number, size, and distribution of residual voids after infiltration.

III. Cracks: why does the material crack during sintering, cooling, or processing?

Cracks in tungsten-copper alloy are usually related to temperature gradient, thermal stress, uneven compact density, interface defects, and mechanical processing stress. Cracks may occur during pressing, sintering, copper liquid infiltration, cooling, or subsequent processing, and the causes at different stages are not the same.

Cracks during sintering and infiltration

If the density differences in different regions of the compact are large, sintering shrinkage may be inconsistent, thereby generating internal stress. For the infiltration method, insufficient tungsten skeleton strength or local structural non-uniformity may also cause damage during the entry of copper liquid and temperature changes.

In addition, the coefficients of thermal expansion of tungsten and copper differ. During heating and cooling, the dimensional changes of the two phases differ, and thermal stress may be generated near the interface. If the microstructure is non-uniform, interface bonding is poor, or local voids exist, stress concentration will be more obvious.

Cracks during cooling

Too fast a cooling rate, uneven temperature distribution inside the product, or large differences in heat dissipation conditions at different parts of the workpiece may all cause temperature gradients and thermal stress. When local stress exceeds the range that the material can withstand, cracks may form.

Cracks during mechanical processing

The tungsten phase and copper phase of tungsten-copper alloy differ in hardness, plasticity, and cutting response. If the tool condition is poor, cutting parameters are unreasonable, or workpiece clamping is improper, local stress concentration, edge chipping, or propagation of existing microcracks may occur.

Stage of crack generation	Main cause	Improvement direction
Pressing and forming	Uneven pressing force, demolding stress, or compact defects	Optimize mold, pressing, and demolding schedule
Sintering stage	Density differences, uneven shrinkage, insufficient skeleton strength	Improve compact uniformity and optimize sintering schedule
Cr liquid infiltration stage	Local skeleton damage, temperature changes, or interface defects	Improve skeleton quality and adjust infiltration process
Cooling stage	Too large temperature gradient, inconsistent thermal deformation of the two phases	Optimize cooling schedule and temperature uniformity
Mechanical processing stage	Excessive cutting force, tool wear, or improper clamping	Optimize tool, cutting parameters, and workpiece support

When improving crack problems, the stage at which the crack forms during manufacturing should first be determined, and then the cause should be located through metallographic examination, fracture analysis, or non-destructive testing. Merely reducing the cooling rate or increasing the sintering temperature cannot solve all types of cracks.

IV. Delamination: why does interface separation occur inside the material?

Delamination refers to sheet-like or layered separation between different regions inside the material, which may occur inside the compact or appear as local debonding near the tungsten-copper interface. Its formation mechanism differs from voids and cracks: voids mainly manifest

as spatial absence, cracks manifest as local cracking, while delamination usually has obvious layered or interface characteristics. During pressing, if powder filling is uneven, mold venting is poor, pressing speed is too fast, or air is entrapped, layered defects may form inside the compact. During sintering, these regions may not be able to fully bond and ultimately remain as delamination. During infiltration and subsequent cooling, if the local strength of the tungsten skeleton is insufficient, copper liquid filling is incomplete, or interface bonding is poor, local interface separation may also form. The stress generated by the difference in thermal expansion of the two phases may further promote the expansion of existing defects. To improve delamination, the focus should be on checking the relationship between the pressing direction and the delamination direction, the density distribution inside the compact, powder filling and venting conditions, and at the same time evaluating skeleton integrity after sintering, copper liquid filling, and cooling stress.

V. Differences among the four types of defects in tungsten-copper alloy and priorities for investigation

Defect type	Main feature	Priority investigation link	Main improvement direction
Uneven Cu phase	Obvious local Cu enrichment, Cu deficiency, or poor phase distribution	Batching, mixing, skeleton pore infiltration	Improve composition & microstructural uniformity
Voids	Gaps inside not filled by material	Pressing, sintering, infiltration	Improve compact quality & pore filling
Cracks	Linear, tip-shaped, or irregular cracking	Sintering, infiltration, cooling, and processing	Reduce stress concentration and improve microstructural and process stability
Delamination	Layered or interface region separation	Pressing, sintering, and interface bonding	Improve compact uniformity and regional bonding quality

These four types of defects may appear simultaneously. For example, insufficient local copper liquid filling leaves voids, and the edges of the voids are prone to stress concentration, which then develops into cracks during cooling or processing. Therefore, production investigation should not target only the single defect finally observed, but should also trace the sequence in which the defects formed.

VI. How to establish an effective quality control process?

It is recommended to carry out quality control in five stages: raw materials, compact, sintered skeleton, infiltrated finished product, and mechanical processing. At the raw material stage, check powder particle size, purity, oxygen content, and batch consistency; at the compact stage, focus on density distribution, delamination, and forming cracks; after sintering, check skeleton strength, porosity, pore connectivity, and microstructural state; after infiltration, test finished product density, residual voids, copper phase distribution, and interface defects; after processing, check dimensional accuracy, surface damage, and cracks.

For applications such as high-voltage electrical contacts, welding electrodes, and electronic packaging materials, electrical conductivity, thermal conductivity, mechanical properties, and arc erosion resistance should also be tested in combination with specific service conditions. For

relevant material selection and process evaluation, reference can be made to the material information of CTIA GROUP, but the final judgment should be based on the specific grade, manufacturing process, and measured results.

In summary, uneven copper phase distribution mainly involves composition distribution and copper liquid penetration; voids mainly involve compact quality, sintering state, and insufficient filling; cracks mainly involve microstructural defects and stress concentration; and delamination is often related to the pressing process and poor regional bonding. Only by analyzing in combination with defect morphology, stage of occurrence, and manufacturing route can the true cause be found and effective improvement measures be formulated.



Q34 How can tungsten-copper alloy improve electrical conductivity and thermal conductivity through process optimization?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) combines the high melting point and arc erosion resistance of tungsten with the high electrical conductivity and high thermal conductivity of copper, and is widely used in electrical contacts, electrodes, electronic packaging, and high-heat-flux heat-dissipating components. Its electrical conductivity and thermal conductivity depend not only on the ratio of tungsten to copper, but are also jointly affected by material density, copper phase continuity, pore distribution, interface state, and the processing process. The core of process optimization is to reduce pores and interface defects as much as possible, improve the continuous distribution of the copper phase, and reduce obstacles in electron conduction and heat transfer, while ensuring the strength of the tungsten skeleton and the dimensional stability of the material. For tungsten-copper alloy prepared by the infiltration method, the focus is on the pore structure of the tungsten skeleton, the copper liquid infiltration effect, and subsequent heat treatment; for the mixed powder pressing and sintering process, the focus should also be on controlling powder mixing uniformity, compact density, and the sintering process.

I. Optimize the tungsten-copper ratio and clarify the direction of performance improvement

Copper is the main conductive and thermally conductive phase in tungsten-copper alloy. Under otherwise similar conditions, increasing copper content is usually conducive to improving electrical conductivity and thermal conductivity, but it also reduces the high-temperature strength, hardness, and arc erosion resistance of the material. Therefore, a higher copper content should not be pursued solely; a reasonable ratio should be determined according to the service conditions.

Optimization direction	Effect on electrical conductivity	Effect on thermal conductivity	Performance to be balanced
Appropriately increasing copper content	Usually conducive to improvement	Usually conducive to improvement	High-temperature strength, arc erosion resistance
Improving W skeleton integrity	Helps stabilize microstructure and dimensions	Depends on copper phase filling and interface state	Skeleton strength, thermal stability
Improving Cu phase continuity	Reduces local obstacles in conductive paths	Improves heat flow transmission paths	Phase distribution uniformity
Reducing porosity	Usually conducive to improvement	Usually conducive to improvement	Manufacturing cost, dimensional accuracy

The performance differences among different tungsten-copper grades are relatively large. When comparing process effects, comparisons should be made under the same tungsten-copper ratio, specimen dimensions, and testing conditions, to avoid mistaking composition differences for improvements brought by process optimization.

II. Improve density and reduce pores and internal defects

Pores reduce the effective conductive cross-section, interrupt the continuous path of the copper phase, and increase thermal resistance in the heat flow transmission process. Therefore,

when the composition is unchanged, improving the density of the finished product is usually one of the most direct process directions for improving electrical conductivity and thermal conductivity. Relative density is calculated as: relative density (%) = measured density ÷ theoretical density × 100%. When the composition and calculation assumptions are applicable, total porosity can be approximately estimated as 100% – relative density (%); however, the effects of open pores, closed pores, and local defects are not completely the same, and the overall microstructural quality cannot be judged solely by relative density.

For the infiltration method, process optimization should focus on three aspects. First, reasonably control the tungsten powder pressing pressure and green compact density so that the tungsten skeleton has sufficient strength while retaining interconnected pores. If pressing or pre-sintering is excessive, the pore channels may shrink or even close, which instead hinders the entry of liquid copper. Second, optimize the sintering temperature and holding time of the tungsten skeleton so that tungsten particles form a stable bonded structure without excessive densification. Relevant studies show that the pore structure and sintering conditions of the tungsten skeleton affect the degree of copper liquid filling and the final thermal conductivity. Third, check whether there are unfilled holes, local looseness, and inclusions inside the finished product. Density testing, metallographic analysis, and applicable non-destructive testing methods can be combined to determine the location and distribution of defects, and then the pressing, sintering, or infiltration process can be adjusted accordingly.

III. Optimize copper liquid infiltration and improve copper phase continuity

For tungsten-copper alloy prepared by the infiltration method, whether liquid copper can fully enter the tungsten skeleton is an important factor determining the electrical and thermal transmission performance of the material. Even if the average density of the finished product is relatively high, if the local copper phase distribution is uneven, low electrical conductivity and thermal conductivity may still occur.

Improve the pore channel connectivity of the tungsten skeleton

The skeleton should have suitable pore size, porosity, and connected structure, avoiding local closed pores, excessively narrow channels, or excessive differences in pore distribution. Optimization needs to balance skeleton strength and copper liquid penetration capability.

Adjust the infiltration temperature and holding time

The temperature should ensure that copper is fully melted and has appropriate fluidity, and the holding time should be sufficient to complete penetration. Too low a temperature or insufficient time easily leads to incomplete filling; excessive temperature or long holding time may increase the risk of microstructural changes, contamination, and dimensional control.

Control the amount of copper material and the wetting state

Insufficient copper material leads to residual porosity; excessive copper material may cause local copper-rich areas or dimensional deviation. The amount of copper material should be determined in combination with the actual pore volume of the tungsten skeleton, the target composition, and process losses, and surface oxidation and contamination of raw materials should be controlled. The infiltration atmosphere is also critical. Vacuum or an appropriate protective atmosphere helps reduce oxidation and gas residue, but the specific conditions should be determined according to the equipment, raw material state, and process route.

Studies show that the connectivity and distribution uniformity of the copper phase, as well as the bonding condition of the tungsten-copper interface, all affect the electrical and thermal transmission performance of the composite material.

IV. Improve powder quality and mixing uniformity

For the mixed powder pressing and sintering process, the raw material particle size distribution, powder morphology, surface oxidation degree, and mixing uniformity all affect the finished product microstructure. If the tungsten powder particle size is too coarse, larger pores or uneven particle contacts may form inside the compact; if the tungsten powder is too fine, agglomeration, mixing difficulties, and uneven sintering shrinkage may occur. A suitable particle size distribution should be selected according to the target composition and forming process, rather than blindly pursuing finer powder. During the mixing process, obvious segregation of tungsten and copper particles should be avoided, and contamination brought by the mixing equipment should be controlled. If oxides, impurities, or residues on the powder surface are not effectively controlled, particle bonding, interface state, and sintering densification may be affected. For the mixed powder sintering route, the synergistic optimization of pressing pressure, sintering temperature, holding time, and atmosphere should also be used to reduce residual porosity and form a stable phase distribution. Unlike the infiltration method, this type of process requires particular attention to the composition uniformity after powder mixing and the consistency of sintering shrinkage.

V. Control interface quality and post-treatment processes

The interface between the tungsten and copper phases affects heat transfer and also affects the local resistance when current passes through the material. If oxides, contaminants, microcracks, or insufficiently filled gaps exist at the interface, even if the overall density is relatively high, further improvement of electrical conductivity and thermal conductivity may be limited. In terms of process, interface defects can be reduced through raw material cleaning, surface oxidation control, vacuum or protective atmosphere, and stability of the infiltration process. For materials with special requirements, the effects of heat treatment and other post-treatment processes can be further evaluated, but it must be confirmed that they will not introduce new microstructural defects or affect dimensional accuracy. Machining also needs reasonable control. Microcracks, surface damage, or residual stress caused by cutting may affect the actual electrical conduction and heat transfer performance of the contact area. For components such as electrical contacts and heat sinks, in addition to the performance of the material itself, the flatness, roughness, and assembly contact pressure of the contact surface should also be checked, because contact resistance and contact thermal resistance may become limiting factors for system performance.

VI. Establish a process optimization workflow based on test data

Process optimization should not involve greatly changing multiple parameters at the same time; otherwise, it is difficult to determine the true cause of performance changes. It is recommended to first fix the tungsten-copper ratio and testing conditions, and then optimize key process parameters one by one.

Test item	Main judgment target	Significance for process optimization
Finished product density and relative density	Judge the overall degree of densification	Identify insufficient pressing, sintering, or infiltration
Metallographic structure and pore analysis	Judge pore location, copper phase distribution, and interface defects	Determine local microstructural problems
Electrical conductivity testing	Evaluate electrical conduction capability	Judge the comprehensive impact of copper phase continuity and defects
Thermal conductivity testing	Evaluate thermal conduction capability	Judge the impact of pores, interfaces, and microstructure on heat transfer
Composition analysis	Verify the tungsten-copper ratio and impurity level	Eliminate the impact of raw material or composition fluctuations
Sampling and testing at different positions	Check microstructural and performance uniformity	Discover performance differences along the infiltration direction

Electrical conductivity can be expressed as a percentage of the International Annealed Copper Standard (IACS); thermal conductivity is usually expressed in watts per meter-kelvin (W/(m·K), watt per meter-kelvin). During testing, the specimen orientation, temperature, specimen preparation method, and measurement method should be unified, and especially it should be avoided to conclude that the entire piece of material has uniform performance based on testing only one position.

In actual production, the following optimization sequence can be adopted first: first confirm the tungsten-copper ratio and raw material quality, then improve the compact and tungsten skeleton structure, subsequently optimize the sintering and infiltration conditions, and finally verify the effect through microstructural testing, electrical conductivity, and thermal conductivity testing. CTIA GROUP (https://www.ctia.com.cn) is involved in the manufacturing field related to tungsten and tungsten-based composite materials; when conducting material selection or supplier comparison, its product technical data can be evaluated in combination with the test data of specific grades.

The improvement of electrical conductivity and thermal conductivity of tungsten-copper alloy cannot rely solely on increasing copper content or increasing sintering temperature, but should be systematically optimized around density, copper phase continuity, pore connectivity structure, interface quality, and composition stability. The infiltration method should focus on improving the matching relationship between the tungsten skeleton and copper liquid filling, while the mixed powder sintering method should focus on controlling powder uniformity and the densification process.

The most effective evaluation method is to compare the relative density, microstructural defects, electrical conductivity, and thermal conductivity before and after optimization under the same composition and testing conditions, and simultaneously confirm that hardness, strength, arc erosion resistance, or thermal expansion performance do not change beyond the range required by the application. Only by correlating microstructural improvement with

performance testing can a repeatable and mass-producible process optimization scheme be formed.

Q35 How do tungsten-copper alloy manufacturing processes affect production cost and product consistency?

The production cost and product consistency of tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) mainly depend on raw material quality, manufacturing process route, equipment operating conditions, production efficiency, yield, and quality control level. Different processes not only affect the material consumption and processing cost of individual products, but also affect the stability of density, electrical conductivity, thermal conductivity, hardness, and dimensional accuracy between batches. In actual production, cost reduction cannot rely solely on reducing raw material usage or shortening processing time; rather, under the premise of meeting product performance requirements, process fluctuations should be reduced, defect rates should be lowered, first-pass yield should be improved, and rework and scrap losses should be controlled.

I. Impact of different manufacturing processes on cost and consistency

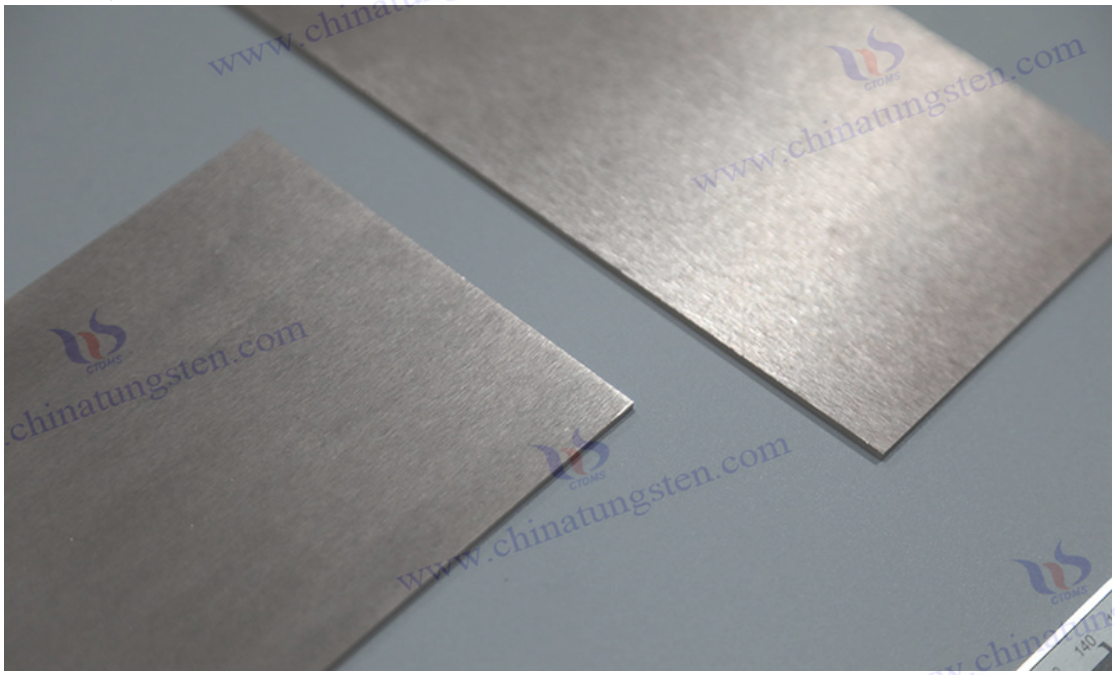
Common manufacturing routes for tungsten-copper alloy include the infiltration method, the mixed powder pressing and sintering method, and other powder metallurgy processes used for specific products. These processes differ in equipment investment, production cycle, material utilization rate, and quality control difficulty.

Manufacturing process	Main cost characteristics	Impact on product consistency	Applicable characteristics
Infiltration method	Requires preparation of W skeleton, Cu infiltration, and subsequent processing; relatively many process steps	Greatly affected by copper liquid filling degree, skeleton pore structure, and infiltration conditions	Suitable for products with relatively high requirements for density, electrical and thermal conductivity, and microstructural stability
Mixed powder pressing and sintering method	Relatively concentrated process steps, but has requirements for powder quality, mixing equipment, and sintering conditions	Greatly affected by powder mixing uniformity, compact density, and sintering shrinkage	Suitable for products with corresponding powder systems and process control capabilities
Precision forming and subsequent machining	Investment in precision molds, processing equipment, and testing may be relatively high	Forming accuracy, machining allowance, and equipment stability directly affect dimensional consistency	Suitable for parts with complex shapes and relatively high dimensional accuracy requirements

It cannot simply be concluded that a certain process is always the lowest cost. Actual cost also depends on product size, tungsten-copper ratio, batch scale, performance indicators, processing difficulty, and yield. For example, for products with high tungsten content and strict structural requirements, the infiltration method may have process advantages; for products with specific compositions and structures, a fully verified pressing and sintering route may also be more economical.

II. How raw material quality affects production cost

Raw material cost is an important part of the manufacturing cost of tungsten-copper alloy; in particular, the price of tungsten powder, powder utilization rate, and fluctuations in raw material quality directly affect the unit product cost. The particle size distribution, purity, particle morphology, and surface oxidation state of tungsten powder affect pressing forming, sintering behavior, and the final microstructure. If powder batches differ greatly, the manufacturer may need to frequently adjust pressing pressure, sintering temperature, or holding time, increasing process debugging and quality testing costs. The purity, surface state, and usage control of copper material are equally important. In the infiltration method, insufficient copper material may lead to incomplete filling, while excessive copper material may cause local copper-rich areas, dimensional deviation, or deviation of material composition from the target; in the mixed powder process, uneven dispersion of copper powder may cause local composition fluctuations. When reducing raw material cost, raw material price, material utilization rate, and final product yield should be considered at the same time. If low-priced raw materials cause a significant increase in defect rate, subsequent rework, testing, and scrap costs may exceed the amount saved on raw materials.



III. How sintering and infiltration processes affect cost

Sintering temperature, holding time, atmosphere, and loading method affect equipment energy consumption, production cycle, and product quality. Too low a temperature or insufficient holding time may cause insufficient bonding of tungsten particles, insufficient skeleton strength, or low density of the finished product; too high a temperature or too long a holding time may increase energy consumption, equipment wear, and the risk of grain growth. For the infiltration method, the key is to allow liquid copper to fully fill the interconnected pores inside the tungsten skeleton. If the skeleton pore distribution is unreasonable, local channels are closed, or the infiltration conditions are unsuitable, residual holes, uneven copper phase distribution, and local performance degradation may occur. These defects not only reduce product yield but may also expose internal defects during subsequent machining, causing the

entire product to be scrapped. When optimizing process parameters, the goal should be to stably obtain qualified products rather than simply pursuing the shortest sintering time or the lowest infiltration temperature. By determining a reasonable process window, reducing equipment temperature fluctuations, unifying the loading method, and standardizing raw material preparation, energy consumption and quality differences between batches can be reduced.

IV. What factors mainly affect product consistency

The consistency of tungsten-copper alloy can be divided into composition consistency, microstructural consistency, performance consistency, and dimensional consistency. These indicators are interrelated but cannot replace one another.

Consistency indicator	Common causes of fluctuation	Main control measures
Composition consistency	Batching errors, powder segregation, unstable copper material usage	Precise batching, standardized mixing, verification of raw material batches
Density consistency	Differences in compact density, uneven sintering shrinkage, insufficient infiltration	Stabilize pressing conditions, optimize skeleton structure and sintering schedule
Electrical & thermal conductivity consistency	Porosity changes, uneven copper phase, interface defects	Control density, improve copper phase distribution, and conduct performance testing
Hardness & strength consistency	Powder particle size fluctuations, grain changes, microstructural defects	Stabilize powder quality and heat treatment or sintering conditions
Dimensional consistency	Forming deviation, shrinkage differences, machining deformation	Unify process parameters, reasonably reserve machining allowance, strengthen dimensional inspection

For example, even if two batches of tungsten-copper alloy have similar average density, they may exhibit different electrical conductivity and thermal conductivity due to different copper phase distribution and local porosity. Therefore, quality control cannot rely only on finished product density; it should also be comprehensively judged in combination with metallographic structure, composition, and key performance.

V. Impact of machining and quality testing on comprehensive cost

Tungsten-copper alloy usually needs to be turned, milled, ground, or otherwise precision-machined according to the product application. Material hardness, microstructural uniformity, and internal defects affect tool wear, machining efficiency, and surface quality. If holes, cracks, or uneven copper phase distribution exist inside the blank, machining may expose defects, causing out-of-tolerance dimensions, unqualified surfaces, or scrapping of the finished product. If the dimensional accuracy of the blank is insufficient, additional machining allowance may be required, further increasing material consumption and processing man-hours. Therefore, quality testing should be moved forward as much as possible. At the raw material stage, check powder quality and batch stability; after pressing or skeleton sintering, check density and pore structure; after infiltration or final sintering, check finished product density and internal defects; and finally conduct dimensional, electrical conductivity, thermal conductivity, and other key performance tests. In this way, process abnormalities can be discovered as early as possible,

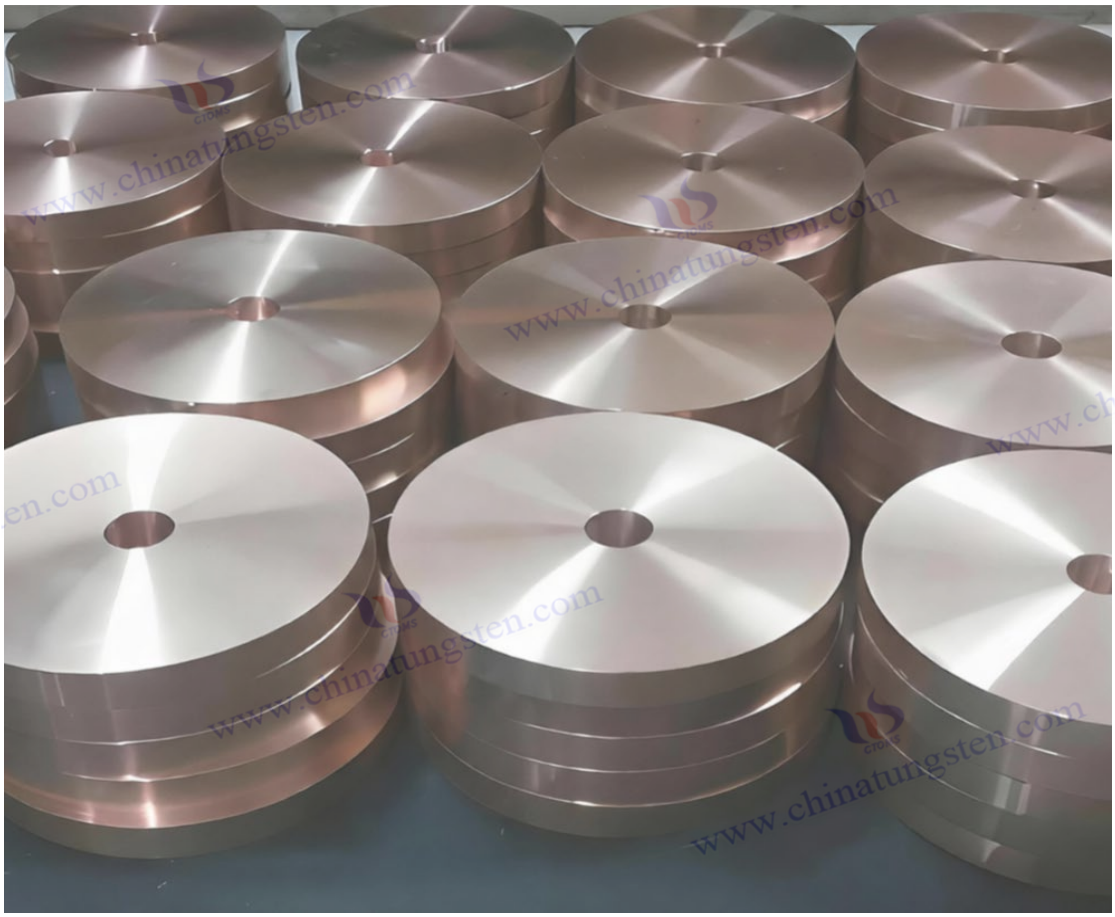
preventing defective products from entering high-cost subsequent processing stages. For suppliers related to tungsten and tungsten-based materials such as CTIA GROUP, when evaluating their products, the focus should also be on checking the composition range, density, electrical conductivity, thermal conductivity, dimensional tolerances, and batch testing capabilities of specific grades, rather than only comparing quotations.

VI. How to improve product consistency while reducing cost

A more effective approach is to establish a production control system based on key process parameters and quality data. First, clarify the key quality indicators of the product, such as target tungsten-copper ratio, relative density, electrical conductivity, thermal conductivity, hardness, and dimensional tolerances, and correlate these indicators with specific application requirements. Second, determine key control parameters for different process routes: the infiltration method focuses on controlling the tungsten skeleton pore structure, copper material usage, infiltration temperature, and holding time; the mixed powder pressing and sintering method focuses on controlling powder mixing uniformity, pressing pressure, compact density, and sintering schedule. Subsequently, determine a reasonable parameter range through small-batch trials, then carry out continuous batch verification, recording raw material batches, equipment status, process parameters, and finished product test results. If density or electrical conductivity fluctuates, the cause should be traced in combination with metallographic structure and production records, rather than compensating only by adjusting a single parameter. Production management should also pay attention to first-pass yield, material utilization rate, equipment utilization rate, rework rate, and scrap rate.

The unit qualified product cost can be expressed in a form convenient for accounting: unit qualified product cost = total production cost ÷ number of qualified products. Total production cost should include raw materials, energy, labor, equipment depreciation, mold and tool consumption, testing, rework, and scrap. This indicator reflects actual economy better than simply comparing the price of raw materials per kilogram. The impact of tungsten-copper alloy manufacturing processes on production cost and product consistency is essentially a comprehensive interaction among material utilization rate, process stability, production efficiency, and quality control level. Raw material stability determines the production foundation; pressing, sintering, and infiltration processes determine the internal microstructure and degree of densification; and machining and testing affect final delivery quality and comprehensive cost.

To achieve cost reduction and efficiency improvement, enterprises should give priority to reducing scrap problems caused by pores, cracks, uneven copper phase, and out-of-tolerance dimensions, and then optimize energy consumption, processing cycle time, and material utilization rate.



Part Two

Core Applications, Processing, & Customization of Tungsten-Copper Alloy

E. Tungsten-Copper Alloy Electrodes and Electrical Machining

Q36 Why is tungsten-copper alloy suitable for making EDM electrodes?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) is suitable for making electrical discharge machining (EDM) electrodes mainly because it combines relatively high electrical conductivity, thermal conductivity, high-temperature stability, resistance to arc erosion, and good mechanical strength. During EDM, the electrode must repeatedly withstand the high temperature, thermal shock, and local material erosion generated by instantaneous discharge while maintaining a stable discharge state and machining shape. Tungsten-copper alloy can balance these requirements well and is especially suitable for precision machining of cemented carbide, mold steel, and other difficult-to-machine conductive materials.

I. Good resistance to arc erosion and relatively low electrode wear

EDM uses pulsed discharge between the electrode and the workpiece to form a high temperature locally, causing the workpiece material to melt or vaporize and be carried away by the working fluid. The electrode itself is also affected by the discharge heat and undergoes melting, evaporation, and surface erosion. Tungsten has a very high melting point of approximately 3422°C and can maintain good thermal stability in a high-temperature discharge environment. Copper is conducive to conducting current and rapidly dissipating heat. After the two are combined, the tungsten phase can improve the material's erosion resistance under local high temperature, while the copper phase helps conduct away the heat generated by discharge. Therefore, under appropriate electrode composition, discharge parameters, and flushing conditions, tungsten-copper electrodes can reduce wear at the electrode end and contour areas, helping maintain the electrode shape and reducing machining dimensional deviations caused by electrode wear.

II. Relatively high electrical conductivity, conducive to stable pulsed discharge

The electrode needs to continuously conduct pulsed current. Better electrical conductivity of the material can reduce the electrode's own resistive losses and unnecessary heating, helping maintain stable current transmission. The copper phase in tungsten-copper alloy plays an important role in electrical conduction. A reasonable tungsten-copper ratio, higher density, and uniform and continuous copper phase distribution help form stable conductive paths. If there are many pores, cracks, or uneven copper phase distribution inside the material, local resistance and heating may increase, thereby affecting discharge stability and machined surface quality. However, the electrical conductivity of tungsten-copper alloy is usually lower than that of pure copper. When selecting electrode materials, electrode wear, machining efficiency, dimensional accuracy, and surface quality need to be comprehensively considered, rather than comparing only electrical conductivity.

III. Good thermal conductivity, helping reduce local heat accumulation

The discharge area in EDM undergoes rapid heating and cooling in an extremely short time. If the electrode cannot conduct heat away in time, local heat accumulation may aggravate melting and erosion of the electrode material and affect the stability of the electrode contour. Copper has high thermal conductivity and can promote heat diffusion inside the material; tungsten provides high-temperature stability and structural support. The combination of the two enables tungsten-copper alloy to achieve a good comprehensive balance between thermal conductivity and high-temperature resistance. The actual thermal conductivity of tungsten-copper alloy is affected by copper content, porosity, phase interface state, and manufacturing process. Increasing material density, reducing internal defects, and improving copper phase distribution are usually conducive to improving heat transfer capability and batch stability.

IV. Good strength and shape stability, suitable for precision electrodes

In machining scenarios such as complex mold cavities, narrow slots, thin ribs, and small fillets, the electrode not only needs heat resistance but also needs to maintain geometric shape. If the electrode undergoes obvious wear, deformation, or local chipping during machining, machining accuracy may be reduced, and the electrode may even need to be remanufactured.

The tungsten phase can improve the hardness and mechanical strength of the material, while the copper phase helps with electrical conduction, thermal conduction, and subsequent processing. A reasonably designed tungsten-copper alloy electrode can balance wear resistance, structural stability, and a certain precision machining capability, making it suitable for occasions with high requirements for electrode shape retention. Its actual machining performance still depends on the tungsten-copper ratio, microstructural uniformity, pore and crack control, and the specific electrode geometry.

V. Differences between tungsten-copper electrodes and pure copper and graphite electrodes

Comparison item	Tungsten-copper electrode	Copper electrode	Graphite electrode
Electrical conductivity	Good, but usually lower than copper	Very good	Affected by graphite grade and direction
Thermal conductivity	Good	Very good	Usually lower than copper, with large differences among grades
High-temperature resistance & arc erosion resistance	Good	Relatively weak	Depends on grade and machining conditions
Fine structure & contour retention	Usually good, suitable for fine structures	Precision machining, wear needs to be controlled	Suitable for various complex cavities; fine edge performance affected by grade
Processing and manufacturing cost	Relatively high material and manufacturing cost	Mature material, convenient processing	Lower material cost; high requirements for dust control and machining accuracy
Typical application tendency	High wear resistance, high precision, and high thermal load electrodes	Conventional cavities, precision machining	Large cavities, mold machining, and higher removal rate scenarios

There is no absolute superiority or inferiority among different materials. Pure copper electrodes have advantages in electrical and thermal conductivity; graphite electrodes have characteristics such as light weight and easy processing in specific mold machining; tungsten-copper electrodes are more suitable for machining tasks that emphasize arc erosion resistance, fine contour retention, and thermal stability.

VI. Which process factors determine the actual performance of tungsten-copper electrodes?

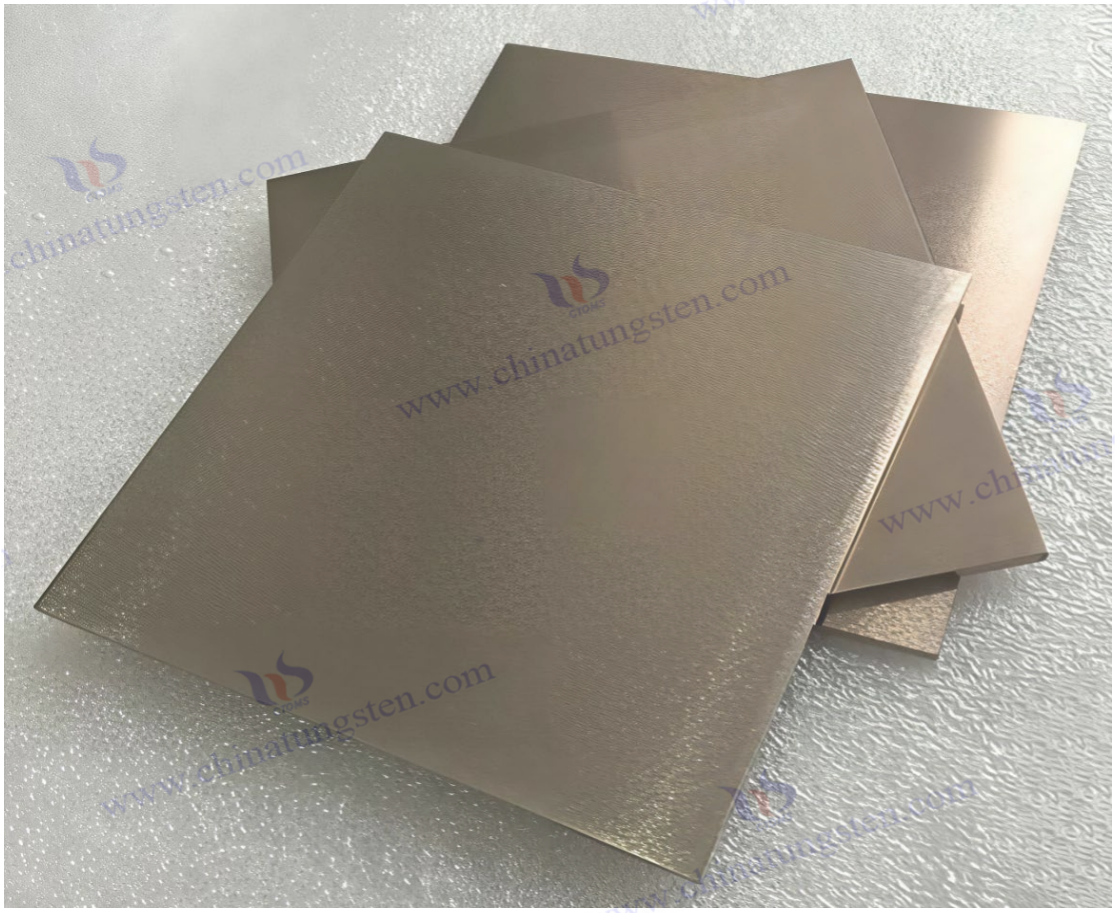
The performance of tungsten-copper electrodes is determined not only by composition but also by the manufacturing process. The first is the tungsten-copper ratio. Increasing copper content is usually conducive to electrical and thermal conductivity, but excessively increasing copper content may reduce high-temperature erosion resistance and mechanical strength. Therefore, an appropriate grade should be selected according to workpiece material, discharge parameters, electrode shape, and precision requirements. The second is density and microstructural uniformity. Pores, cracks, and uneven copper phase distribution weaken conductive and thermal paths, leading to local heat accumulation and uneven wear. Adopting reasonable powder preparation, tungsten skeleton sintering, and copper infiltration processes helps improve the consistency of material performance. Finally, electrode processing and discharge parameters. Electrode surface quality, geometric accuracy, pulse current, pulse duration, discharge gap, and working fluid circulation all affect electrode wear and workpiece

surface quality. Even if a tungsten-copper material with good performance is used, improper discharge parameters may still cause problems such as excessive electrode wear, rough surfaces, or reduced machining efficiency.

For tungsten-copper material selection and manufacturing evaluation, relevant material information from CTIA GROUP can be referenced: https://www.ctia.com.cn, and comparisons can be made in combination with the density, electrical conductivity, hardness, microstructure, and electrode wear test data of specific grades.

Tungsten-copper alloy is suitable for making EDM electrodes because the key lies in the tungsten phase providing a high melting point, arc erosion resistance, and structural support, while the copper phase provides electrical and thermal conductivity. The composite advantages of the two help reduce electrode wear, maintain the machining contour, and improve stability under high thermal load discharge conditions.

For precision molds, cemented carbide machining, and small complex electrodes, when selecting tungsten-copper alloy, the focus should be on evaluating electrode wear rate, workpiece material removal rate, machined surface roughness, dimensional accuracy, and manufacturing cost, rather than judging whether the material is suitable based only on electrical conductivity or melting point.



Q37 What are the differences between tungsten-copper alloy electrodes, graphite electrodes, and pure copper electrodes?

In electrical discharge machining (EDM), the main differences among tungsten-copper alloy electrodes, graphite electrodes, and pure copper electrodes lie in arc erosion resistance, electrical and thermal conductivity, machining accuracy, material removal efficiency, and manufacturing cost. Each of the three has its own advantages, and the selection should be comprehensively judged in combination with workpiece material, cavity structure, dimensional accuracy, surface roughness, and production budget. Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) combines the high melting point of tungsten with the electrical and thermal conductivity of copper and is usually more suitable for occasions with high requirements for electrode wear, fine structures, and contour stability; pure copper has excellent electrical and thermal conductivity and is suitable for a variety of precision machining tasks; graphite has advantages such as low density and easy processing of large electrodes and is widely used in mold manufacturing.

I. Core differences among tungsten-copper alloy electrodes, graphite electrodes, and pure copper electrodes

Comparison item	WCu alloy electrode	Copper electrode	Graphite electrode
Material composition	W & Co phase composite	Metal material mainly composed of Cu	Graphite material mainly composed of carbon
Electrical conductivity	Good, usually lower than copper	Very good	Depends on graphite grade, density, and direction
Thermal conductivity	Good	Very good	Usually lower than copper, depending on grade
High-temperature stability	Good, high melting point of tungsten phase	Copper melting point 1084.6°C, high risk of local high-temperature erosion	No metallic melting; may sublime, oxidize, or erode at high temperature
Arc erosion resistance	Usually good	Depends on discharge parameters; obvious wear under strong thermal load	Depends on grade, discharge conditions, and electrode shape
Fine contour machining	Suitable for small, precise structures	Suitable for various precision structures	High-grade graphite can be precision machined; thin edges and thin-walled structures require caution
Material density	Relatively high	Relatively high	Relatively low
Processing method	Requires hard material processing technology	Mature cutting processing	Relatively high mechanical processing efficiency, but generates graphite dust
Comprehensive cost	Relatively high material manufacturing cost	Medium to high, depending on copper material grade and processing volume	Material cost advantage, affected by graphite grade and precision machining requirements

The table provides a general comparison; actual performance varies with material grade, tungsten-copper ratio, graphite particle structure, manufacturing process, and discharge parameters.

II. Tungsten-copper electrode: advantage lies in erosion resistance and contour retention

The main advantage of tungsten-copper electrodes is the combination of electrical and thermal conductivity with high-temperature erosion resistance. The tungsten phase helps resist the high temperature generated by local discharge, while the copper phase helps conduct current and heat. Therefore, under reasonable material ratio and discharge parameters, the electrode can better maintain the end and edge contours. Tungsten-copper electrodes are especially suitable for cemented carbide machining, fine structures of precision molds, narrow slots, thin ribs, and machining tasks sensitive to electrode wear. For workpieces with complex shapes and small electrode dimensions, reducing electrode wear helps control machining errors and reduces the need for compensation correction and repeated machining. Its main limitations are high material density, relatively difficult processing, and raw material and manufacturing costs usually higher than ordinary graphite electrodes. Therefore, if machining large, simple cavities and electrode wear is not the main limiting factor, tungsten-copper may not be the most economical choice.

III. Pure copper electrode: advantage lies in electrical and thermal conductivity and surface quality

Pure copper has relatively high electrical and thermal conductivity, uniform material structure, and mature cutting processing technology, making it suitable for a variety of precision EDM scenarios. After reasonably controlling discharge parameters and electrode surface state, pure copper electrodes can achieve good machined surface quality.

Pure copper is often used for small and medium-sized mold cavities, precision parts, and machining tasks requiring good surface quality. Its advantages are mature material performance, easy establishment of processing technology, and suitability for various electrode structures. However, the melting point of copper is approximately 1084.6℃, far lower than that of tungsten. The instantaneous temperature in the discharge area is very high, and pure copper electrodes may undergo local melting and erosion, especially in high thermal load or fine structure machining, where discharge parameters need to be optimized more carefully. Compared with tungsten-copper, pure copper may be more difficult to balance low electrode wear and contour stability under some severe working conditions.

IV. Graphite electrode: advantage lies in light weight and processing efficiency

Graphite has relatively low density, usually making it convenient to manufacture large electrodes, and has relatively high mechanical processing efficiency, so it is widely used in mold EDM. For large cavities, multi-electrode machining, and tasks requiring higher material removal efficiency, graphite often has better comprehensive economy. The performance of graphite is closely related to its grade. High-grade graphite with small particle size and uniform structure can be used for precision machining, but graphite itself has a particle structure, and the strength and damage resistance of fine edges, thin walls, and sharp corners need to be carefully evaluated. Graphite processing also generates dust, requiring appropriate dust removal facilities and equipment cleaning. In addition, the electrical and thermal conductivity of graphite cannot simply be regarded as fixed values; its anisotropy and microstructure may affect discharge performance. When selecting graphite electrodes, the specific grade should

be checked, and performance should not be judged only by the material name "graphite."

V. How to choose among tungsten-copper alloy electrodes, graphite electrodes, and pure copper electrodes for different machining tasks?

Machining requirement	Material to prioritize	Main reason
Cemented carbide, strong thermal load discharge	Special electrode material suitable for tungsten-copper	Emphasizes erosion resistance and contour stability
Fine structures, narrow slots, precision edges	Tungsten-copper, pure copper, or high-grade graphite	Needs to be judged in combination with electrode size, wear compensation, and target accuracy
Precision cavities with high surface quality	Pure copper or suitable tungsten-copper grade	Good electrical conductivity; surface quality can be controlled through fine parameter control
Large mold cavities	Graphite usually has a cost advantage	Low density and relatively high processing efficiency, suitable for larger electrodes
Budget-sensitive, batch processing	Accounting of electrode life and processing cycle	Cannot compare only unit price; should compare total cost per qualified workpiece

When selecting electrodes, rough machining and finish machining should also be distinguished. Rough machining usually focuses more on material removal rate, discharge stability, and overall electrode cost; finish machining focuses more on electrode wear, detail retention capability, dimensional accuracy, and surface roughness. The same material may also perform significantly differently under different discharge parameters.

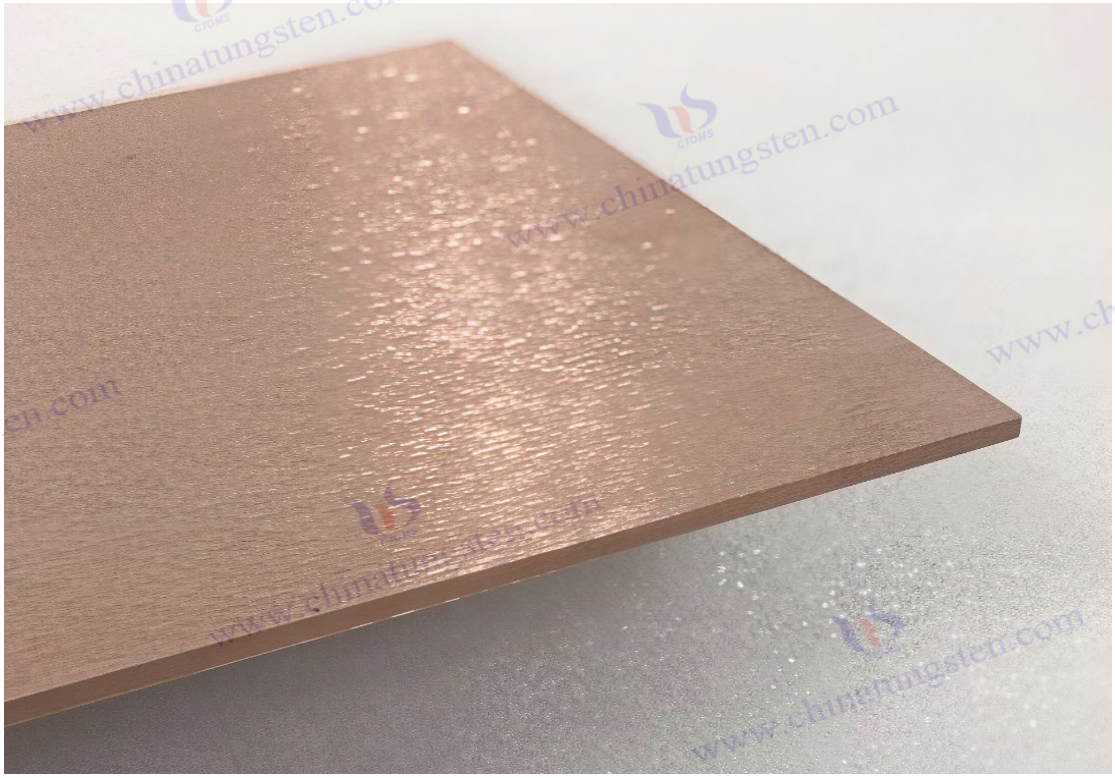
VI. How to compare the real cost of use?

The purchase price of the electrode is only part of the cost. A more reasonable evaluation method is to calculate the comprehensive cost per qualified workpiece, including electrode material cost, manufacturing and processing cost, equipment occupancy time, electrode wear, compensation correction, rework, and scrap losses. For example, graphite electrodes have a lower unit price and faster processing speed, but if wear of fine structures is obvious, correction times may increase; although tungsten-copper electrodes have higher costs, under specific precision working conditions, if they can significantly reduce electrode wear and repeated machining, the comprehensive cost may be more competitive. Pure copper may provide a suitable balance among machined surface quality, manufacturing convenience, and material performance.

For the selection of tungsten-copper electrodes, relevant material information from CTIA GROUP can be referenced: https://www.ctia.com.cn, and the focus should be on comparing the tungsten-copper ratio, density, electrical conductivity, hardness, dimensional tolerance, and actual electrode wear data of specific grades.

In short, tungsten-copper electrodes are more outstanding in arc erosion resistance and fine contour retention, pure copper electrodes are more outstanding in electrical and thermal conductivity and mature precision machining capability, and graphite electrodes are more outstanding in light weight, easy processing, and economy in large mold applications. The final

choice should be based on actual workpiece material, machining accuracy, discharge parameters, and cost per qualified workpiece.



Q38 Which is more suitable for EDM, W70Cu30 or W80Cu20?

Both W70Cu30 and W80Cu20 can be used for electrical discharge machining (EDM) electrodes, but their applicable emphases are different. W70Cu30 contains 70% tungsten and 30% copper; W80Cu20 contains 80% tungsten and 20% copper. The former usually focuses more on the balance among electrical conductivity, thermal conductivity, and machining efficiency, while the latter usually focuses more on arc erosion resistance, high-temperature resistance, and electrode contour retention capability. If mainly machining cemented carbide, requiring lower electrode wear, or maintaining fine structures, W80Cu20 can be evaluated first; if more emphasis is placed on electrical and thermal conductivity, machining efficiency, and comprehensive cost, W70Cu30 can be evaluated first. However, the final performance still depends on the specific grade, manufacturing quality, and discharge parameters.

I. Main differences between W70Cu30 and W80Cu20

Comparison item	W70Cu30	W80Cu20
Tungsten content	70%	80%
Copper content	30%	20%
Electrical conductivity	Usually higher	Usually lower
Thermal conductivity	Usually higher	Usually lower
High-temperature erosion resistance	Good	Usually more advantageous
Electrode contour retention capability	Good	Usually more advantageous under high thermal load conditions
Density	Usually lower	Usually higher
Material and processing cost	Needs comparison according to specific supplier quotations	Needs comparison according to specific supplier quotations
Typical selection direction	Balances electrical conductivity, thermal conductivity, and machining efficiency	Emphasizes erosion resistance and fine structure stability

The trends here are general judgments when manufacturing quality, testing conditions, and other process factors are similar, and do not mean that W80Cu20 is more wear-resistant than W70Cu30 under all discharge conditions.

II. Why is W80Cu20 more suitable for some high-precision machining?

The melting point of tungsten is approximately 3422°C, and the melting point of copper is approximately 1084.6°C. Increasing tungsten content usually enhances the high-temperature stability of the material and improves arc erosion resistance under certain working conditions. W80Cu20 has a higher tungsten content, so when machining cemented carbide, fine groove shapes, narrow ribs, and structures sensitive to electrode tip wear, it is worth prioritizing experimental verification. Its advantage lies in the opportunity to reduce electrode contour changes, thereby reducing dimensional compensation and repeated machining. However, increasing tungsten content also reduces the proportion of the copper phase, which is usually detrimental to electrical and thermal conductivity. Therefore, machining efficiency cannot be judged solely by tungsten content, and it cannot be directly concluded that W80Cu20 has a

lower electrode wear rate under all conditions.

III. Why might W70Cu30 also be more suitable?

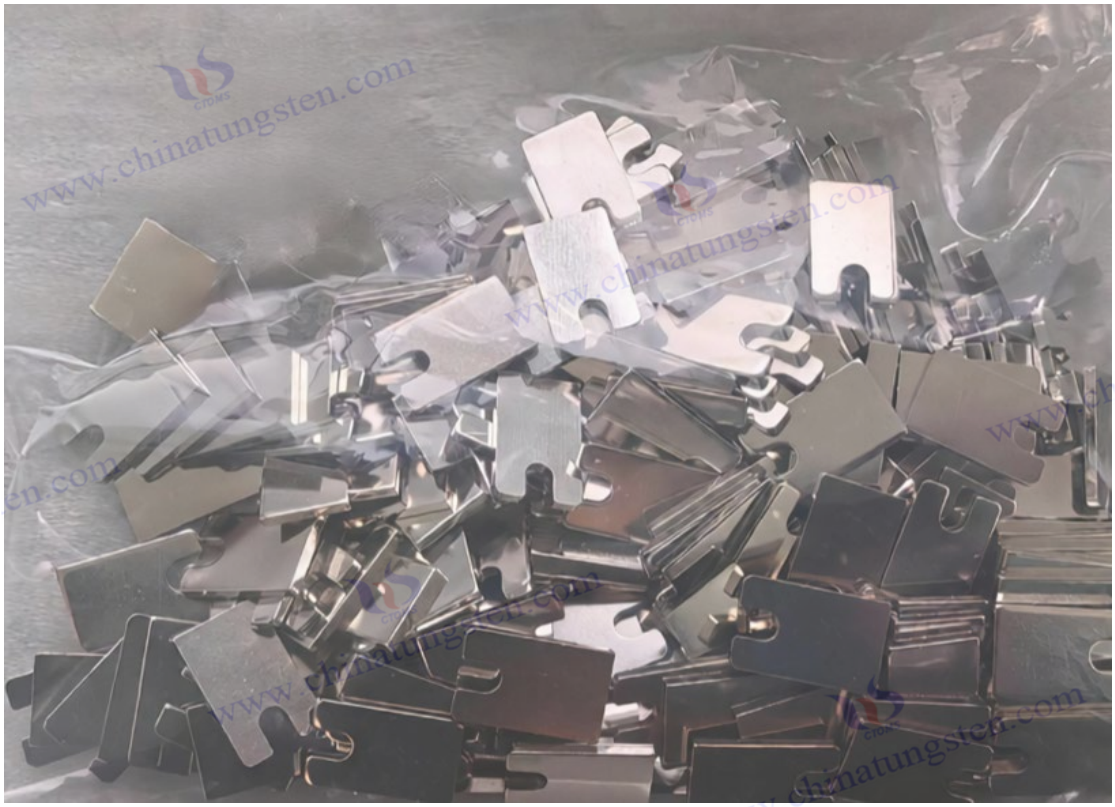
W70Cu30 contains more copper phase and usually has higher electrical and thermal conductivity. This is conducive to current transmission and heat diffusion and, under appropriate discharge parameters, may make it easier to balance discharge stability, material removal efficiency, and electrode life. If the machining task has a higher tolerance for electrode wear, or if more emphasis is placed on electrical conductivity and comprehensive production efficiency, W70Cu30 may have better comprehensive performance. Especially in batch production, if W70Cu30 can already meet dimensional accuracy and surface quality requirements, it may not be necessary to increase material cost in pursuit of higher tungsten content.

IV. Selection according to machining tasks

Machining scenario	Recommended to evaluate 1st	Basis for selection
Precision machining of cemented carbide	W80Cu20	Focus on electrode wear and contour retention capability
Fine slots, thin ribs, sharp corner structures	W80Cu20	Focus on wear and dimensional changes of fine structures
Electrodes with higher requirements for electrical and thermal conductivity	W70Cu30	Higher copper content, usually more conducive to electrical and thermal conductivity
Balancing machining efficiency & electrode life	Test both materials	Decide based on actual material removal rate and wear rate
Cost-sensitive batch processing	Choose based on comprehensive cost	Simultaneously account for electrode manufacturing cost, wear, machining time, and scrap rate

V. What data should be compared in actual material selection?

It is recommended to require suppliers to provide the density, electrical conductivity, hardness, microstructural uniformity, and testing conditions of specific grades. During trial machining, under the same workpiece material, discharge current, pulse duration, pulse interval, working fluid, and flushing conditions, compare the material removal rate, electrode wear rate, machined surface roughness, and final dimensional deviation of the two electrodes. Among these, the relative electrode wear rate can be calculated on a unified mass or volume basis; if the volume basis is used, then relative electrode wear rate (%) = electrode wear volume ÷ workpiece removal volume × 100%. Both materials must use the same calculation basis for the comparison results to be meaningful. For tungsten-copper material selection and manufacturing evaluation, relevant information from CTIA GROUP can also be referenced: https://www.ctia.com.cn, focusing on checking the measured performance of specific grades rather than making judgments based only on the nominal composition of W70Cu30 or W80Cu20. Our recommendation is: if your primary goal is to reduce electrode wear and maintain fine contours, try W80Cu20 first; if you place more emphasis on electrical and thermal conductivity and comprehensive machining efficiency, try W70Cu30 first.



Q39 What Factors Affect the Wear Rate and Service Life of Tungsten-Copper Alloy Electrodes?

The wear rate and service life of tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) electrodes are primarily affected by the tungsten-to-copper ratio, material density, microstructural uniformity, discharge parameters, workpiece material, working fluid condition, and electrode geometry. Among these factors, discharge parameters determine the thermal load imposed on the electrode, material microstructure affects resistance to arc erosion, while machining methods and electrode geometry determine localized wear and dimensional stability. In electrical discharge machining (EDM), electrode service life should not be evaluated solely by the number of hours it has been used. A more practical evaluation criterion is the amount of machining that can be completed while meeting workpiece dimensional accuracy and surface quality requirements, together with the electrode wear corresponding to each unit of workpiece material removal.

I. The Tungsten-to-Copper Ratio Determines the Balance Between Erosion Resistance and Electrical/Thermal Conductivity

Tungsten-copper alloy consists of a high-melting-point tungsten phase and a copper phase with good electrical and thermal conductivity. Tungsten has a melting point of approximately 3,422°C, while copper has a melting point of approximately 1,084.6°C. Increasing the tungsten content generally helps improve high-temperature stability and resistance to arc erosion under certain operating conditions. However, it also reduces the proportion of copper, typically resulting in lower electrical and thermal conductivity.

Taking the commonly used W70Cu30 and W80Cu20 grades as examples:

Comparison Item	W70Cu30	W80Cu20
Tungsten content	70%	80%
Copper content	30%	20%
Electrical and thermal conductivity	Generally relatively high	Generally relatively low
High-temperature erosion resistance potential	Good	Generally more advantageous
Application focus	Balances electrical conductivity, thermal conductivity, and machining efficiency	Emphasizes erosion resistance and profile retention

These are general trends and do not mean that a higher tungsten content will necessarily result in lower actual electrode wear. If the material contains pores, cracks, or uneven copper-phase distribution, a higher tungsten content alone cannot guarantee excellent service life.

II. Material Density and Microstructure Affect Localized Wear

Pores, cracks, inclusions, and uneven copper-phase distribution inside tungsten-copper electrodes may cause variations in local electrical and thermal conduction. Under repeated pulsed discharge, heat may become concentrated in localized areas, thereby accelerating material erosion, edge wear, or minor structural damage.

The major material-related factors include:

Density

Excessive porosity reduces the effective conductive cross-section and may concentrate the local discharge thermal load.

Copper-phase continuity

Uneven copper distribution may cause differences in local electrical resistance and heat dissipation.

Tungsten skeleton structure

Insufficient bonding between tungsten particles or nonuniform microstructure may reduce localized structural stability.

Impurities and interfacial defects

Oxides, contaminants, and interfacial gaps may affect heat transfer and material bonding.

Therefore, manufacturing processes have a direct impact on electrode service life. Proper control of powder quality, compaction, tungsten skeleton sintering, and copper infiltration conditions helps improve material density and microstructural consistency. For tungsten-copper materials supplied by CTIA GROUP, the selection process can be supported by evaluating measured density, electrical conductivity, hardness, and microstructural inspection results for the specific grade: https://www.ctia.com.cn

III. Discharge Parameters Are Usually a Key Factor Affecting the Wear Rate

Electrode wear in electrical discharge machining is closely related to the energy of individual discharges, discharge frequency, and the distribution of heat between the electrode and the workpiece.

Discharge Parameter	Typical Effect on Electrode Wear	Process Adjustment Direction
Peak current	Increasing it generally increases the thermal load of each discharge	Adjust according to roughing or finishing requirements
Pulse duration	Longer duration may increase discharge energy and thermal effects	Avoid unnecessarily long pulses
Pulse interval	Affects cooling, debris removal, and conditions for the next discharge	Ensure stable recovery of the discharge gap
Polarity setting	Changes the distribution of erosion between the electrode and workpiece	Conduct trials based on the machine, workpiece, and electrode material
Discharge gap and servo control	Affect short circuits, abnormal discharges, and discharge stability	Optimize servo parameters and reduce abnormal discharges

Roughing and finishing must be distinguished. Roughing generally uses higher discharge energy to increase the material removal rate, while finishing usually employs lower discharge energy to improve surface quality and dimensional control. Higher discharge energy does not necessarily result in a higher relative electrode wear rate, because wear also depends on polarity, pulse conditions, and workpiece material.

Therefore, when adjusting parameters, the workpiece material removal rate, electrode wear rate, surface roughness, and dimensional deviation should be recorded simultaneously rather than evaluating only the amount of electrode wear.

IV. Workpiece Material and Working Fluid Also Affect Electrode Service Life

Different workpiece materials exhibit different melting, vaporization, and debris-removal characteristics. The heat distribution between the electrode and workpiece during discharge may therefore vary. As a result, the same tungsten-copper electrode may exhibit significantly different wear behavior when machining cemented carbide, tool steel, or other conductive materials.

The working fluid primarily affects dielectric recovery, cooling, and the removal of machining debris from the discharge gap. If the working fluid is contaminated, circulation is insufficient, or flushing conditions are inappropriate, debris may accumulate in the machining gap, resulting in abnormal discharges and localized overheating. These conditions can increase electrode wear and reduce machining stability.

Debris removal is particularly important when machining deep grooves, narrow slots, and deep cavities. Even if the electrode material itself has excellent erosion resistance, poor access of the working fluid to the machining area or inadequate removal of debris may still cause abnormal discharge conditions and increased electrode wear.

V. Electrode Geometry and Dimensions Determine the Degree of Localized Wear

The overall wear of a tungsten-copper electrode does not necessarily reflect its actual usable service life. For complex electrodes, localized dimensional changes are often more important

than total volume loss.

For example, thin ribs, sharp corners, thin walls, and small-radius features are susceptible to localized thermal loads and machining stresses. Even minor wear at the tip or edge may cause the cavity dimensions to exceed tolerance. In contrast, a large, simple electrode may remain suitable for machining even after experiencing a certain amount of volume loss.

Therefore, electrode service life should be evaluated using the following indicators: total mass or volume loss, axial wear at the tip, changes in edge profile, dimensional deviations after machining, and the number of workpieces that can be completed before dimensional or surface quality limits are reached. For high-precision electrodes, reserving an appropriate wear compensation allowance, optimizing flushing direction, improving electrode clamping rigidity, and properly arranging roughing and finishing parameters are often more effective than simply increasing the tungsten content.

VI. How to Calculate the Wear Rate and Evaluate Service Life

To compare different grades and machining processes fairly, the following standardized calculation method is recommended: Electrode volumetric wear rate = Electrode volume loss ÷ Workpiece material removal volume × 100%. If mass measurements are used, electrode mass loss can also be calculated. However, the densities of tungsten-copper electrodes and different workpiece materials may vary considerably, so mass wear rate cannot directly replace volumetric wear rate. During comparative testing, the measurement method and calculation basis should be standardized. Electrode service life can be defined as the effective machining volume or number of qualified workpieces that can be completed under specified machining conditions, from the beginning of use until the electrode dimensions, profile, or surface condition no longer meet acceptance requirements.

It is recommended to compare different tungsten-copper grades under identical workpiece material, discharge parameters, working fluid conditions, and electrode geometry, while recording electrode wear, workpiece material removal, surface roughness, and final dimensional accuracy. Only comparisons conducted under identical conditions can determine whether a particular material genuinely extends service life. The wear rate and service life of tungsten-copper alloy electrodes are the result of the combined effects of material characteristics and machining conditions. The tungsten-to-copper ratio affects high-temperature erosion resistance and electrical/thermal conductivity, while material density and microstructural uniformity determine local heat transfer and structural stability. Discharge parameters, working fluid, and electrode geometry directly affect actual wear.

If the objective is to extend electrode service life, it is recommended to first examine internal material defects and discharge parameters, followed by optimization of polarity, flushing, debris removal, and electrode geometry. For W70Cu30 and W80Cu20, the lower wear rate should not be determined solely by composition. Selection should instead be based on actual workpiece wear rate, dimensional retention capability, and overall machining cost.

Q40 Is Tungsten-Copper Alloy Suitable for Machining Cemented Carbide and High-Hardness Tool Steel?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) is commonly used as an electrode material for electrical discharge machining (EDM, Electrical Discharge Machining), particularly for machining certain cemented carbides, high-hardness tool steels, and complex precision cavities. Its main advantages include good electrical and thermal conductivity combined with resistance to arc erosion. These characteristics help control electrode wear, maintain fine profiles, and achieve stable machining performance under appropriate discharge parameters. However, tungsten-copper alloy is not necessarily the optimal choice for every machining task involving hard materials. Actual performance also depends on the workpiece material, electrode grade, machining stage, and machine parameters.

I. Why Is It Suitable for Machining Cemented Carbide?

Cemented carbide generally has high hardness, wear resistance, and strength, making conventional mechanical machining difficult. For electrically conductive cemented carbide, EDM removes material through pulsed electrical discharges without relying on direct cutting by a tool of greater hardness. This makes it suitable for machining complex cavities, narrow slots, and fine structures. The advantages of tungsten-copper electrodes are mainly reflected in three aspects.

First, the tungsten phase has a high melting point, helping improve electrode stability in the localized high-temperature discharge environment. The copper phase facilitates current and heat conduction, reducing unnecessary localized heat accumulation.

Second, under appropriate discharge conditions, tungsten-copper electrodes can maintain tip and edge geometry relatively well, making them suitable for narrow slots, thin ribs, sharp corners, and other structures sensitive to electrode profile retention.

Third, when tungsten-copper materials have good density and microstructural uniformity, they generally help achieve more stable electrode wear behavior, reducing dimensional deviations caused by electrode wear.

However, the EDM performance of cemented carbide is also affected by tungsten carbide particles, binder-phase composition, and the specific workpiece grade. If the workpiece has poor electrical conductivity, an unusual microstructure, or extremely demanding machining requirements, applicability should first be confirmed through trial machining.

II. Why Is It Suitable for Machining High-Hardness Tool Steel?

High-hardness tool steel becomes significantly more difficult to machine after heat treatment such as quenching. EDM can be used to manufacture deep cavities, narrow slots, complex curved surfaces, and other structures that are difficult to produce through conventional cutting.

Machining Applications for Tungsten-Copper Electrodes

Machining Scenario	Suitability of WCu Electrodes	Main Reason
Precision cavities in high-hardness tool steel	Highly suitable	Helps control electrode wear and cavity dimensions
Narrow slots, thin ribs, and small-radius corners	Highly suitable	Balances localized erosion resistance and profile retention
Deep cavity machining	Depends on geometry	Requires simultaneous optimization of flushing, debris removal, and discharge stability
Rough machining of large, simple cavities	Not necessarily the most economical	Graphite and other electrode materials may offer better machining efficiency or cost advantages
High-surface-quality finishing	Can be considered	Requires lower-energy discharge parameters and precise dimensional compensation

For tool steel, electrode material is only one factor affecting machining results. Pulse energy, polarity, discharge gap, working fluid circulation, and machining strategy are equally important. Even when tungsten-copper electrodes are used, inappropriate parameter settings may still result in excessive electrode wear, poor surface finish, or unstable localized discharges.

III. How Should W70Cu30 and W80Cu20 Be Selected?

For machining cemented carbide or high-hardness tool steel, these two grades can be considered as candidate materials. However, the final decision should not be based solely on tungsten content.

Comparison Dimension	W70Cu30	W80Cu20
Copper content	Higher	Lower
Electrical and thermal conductivity	Generally relatively higher	Generally relatively lower
High-temperature erosion resistance potential	Good	Generally more advantageous
Application considerations	Balances electrical/thermal conductivity and machining efficiency	Greater emphasis on electrode profile retention under high thermal loads
Final selection criteria	Measured wear rate, machining efficiency, and accuracy	Measured wear rate, machining efficiency, and accuracy

For precision structures in cemented carbide or machining tasks where electrode wear is particularly critical, W80Cu20 can be prioritized for trial testing. If electrical/thermal conductivity and overall machining efficiency are more important, W70Cu30 can also be evaluated.

These recommendations represent general trends. Actual electrode wear is also closely related to manufacturing processes, material density, microstructural uniformity, workpiece grade, and discharge conditions. W80Cu20 cannot be guaranteed to exhibit lower wear than W70Cu30 under all circumstances.

IV. How Can Tungsten-Copper Electrode Machining Performance Be Improved?

To maximize the advantages of tungsten-copper electrodes, both material quality and machining parameters should be addressed.

Material Considerations

Density, porosity, cracks, copper-phase distribution, and dimensional tolerances should be carefully examined. When defects exist inside the material, local electrical and thermal conduction may become nonuniform, affecting electrode wear and machining stability.When purchasing electrodes, verify the density, electrical conductivity, hardness, and relevant inspection data for the specific grade rather than relying solely on nominal composition.

Machining Considerations

Roughing and finishing should be treated separately. Roughing generally prioritizes material removal rate and machining cycle time, whereas finishing focuses on electrode wear, surface roughness, and dimensional accuracy.For deep-slot or deep-cavity machining, working fluid circulation and debris removal must also be optimized to prevent debris accumulation and abnormal discharges.

Material information and electrode selection can be referenced through CTIA GROUP: https://www.ctia.com.cn. During procurement, suppliers should be required to provide performance data for the specific grade, followed by trial machining using the target workpiece. Tungsten-copper alloy is suitable for EDM machining of cemented carbide and high-hardness tool steel, particularly when electrode wear, fine structures, and profile accuracy are critical.
For large, simple cavities or applications primarily focused on roughing efficiency, other electrode materials may offer better economic advantages.

If the objective is to machine precision cavities in cemented carbide molds or high-hardness tool steel, it is recommended to first compare W70Cu30 and W80Cu20 under identical machining conditions, using electrode volumetric wear rate, workpiece material removal rate, surface roughness, and final dimensional deviation as evaluation criteria before determining the most suitable grade.



41 How Can the Machining Accuracy and Surface Quality of Tungsten-Copper Alloy Electrodes Be Improved?

Improving the machining accuracy and surface quality of tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) electrodes requires simultaneous control of material microstructure, machining equipment, tooling and cutting parameters, discharge conditions, and inspection methods.

For EDM electrodes, dimensional accuracy, surface roughness, and microscopic defects directly affect discharge stability, workpiece surface quality, and final cavity dimensions.

Tungsten-copper alloy has relatively high hardness and erosion resistance, but the tungsten and copper phases differ in hardness, ductility, and machining response. If machining parameters are inappropriate, localized smearing of the copper phase, tungsten particle pullout, minor edge chipping, surface scratches, and dimensional deviations may occur.

Therefore, a machining strategy should be developed according to the material grade and electrode geometry rather than relying solely on reducing feed rate or increasing the number of finishing passes.

I. Improve Material Microstructural Uniformity and Reduce Machining Defects

Machining quality first depends on the material itself. If tungsten-copper alloy contains pores, cracks, uneven copper-phase distribution, or localized loose regions, precision machining equipment alone may not prevent surface defects and dimensional variations.

Material Issue	Effect on Machining Quality	Improvement Measures
Excessive porosity	Pores may be exposed after machining, affecting surface integrity	Optimize compaction, sintering, or infiltration processes to improve density
Uneven copper-phase distribution	May cause localized differences in cutting response and inconsistent surface quality	Improve powder mixing, tungsten skeleton structure, and copper infiltration
Insufficient tungsten particle bonding	May cause particle pullout, small pits, or edge chipping	Optimize sintering conditions and raw material quality
Internal cracks or residual stress	May propagate during machining or cause dimensional changes	Strengthen billet inspection and optimize heat treatment and machining sequence
Material batch variation	May cause fluctuations in tool wear and machining dimensions	Maintain consistent material grades and implement batch quality inspection

For high-precision electrodes, billet density, microstructural uniformity, and critical dimensions should be checked before finishing.

If significant internal defects exist, material quality should be addressed first rather than attempting to conceal them through subsequent polishing.

II. Optimize Cutting Parameters to Control Dimensional Errors and Surface Roughness

Mechanical machining of tungsten-copper alloy must accommodate both the high hardness of

the tungsten phase and the ductility of the copper phase.

Aggressive parameters may cause tool wear, edge chipping, and surface damage. Excessively conservative parameters may increase machining time without necessarily improving surface quality. The main optimization directions include:

Tool selection: Select suitable tool materials, cutting-edge geometries, and coatings according to the tungsten-copper grade, tungsten content, and machining method. The tool should provide sufficient wear resistance and cutting-edge stability.

Cutting speed and feed rate: Roughing should prioritize stable material removal. During finishing, the feed rate should be appropriately reduced, and the cutting speed should be determined through trial machining to avoid dimensional deviations caused by tool wear or localized heating.

Depth of cut: During finishing, use a reasonable small machining allowance to avoid excessive material removal in a single pass, which may cause edge damage or surface quality fluctuations.

Cooling and lubrication: Select appropriate cooling methods based on the machine, tool, and material characteristics to control cutting heat, chip evacuation, and surface contamination.

Tool wear management: Regularly inspect tool cutting edges to prevent cumulative dimensional deviations caused by progressive tool wear.

Specific parameters cannot be determined solely from the nominal composition of W70Cu30 or W80Cu20. Workpiece dimensions, tool diameter, tool overhang, machine rigidity, and machining method must also be considered. A stable parameter range should be established through small-batch trial machining.

III. Improve Clamping and Machine Stability to Control Deformation

Precision electrodes often contain slender, thin-wall, narrow-slot, or sharp-cornered structures. Uneven clamping forces, excessive tool overhang, machine vibration, and thermal deformation may cause actual machining dimensions to deviate from programmed values. The following measures are recommended:

Use sufficiently rigid and reliable fixtures to minimize unnecessary tool overhang.

For slender or thin-wall electrodes, arrange the machining sequence appropriately to avoid removing supporting material too early.Before finishing, inspect workpiece positioning and datum surfaces, and perform repositioning when necessary.

For high-precision machining sensitive to temperature changes, maintain stable machine and workpiece temperatures as much as possible and remeasure dimensions after machining.

For complex electrodes, machining allowances should be properly distributed among roughing, semi-finishing, and finishing operations. Maintaining a uniform allowance after roughing helps reduce fluctuations in cutting load during finishing caused by uneven local material removal.

IV. Improve Surface Quality Through Finishing and Deburring Processes

The surface quality of tungsten-copper electrodes depends not only on cutting parameters but also on the final finishing method.

For electrodes intended for EDM, surface quality should be improved without damaging sharp corners, thin ribs, or profile dimensions.

Post-Processing Method	Main Function	Key Control Considerations
Precision grinding	Improves flatness, dimensional accuracy, and surface condition	Prevent localized overheating, grinding damage, and edge cracking
Fine polishing	Reduces surface roughness and removes minor machining marks	Control material removal to prevent distortion of radii and sharp edges
Light deburring	Removes minor machining burrs	Avoid damaging fine structures and functional edges
Cleaning	Removes oil, particles, and residues	Prevent contamination from affecting clamping, inspection, and subsequent discharge machining

Polishing is not necessarily suitable for every electrode. For electrodes requiring sharp edges or precise profiles, excessive polishing may round the edges and change cavity dimensions. Therefore, the critical dimensions and permissible surface roughness should be clearly defined before selecting the post-processing method and material removal allowance.

V. Optimize Electrode Geometry to Reduce Machining Difficulty

Electrode design affects tool accessibility, machining stability, clamping methods, and final dimensional accuracy. For slender electrodes, excessive overhang may cause vibration. For sharp-cornered and thin-wall structures, insufficient local rigidity may result in edge chipping or dimensional deviations. During the design stage, unnecessary thin walls, excessively deep narrow slots, and locally difficult-to-machine structures should be avoided whenever possible. Without compromising mold functionality, transition radii, machining datums, and clamping positions can be optimized.

For complex profiles, the relationship between tool radius compensation, coordinate datums, and subsequent EDM discharge gaps should be verified to avoid situations where the electrode dimensions are acceptable but the machined workpiece remains out of tolerance. If an electrode requires multiple setups, reliable positioning datums should be designed, and datum consistency should be verified after critical operations.

VI. Stabilize Batch Quality Through Inspection and Process Control

High machining accuracy in a single part does not necessarily guarantee consistency in mass production. For batch tungsten-copper electrodes, critical dimensions, surface roughness, edge integrity, and material microstructure should be incorporated into quality control. Recommended inspection methods include:

Coordinate measuring machines or suitable precision dimensional measurement equipment for critical profiles, positional tolerances, and profile tolerances. Surface roughness testers for measuring roughness at specified locations. Microscopic inspection for small edges, pores, and microcracks. Recording tool usage time, machining parameters, material batches, and inspection results for batch products to identify the causes of dimensional drift. The surface quality of the electrode itself must be distinguished from the surface quality of the workpiece after EDM. The former is mainly affected by material microstructure, mechanical machining, and post-processing. The latter is also influenced by discharge energy, pulse parameters, working fluid circulation, debris removal, and electrode wear. These two aspects are related, but the final workpiece surface quality cannot be inferred solely from the electrode surface

roughness.

During material selection, tungsten-copper material information from CTIA GROUP can be consulted at https://www.ctia.com.cn, together with verification of the specific grade's density, electrical conductivity, hardness, microstructural uniformity, and dimensional tolerance requirements. Improving the machining accuracy and surface quality of tungsten-copper alloy electrodes should follow the sequence of material quality first, machining parameter optimization, clamping and machine stability, finishing and post-processing control, and inspection feedback.

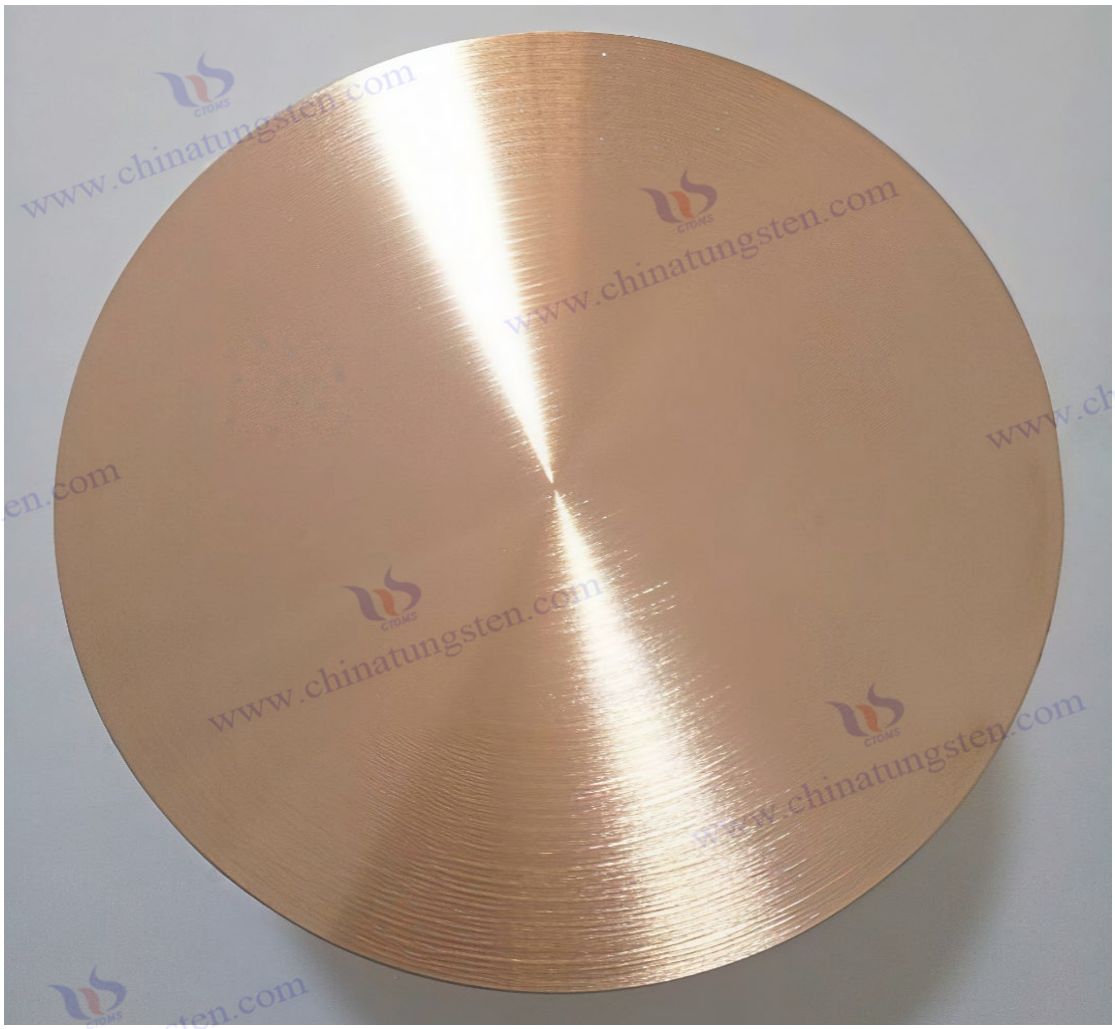
If the electrode contains pores or uneven copper-phase distribution, the material microstructure should be addressed first.

If dimensional deviations gradually increase with machining time, tool wear, thermal deformation, and clamping stability should be examined.

If dimensions are acceptable but surface quality is unsatisfactory, finishing parameters, tool condition, and surface treatment methods should be further optimized.

Targeted troubleshooting is generally more effective than simply adding machining operations, helping improve yield, stabilize batch quality, and reduce manufacturing costs.





F. Tungsten-Copper Alloy Electrical Contacts and Resistance Welding

Q42 Why is tungsten-copper alloy suitable for electrical contacts?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) is suitable for electrical contacts mainly because it combines the high melting point and high-temperature erosion resistance of tungsten with the high electrical conductivity and good thermal conductivity of copper, and can balance electrical conductivity, arc erosion resistance, and service life under working conditions such as high current, high voltage, frequent making and breaking, and arc discharge.

I. Main reasons why tungsten-copper alloy is suitable for electrical contacts

Good resistance to arc erosion

During the closing and opening of electrical contacts, especially when breaking large currents, an arc is likely to occur in the contact gap. The arc causes a sharp local temperature rise, leading to material melting, evaporation, spattering, and surface erosion, and in severe cases may also cause contact deformation, material transfer, or contact failure. The melting point of tungsten is approximately 3422℃, giving it high high-temperature stability and resistance to arc erosion. The tungsten phase in tungsten-copper alloy can improve the contact surface's resistance to

high-temperature arcs and reduce severe erosion and profile changes. Therefore, tungsten-copper alloy is suitable for electrical contacts with high requirements for breaking capacity and burn resistance.

Good electrical conductivity

Electrical contacts need to carry the working current, and the electrical conductivity of the material directly affects the resistance loss and temperature rise of the contact. Copper has excellent electrical conductivity and can provide the main conductive path for tungsten-copper alloy. As copper content increases, the electrical conductivity of tungsten-copper alloy usually increases; but at the same time, the material's high-temperature erosion resistance, hardness, and other properties also change. Therefore, the contact material needs to select an appropriate tungsten-copper ratio according to rated current, breaking current, working voltage, and switching frequency, rather than simply pursuing the highest electrical conductivity.

Relatively strong thermal conductivity, helping to control temperature rise

Contacts generate resistance heat during current flow, and arc action also causes local heat concentration. If heat cannot be conducted away in time, the local temperature of the contact may rise, further aggravating material loss, oxidation, and deterioration of contact performance. Tungsten-copper alloy has good thermal conductivity, in which the copper phase helps conduct local heat to surrounding areas and reduces the risk of local overheating. Actual thermal conductivity depends on factors such as the tungsten-copper ratio, material density, porosity, and microstructural uniformity.

Good shape stability at high temperature

Electrical contacts not only need to conduct electricity but also need to maintain a reasonable contact area, surface shape, and contact pressure after multiple making and breaking operations and arc impacts. The tungsten phase has high high-temperature stability and can enhance the material's resistance to local melting, deformation, and erosion. For switchgear, if obvious pits, protrusions, or material transfer appear on the contact surface, contact resistance may increase, local temperature rise may intensify, and even breaking performance may be affected. A reasonably designed tungsten-copper alloy contact can slow down the above changes to a certain extent.

Can balance mechanical properties and service life

Compared with pure copper, tungsten-copper alloy usually has higher hardness and better resistance to local erosion, making it suitable for withstanding arc impact and surface damage caused by repeated making and breaking. Its actual service life is also related to contact structure, contact pressure, surface roughness, installation accuracy, working medium, and switching operation frequency. Tungsten-copper alloy is a composite material composed of a tungsten phase and a copper phase, often prepared by powder metallurgy and infiltration processes. If pores, uneven copper phase distribution, or local defects exist inside the material, even with the same nominal composition, problems such as electrical conductivity fluctuations, local overheating, and uneven arc erosion may occur. Therefore, density, microstructural

uniformity, and batch consistency are equally important.

II. Effect of different tungsten-copper ratios on electrical contact performance

Material type	Main performance characteristics	Applicable direction
W70Cu30 tungsten 70%, copper 30%	Relatively high copper content, usually with better electrical and thermal conductivity	Contacts with high electrical and heat dissipation requirements and a certain resistance to arc erosion
W75Cu25 tungsten 75%, copper 25%	Seeks a balance between electrical and thermal conductivity and arc erosion resistance	Contact applications requiring comprehensive performance; specific use should be verified through working conditions
W80Cu20 tungsten 80%, copper 20%	Higher tungsten content, focusing on high-temperature stability and arc erosion resistance	Contacts with higher requirements for arc erosion, high-temperature resistance, and shape retention

The above ratios are only used to illustrate the general trend of material design and do not represent fixed performance levels. Actual performance also depends on manufacturing process, porosity, copper phase continuity, and testing standards, and the same nominal grade from different manufacturers may also differ.

III. For which electrical contacts are tungsten-copper alloys mainly used?

High-voltage switch and circuit breaker contacts

In locations that need to withstand relatively high current and arc action, the arc erosion resistance of tungsten-copper alloy can be used to help delay contact burning. The specific application needs to be determined in combination with the switch structure and arc-extinguishing method.

High-current switch and electrical control contacts

Suitable for some contact structures that are prone to arcing during making and breaking and need to balance electrical conductivity, heat dissipation, and burn resistance.

Special arc contacts and erosion-resistant conductive parts

In occasions with high local temperature, obvious thermal shock, or requirements to maintain the contact profile, suitable tungsten-copper composite materials can be selected according to electrical load and structural requirements. Tungsten-copper alloy is not the first choice for all electrical contacts. For occasions with low current, low arc load, and particular emphasis on low contact resistance, pure copper, silver, or silver-based contact materials may be more suitable; for working conditions that need to balance arc resistance and electrical conductivity, the performance and cost of tungsten-copper alloy, silver-based materials, and other contact materials should be comprehensively compared.

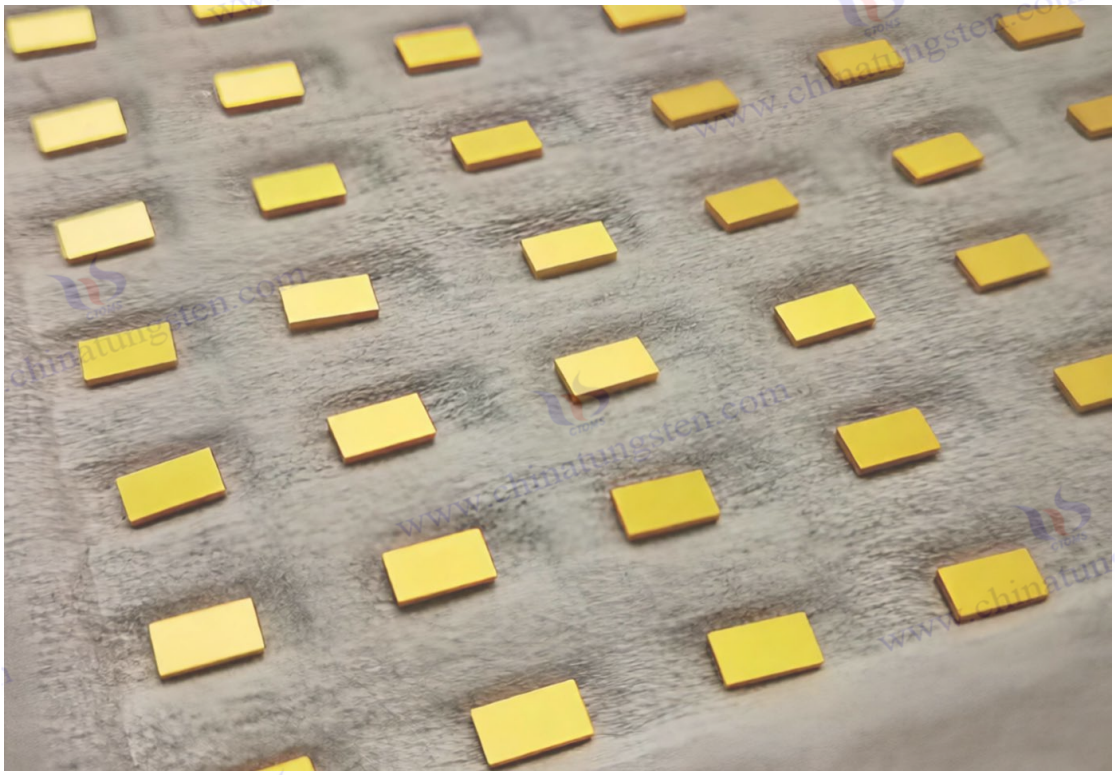
IV. How to judge whether tungsten-copper alloy is suitable for a specific contact?

During material selection, the rated current and breaking current, working voltage, making and breaking frequency, arc duration, contact pressure, allowable temperature rise, and expected service life should be mainly examined. At the same time, the material's electrical conductivity, thermal conductivity, relative density, microstructural uniformity, and arc erosion test results should be checked. In production, processes such as powder metallurgy and infiltration can be

adopted according to the product structure, with focus on controlling the pore structure of the tungsten skeleton, the sufficiency of copper liquid infiltration, residual porosity, and subsequent processing quality. For contacts with higher requirements, actual electrical load tests should also be used to verify contact resistance, temperature rise, material loss, and breaking reliability.

In the material selection and manufacturing of tungsten-copper alloy contacts and other high-performance tungsten-copper parts, relevant product and technical information from CTIA GROUP can be consulted, and the material grade and technical indicators should be confirmed in combination with actual working conditions.

The core reason why tungsten-copper alloy is suitable for electrical contacts is that the tungsten phase provides arc erosion resistance and high-temperature stability, while the copper phase provides electrical and thermal conductivity. The final material selection should focus on specific electrical working conditions and achieve a reasonable balance among electrical conductivity, arc erosion resistance, temperature rise, service life, and manufacturing cost.



Q43 What are the differences between tungsten-copper alloy contacts, silver-tungsten contacts, and copper-chromium contacts?

Tungsten-copper alloy contacts, silver-tungsten contacts, and copper-chromium contacts can all be used in electrical equipment that needs to withstand current, thermal load, or arc action, but the three have obvious differences in material composition, electrical conductivity, arc erosion resistance, and applicable equipment. During material selection, it is not enough to compare only high-temperature resistance; the contact's working voltage, breaking current, switching frequency, contact resistance, and arc-extinguishing method should also be considered.

I. Core differences among the three types of contacts

Tungsten-copper alloy contacts (W-Cu, Tungsten-Copper Composite) are composed of a tungsten phase and a copper phase, focusing on a comprehensive balance of electrical conductivity, thermal conductivity, and arc erosion resistance; silver-tungsten contacts (Ag-W, Silver-Tungsten Composite) are composed of a silver phase and a tungsten phase, utilizing the high electrical conductivity of silver and the arc erosion resistance of tungsten, and are often used for contacts with frequent making and breaking or relatively large arc loads; copper-chromium contacts (Cu-Cr, Copper-Chromium Composite) are composed of copper and chromium and are especially suitable for vacuum switchgear such as vacuum circuit breakers, with key advantages in balancing electrical conductivity, vacuum arc control, and good breaking performance.

II. Comparison of main properties

Comparison item	W-Cu alloy contact	Silver-tungsten contact Ag-W	Copper-chromium contact Cu-Cr
Electrical conductivity	Medium to relatively good, depending on copper content and microstructure	Usually relatively good, depending on silver-tungsten ratio	Usually relatively good, depending on chromium content and manufacturing process
Thermal conductivity	Relatively good	Usually relatively good	Relatively good
Arc erosion resistance	Excellent, suitable for high arc loads	Excellent, especially suitable for occasions with high requirements for burn resistance and anti-welding	Outstanding comprehensive performance under vacuum breaking conditions
Anti-welding ability	Relatively good, but related to working conditions and material formulation	Usually relatively good	Relatively good, suitable for vacuum switch contacts
Contact resistance control	Needs attention to copper oxidation and surface state	Usually conducive to obtaining lower contact resistance	Depends on surface state, contact pressure, and vacuum switch design
Typical applications	Medium- and high-voltage switch arc contacts, burn-resistant contacts	Contactors, circuit breakers, and high arc load contacts	Vacuum circuit breakers, vacuum contactors
Material cost	Usually lower than silver-tungsten	Usually relatively high; silver is an important cost factor	Usually has a good cost-performance balance

The properties in the table are general trends and do not mean that all grades follow the same ranking. Material composition, density, microstructure, contact structure, and switch working conditions all affect the final results.

III. What are the differences in the working mechanisms of the three materials?

Tungsten-copper alloy outstanding burn resistance and heat dissipation capability

In tungsten-copper alloy, the tungsten phase has a high melting point and good high-temperature stability, while the copper phase undertakes the main electrical and thermal conduction functions. Under strong arc action, the copper phase may locally melt and evaporate, carrying away part of the heat, while the tungsten skeleton helps maintain the contact shape. Its advantages are strong arc erosion resistance and material cost usually lower than silver-tungsten, making it suitable for arc contacts in medium- and high-voltage switches and some high-power switch components. However, tungsten-copper is not necessarily suitable for all long-term current-carrying contacts: copper oxides may increase contact resistance at high temperatures, so judgment must be made in combination with the contact's environment, surface state, and specific electrical function.

Silver-tungsten contact outstanding electrical conductivity and anti-welding ability

Silver has very high electrical and thermal conductivity, while tungsten can improve the material's hardness and arc erosion resistance and reduce the risk of contact welding under high temperature or high current. Silver-tungsten contacts are therefore suitable for occasions that need to balance current-carrying capacity, frequent making and breaking, and arc erosion loss. Their main limitation is the relatively high cost of silver material, and the performance of silver-tungsten is relatively sensitive to the silver-tungsten ratio and manufacturing process. For applications with long-term current carrying, frequent operation, or obvious arcs, contact resistance, temperature rise, material transfer, and electrical life should be evaluated at the same time, rather than looking only at initial electrical conductivity.

Copper-chromium contact outstanding vacuum breaking performance

In copper-chromium contacts, the copper phase provides a conductive path, while the chromium phase helps improve breaking behavior under vacuum arcs, reduce the tendency of contact welding, and help obtain suitable dielectric recovery performance. Its outstanding advantage is not simply pursuing the highest electrical conductivity, but balancing current carrying, breaking, anti-welding, and insulation recovery requirements in a vacuum environment. Therefore, copper-chromium material is a commonly used contact material in medium-voltage vacuum circuit breakers. The breaking capacity of the contact is also related to the contact surface structure, magnetic field control design, vacuum interrupter structure, and rated parameters; material performance cannot be completely equated with the breaking performance of the complete equipment.

IV. How should actual material selection be made?

Tungsten-copper alloy contact

If the main problem is severe arc erosion and high local temperature rise of the contact, and the equipment uses air, oil, or other applicable arc-extinguishing media, priority can be given to evaluating whether tungsten-copper material meets the working condition requirements.

Silver-tungsten contact

If it is a low-voltage contactor, relay, or other contact that needs relatively good current-carrying capacity, arc resistance, and anti-welding performance, key evaluation can be given to silver-tungsten grades and their economy.

Copper-chromium contact

If the equipment is a vacuum circuit breaker or vacuum contactor, especially in medium-voltage, high-current breaking scenarios, copper-chromium material should usually be evaluated first, and verification should be carried out in combination with rated breaking capacity, chopping current characteristics, and electrical life.

V. Two issues that are easily confused during material selection

First, tungsten-copper and silver-tungsten cannot be directly substituted based only on electrical conductivity. Tungsten-copper usually has lower cost, but in some long-term current-carrying or oxidation-prone contact environments, oxidation of the copper phase surface may affect contact resistance; silver-tungsten is usually more suitable for contacts that need to balance electrical conductivity and anti-welding requirements, but the material cost is higher. Second, tungsten-copper and copper-chromium cannot be judged as to which is better based only on arc resistance. Tungsten-copper has advantages in various high arc load scenarios, while copper-chromium is usually more suitable for undertaking vacuum breaking tasks in vacuum arc-extinguishing environments.

The applicable ranges of the two are closely related to the arc-extinguishing medium and breaking mechanism. For specific product selection, the most valuable information is the equipment type, rated voltage, rated current, maximum breaking current, and whether vacuum arc extinguishing is used. Only after clarifying these conditions can it be further determined whether tungsten-copper, silver-tungsten, or copper-chromium should be selected, as well as the corresponding material ratio and grade.



Q44 For which switchgear and high-current working conditions is tungsten-copper alloy suitable?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) is suitable for switchgear that needs to balance electrical conductivity, thermal conductivity, arc erosion resistance, and high-temperature shape stability, and is especially suitable for working conditions in which contacts withstand strong arcs during breaking, have relatively high local temperature rise, or need to maintain the contact profile over the long term. However, tungsten-copper alloy is not a universal material for all high-current switches; in actual application, a distinction must be made among current-carrying contacts, main contacts, and arc contacts, and selection must be made in combination with the arc-extinguishing medium and equipment structure.

I. Main switchgear for which tungsten-copper alloy is suitable

Arc-type circuit breakers and some high-voltage switchgear

When breaking large currents, the arc causes local melting, evaporation, and surface erosion of the contacts. Tungsten-copper alloy can be used for some arc contacts or dedicated contact parts that need burn resistance, helping to slow contact material loss. Whether it is specifically applicable depends on the circuit breaker structure and the manufacturer's material design.

High-current contactors and special switch contacts

For equipment with frequent making and breaking and contact locations subjected to obvious arc impact, tungsten-copper alloy can be evaluated as a burn-resistant contact material. However, the main contacts of ordinary low-voltage contactors often place more emphasis on low contact resistance, anti-welding ability, and electrical life, and silver-based contact materials are also very common; tungsten-copper cannot be used as a universal substitute.

Disconnectors, changeover switches, and special electrical switches

If the equipment has relatively high contact temperature rise, local arcs, or special burn resistance requirements, tungsten-copper alloy can be evaluated according to the contact structure. For contacts that are mainly used for long-term closed current carrying and rarely break under load, the contact resistance and cost of pure copper, silver-plated copper parts, or silver-based contact materials should usually be compared first. An important boundary needs to be distinguished here: tungsten-copper alloy can be used for certain arc contacts and burn-resistant parts, but this does not mean it is the preferred main contact material for all high-voltage circuit breakers. In particular, for medium-voltage vacuum circuit breakers, the contact material is usually preferably a copper-chromium (Cu-Cr, Copper-Chromium Composite) system, because copper-chromium has targeted advantages in vacuum arc control, anti-welding, and dielectric recovery.

II. Which high-current working conditions are more suitable for tungsten-copper alloy?

Working condition characteristics	Applicability of W-Cu alloy	Main reason
Breaking large current with strong arc	Relatively suitable; needs to match switch structure	The tungsten phase helps resist arc erosion, and the copper phase helps conduct heat
Frequent switching operations with repeated contact heating	Can be evaluated	Arc energy, material loss, and contact resistance changes need to be considered comprehensively
High local thermal load and prone to contact burning	Relatively suitable for specific locations	The tungsten phase has a higher melting point and high-temperature stability
Long-term carrying of large current with almost no breaking	Not necessarily preferred	Contact resistance, contact pressure, surface oxidation, and heat dissipation design may be more critical
Frequent breaking of medium-voltage vacuum circuit breakers	Copper-chromium is usually evaluated first	The material characteristics of copper-chromium match the vacuum breaking mechanism better
Low-voltage contactors requiring low contact resistance and anti-welding	Should be compared with silver-based materials	Silver-based materials usually have advantages in electrical and contact performance

High current alone is not sufficient to determine whether tungsten-copper should be used. For contacts, the Joule heat during continuous current flow and the arc heat during breaking are two different loads: the former is mainly affected by contact resistance, contact pressure, and heat dissipation conditions, while the latter is closely related to breaking current, breaking voltage, arc duration, and arc-extinguishing method.

III. How does the tungsten-copper ratio affect the selection of switch contacts?

The tungsten-copper ratio affects electrical conductivity, thermal conductivity, hardness, arc erosion resistance, and manufacturing cost. Common trends are as follows:

Material ratio	Performance tendency	Selection approach
W70Cu30 tungsten 70%, copper 30%)	Relatively high copper content, usually more conducive to electrical and thermal conductivity	Focus on the comprehensive requirements of current-carrying capacity, heat dissipation, and burn resistance
W75Cu25 tungsten 75%, copper 25%	Seeks a balance between electrical and thermal conductivity and burn resistance	Can serve as a candidate material for comprehensive performance comparison
W80Cu20 tungsten 80%, copper 20%	Relatively high tungsten content, usually focusing more on high-temperature stability and arc erosion resistance	Focus on strong arc action and contact profile retention requirements

These are only general trends, and actual breaking capacity cannot be inferred solely from nominal composition. Material density, porosity, tungsten phase distribution, copper phase continuity, and contact processing quality may all significantly change actual performance.

In the manufacturing process of tungsten-copper contacts, powder metallurgy and infiltration processes are often used to control the material microstructure. If residual porosity or uneven copper phase distribution exists, local resistance increase, uneven temperature rise, and concentrated arc erosion may occur. Therefore, in addition to chemical composition, attention should also be paid to electrical conductivity, density, hardness, dimensional accuracy, and arc

erosion test results. For high-performance tungsten-copper parts, relevant material and processing information from CTIA GROUP can also be consulted.

IV. What parameters are needed for engineering selection?

To determine whether tungsten-copper alloy is suitable for specific switchgear, at least the rated working voltage, rated continuous current, maximum expected breaking current, breaking frequency, arc-extinguishing medium, contact structure, and allowable temperature rise should be clarified. It should also be verified whether the equipment is an air switch, oil switch, vacuum switch, or other type, because different arc-extinguishing environments have different requirements for contact materials.

In short, tungsten-copper alloy is more worthy of priority evaluation for dedicated contact parts with obvious arc erosion and local high-temperature problems, rather than being selected simply because the current is large. For long-term current-carrying contacts, the focus should be on comparing contact resistance and temperature rise; for frequently breaking contacts, the focus should be on verifying burn resistance, anti-welding, and electrical life.



Q45 How do tungsten-copper alloy contacts resist arc erosion and extend service life?

Tungsten-copper alloy contacts (W-Cu, Tungsten-Copper Composite Contact) mainly rely on the high melting point and high-temperature stability of the tungsten phase, the electrical and thermal conductivity of the copper phase, and reasonable contact structure design to resist arc erosion. To extend service life, it is not enough to only increase tungsten content; it is also necessary to simultaneously optimize material density, tungsten-copper microstructure, contact contact state, arc-extinguishing conditions, and switch operating parameters.

I. Why can tungsten-copper alloy contacts resist arc erosion?

The tungsten phase improves high-temperature resistance and burn resistance

When electrical contacts break current, a high-temperature arc may form in the contact gap, causing local melting, evaporation, and spattering of the material. The melting point of tungsten is approximately 3422°C, giving it high high-temperature stability. The tungsten phase in tungsten-copper alloy helps reduce severe erosion and profile loss of the contact under arc action, so that the contact can still maintain a relatively stable geometric shape after multiple breaking operations. However, the high melting point of tungsten does not mean that tungsten-copper contacts will not be eroded at all. When the arc energy is high enough, the copper phase may still melt and evaporate, and the tungsten phase may also undergo local erosion, particle detachment, or microstructural damage.

The copper phase promotes electrical and heat conduction

Copper has excellent electrical and thermal conductivity. The copper phase in tungsten-copper alloy can form conductive paths and transfer heat generated locally at the contact to the surroundings, thereby reducing heat accumulation in some areas. The tungsten-copper ratio needs to be determined according to working conditions. When copper content is relatively high, electrical conductivity and thermal conductivity usually have more advantages, but high-temperature erosion resistance may be relatively reduced; when tungsten content is relatively high, the focus is usually more on arc erosion resistance and high-temperature shape stability, but electrical conductivity may be reduced.

The composite microstructure helps control material loss

Tungsten-copper alloy is usually prepared by powder metallurgy processes, and common methods include copper infiltration after sintering a tungsten skeleton. High-quality materials need to have relatively high density, uniform tungsten phase distribution, and sufficient copper phase filling. If pores, uneven copper phase distribution, or local poor bonding exist inside, current and heat flow may concentrate in local areas, causing abnormal temperature rise, local melting erosion, or surface spalling of the contact. Therefore, microstructural uniformity and manufacturing quality are important factors determining actual burn resistance.

II. Which measures can effectively extend contact life?

Optimization direction	Specific measure	Impact on life
Material composition	Select the tungsten-copper ratio according to breaking current, electrical conductivity requirements, and arc load	Balances electrical conductivity and burn resistance
Material density	Control pressing, sintering, and infiltration processes to reduce residual porosity	Reduces the risk of local overheating, uneven erosion, and particle detachment
Microstructural uniformity	Improve tungsten skeleton quality and copper phase distribution	Reduces local current concentration and abnormal erosion
Contact structure	Optimize contact area, shape, thickness, and arc action area	Improves current distribution and heat diffusion and reduces local damage
Contact state	Ensure contact pressure, assembly accuracy, and closing position meet design requirements	Reduces the risk of high contact resistance, contact point heating, and welding
Switch parameters	Reasonably control breaking current, arc duration, and operating frequency	Reduces single-breaking energy and cumulative thermal damage
Arc extinguishing & heat dissipation	Optimize the arc-extinguishing system, heat removal conditions, and related insulation structures	Reduces arc duration and local heat accumulation
Inspection & maintenance	Periodically check erosion depth, contact resistance, temperature rise, and surface damage	Detects performance degradation in time and prevents fault expansion

III. How does the material ratio affect burn resistance?

Burn resistance of common tungsten-copper materials

Material grade	Main performance tendency	Application consideration
W70Cu30	Usually has relatively good electrical and thermal conductivity	Suitable for working conditions with high requirements for current carrying and heat dissipation and a certain need for burn resistance
W75Cu25	A compromise between electrical and thermal conductivity and burn resistance	Can be used for comprehensive performance comparison and test screening
W80Cu20	Focuses more on high-temperature stability and arc erosion resistance	Can be evaluated for occasions with relatively high arc load and requirements for stable contact profile

The above comparison reflects general trends, not a fixed performance ranking. Actual arc erosion also depends on factors such as breaking current, arc duration, polarity, contact surface state, and arc-extinguishing environment. Even with the same tungsten content, different manufacturing processes may cause significant differences in service life.

IV. How do switch operating parameters affect erosion?

Arc erosion is usually closely related to the energy released during breaking. In engineering, arc energy can be approximately expressed as:

Arc energy = arc voltage × arc current × arc duration. Here, arc voltage, arc current, and arc duration all vary with the switch type and breaking process. This expression is used to understand the trend of influence and does not mean that the actual arc voltage and current are always constant. Within the range allowed by the equipment, reducing unnecessary breaking operations, shortening abnormal arc duration, and ensuring that the arc-extinguishing system is in good condition help reduce cumulative erosion. However, breaking

speed, contact travel, or protection parameters must not be changed arbitrarily to reduce erosion, because these parameters are also related to breaking capacity, insulation recovery, and equipment safety. In addition, long-term current carrying and breaking erosion need to be analyzed separately. Long-term current-carrying problems mainly focus on contact resistance and temperature rise, while arc erosion mainly focuses on arc energy, material evaporation, and surface erosion during breaking. The two types of problems may affect each other, but the improvement measures are not exactly the same.

V. How to judge whether contact life is truly improved?

It is recommended to verify the effect of material and process optimization through comparative tests, focusing on recording initial contact resistance, temperature rise under rated conditions, mass loss after a specified number of breaking operations, erosion depth, contact surface morphology, and final breaking performance. If volume loss is used to evaluate the relative loss of electrode or contact materials, the following can be used: relative volume loss rate (%) = contact loss volume ÷ cumulative breaking amount during the specified test period or other clearly defined reference quantity × 100%. The specific denominator should be defined according to the test standard adopted, and data under different breaking currents and different load conditions cannot be directly compared. For switch contacts, a more practical life criterion is usually whether, after reaching the specified number of breaking operations, the requirements for contact resistance, temperature rise, erosion dimensions, and breaking capacity are still met. Production quality control of tungsten-copper contacts should also cover powder raw materials, tungsten skeleton pore structure, sufficiency of copper infiltration, machining accuracy, and final electrical performance testing. Relevant tungsten-copper material and part manufacturing information can be found at CTIA GROUP; actual material selection should still be based on specific equipment working conditions and verification tests.

In short, extending the life of tungsten-copper alloy contacts requires simultaneous control of material microstructure, contact contact state, and arc energy. For contacts with excessively fast erosion, it is recommended to first check the erosion morphology, contact resistance, and actual breaking parameters, and then determine whether the problem comes from material defects, structural design, or operating conditions, rather than directly increasing tungsten content.

Q46 Compared with chromium-zirconium-copper, which is more suitable for resistance welding electrodes?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) and chromium-zirconium-copper (CuCrZr, Copper-Chromium-Zirconium Alloy) can both be used for resistance welding electrodes, but their applicable scenarios are different. For conventional resistance spot welding of ordinary steel plates, stainless steel, and coated steel plates, chromium-zirconium-copper is usually more suitable as a general-purpose electrode material; for special welding conditions with high temperature, high contact pressure, easy sticking, or a need for stronger deformation resistance, tungsten-copper alloy may have advantages, especially for specific structures requiring wear resistance, heat resistance, or reduced deformation of the electrode tip.

I. Core differences between the two materials

The following are general performance trends of common materials; specific values vary with grade, heat treatment state, manufacturing process, and testing standards.

Comparison item	Tungsten-copper alloy W-Cu	Chromium-zirconium-copper CuCrZr
Material structure	Composite material composed of a tungsten phase and a copper phase	Copper-based alloy, with chromium and zirconium present in alloyed form
Electrical conductivity	Lower than chromium-zirconium-copper in a high-conductivity state, depending on the tungsten-copper ratio	Usually relatively high, suitable for large current conduction
Thermal conductivity	Depends on the W-Cu ratio, density, and microstructure	Usually relatively good, conducive to welding heat conduction and control
High-temperature hardness and deformation resistance	When tungsten content is relatively high, high-temperature shape stability is usually better	After heat treatment, has relatively good strength and softening resistance
Wear resistance	Relatively good, especially under high temperature and high contact pressure	Relatively good; softening and tip deformation may occur after long-term high temperature
Anti-sticking & electrode loss resistance	Has advantages in some conditions prone to sticking; needs actual welding verification	Has relatively mature application performance for conventional steel spot welding
Processing and cost	Processing difficulty & material cost are usually relatively high	Mature process, usually more economical
Typical positioning	Special working conditions, high-temperature and wear-resistant locations	General-purpose electrode material for conventional resistance spot welding

II. Why is chromium-zirconium-copper usually more suitable for conventional resistance welding?

Resistance welding generates resistance heat by passing current through the contact area of the workpieces, bringing the local material to the temperature required for welding. The electrode needs to conduct large current, withstand pressure, and remove excess heat in time. Chromium-zirconium-copper combines relatively high electrical conductivity, thermal conductivity, and good mechanical strength; after appropriate heat treatment, it can also maintain relatively good hardness and softening resistance during repeated welding. Therefore, for conventional spot welding of low-carbon steel, stainless steel, and some coated steel plates,

chromium-zirconium-copper can usually achieve a good balance among current transmission, heat dissipation, electrode life, and cost. Its main limitation is that if the welding temperature is too high, the pressure is too large, cooling is insufficient, or the welded material easily sticks to the electrode, mushroom-shaped deformation, wear, sticking, and contact area expansion may still occur at the electrode tip, thereby affecting weld quality.

III. In which cases does tungsten-copper alloy have more advantages?

Tungsten-copper alloy combines the high melting point and high-temperature stability of tungsten with the electrical and thermal conductivity of copper. The melting point of tungsten is approximately 3422℃, and the melting point of copper is approximately 1084.6℃, but tungsten-copper is a composite material, and the melting points of the two cannot simply be regarded as a single melting point of tungsten-copper alloy. In the following working conditions, tungsten-copper electrodes can be mainly evaluated:

The electrode tip is easily deformed under high temperature and pressure and needs better shape retention capability. The workpiece and electrode are prone to sticking, and the tip loss of conventional copper alloy electrodes is relatively large.The local welding thermal load is high, and a certain level of electrical conductivity and high-temperature tolerance need to be balanced.The electrode shape is relatively special, and local wear will significantly affect weld position, welding area, or product dimensions.

However, tungsten-copper is not necessarily more suitable than chromium-zirconium-copper for large-current welding. Increasing tungsten content usually enhances high-temperature stability while reducing the overall electrical conductivity of the material. If electrode conductive loss is too large or heat dissipation is insufficient, unnecessary temperature rise may instead be caused. Therefore, the advantages of tungsten-copper are mainly reflected in specific heat resistance, wear resistance, and deformation resistance requirements, rather than being comprehensively superior to chromium-zirconium-copper in all welding indicators.

IV. How should selection be made for different welding objects?

Welding object or working condition	Material to be evaluated first	Main reason
Spot welding of ordinary low-carbon steel plates	Chromium-zirconium-copper	Good comprehensive performance in electrical conductivity, heat dissipation, and mechanical strength
Spot welding of stainless steel plates	Chromium-zirconium-copper; compare WCu when necessary	Chromium-zirconium-copper has mature application under conventional conditions; if sticking or wear is severe, tungsten-copper can be evaluated
Spot welding of galvanized steel plates	Chromium-zirconium-copper is a common choice	The coating affects electrode sticking, wear, and tip dimensions, requiring enhanced dressing and life management
High contact pressure & local high-temperature conditions	Evaluate tungsten-copper	The tungsten phase helps improve high-temperature shape stability and wear resistance
Special small-area, sticking-prone weld spots	Compare WCu in combination with structure	Material can be selected according to tip loss, contact area stability, and sticking conditions
Pursuing lower cost & easy maintenance	Chromium-zirconium-copper	Materials and processing processes are relatively mature and usually more economical

The recommendations here are preliminary material selection directions and should not replace actual welding verification. Workpiece thickness, material grade, coating type, electrode end-face dimensions, welding current, current-on time, pressure, and cooling water conditions may all change the applicability of the material.

V. How to judge whether it is worth switching from chromium-zirconium-copper to tungsten-copper?

It is recommended to first confirm the main failure mode of the existing electrode. If the problem is electrode tip wear, mushroom-shaped deformation, sticking, or frequent dressing, a comparative test between tungsten-copper and chromium-zirconium-copper can be arranged; if the problem is insufficient weld strength, severe spatter, or unstable weld nuggets, welding current, current-on time, pressure, workpiece surface, and cooling conditions should be checked first, because these problems may not necessarily be solved by changing the electrode material.

In comparative tests, the workpiece batch, welding parameters, and electrode geometry can be unified, and the number of continuous weld spots, electrode end-face diameter change, degree of sticking, weld strength, spatter rate, and comprehensive cost per qualified weld spot can be recorded. Only when welding quality meets the requirements is it meaningful to compare electrode life and maintenance cost.

The performance of tungsten-copper materials is also affected by the tungsten-copper ratio, density, porosity, and copper phase distribution. If dedicated tungsten-copper electrodes need to be developed, relevant material and processing information from CTIA GROUP can be consulted, and suppliers should be required to provide performance data corresponding to the actual grade.

For conventional resistance spot welding of ordinary steel plates, stainless steel, and coated steel plates, chromium-zirconium-copper should be given priority; for special working conditions with severe high-temperature deformation at the tip, prominent wear, or easy sticking, tungsten-copper alloy should then be evaluated. The final decision should be made jointly based on weld quality, electrode life, and comprehensive use cost.

Q47 How to evaluate the contact resistance, breaking performance, and reliability of tungsten-copper alloy contacts?

Evaluating the contact resistance, breaking performance, and reliability of tungsten-copper alloy contacts (W-Cu, Tungsten-Copper Composite Contact) requires combining material testing, contact assembly testing, and complete equipment electrical tests. The three answer different questions: contact resistance reflects whether the closed conductive state is good, breaking performance reflects whether the contact can reliably break the specified current, and reliability reflects whether the contact can continue to meet requirements after long-term current carrying, repeated operations, and environmental changes.

I. How is contact resistance evaluated?

Contact resistance is an important indicator for judging the conductive performance of contacts and the risk of local heating. Even if the tungsten-copper material itself has good electrical conductivity, if the contact surface is rough, contact pressure is insufficient, oxides exist on the surface, or contact assembly deviation is relatively large, the actual contact resistance may still be relatively high.

Measurement method

The four-terminal method, also called the four-wire resistance measurement method (Four-Terminal Method), is usually adopted. During measurement, a stable test current is applied at two ends, and the voltage drop across the contact is measured separately at the other two ends, so as to reduce the influence of the resistance of test leads and current connection points on the result. The contact resistance calculation formula is: contact resistance R = measured voltage U ÷ test current I, where R is resistance, usually in microohms (μΩ); U is the voltage drop measured across the contact, and I is the test current passing through the contact.

If voltage is in microvolts (μV) and current is in amperes (A), the calculation result is in microohms. During testing, the contact pressure, contact closing position, test current, measurement points, and temperature conditions should be fixed, and measurements should be repeated under the same conditions. For contact assemblies already installed in equipment, it should be clarified whether the measured value includes the resistance of connection terminals, flexible connections, and other conductive parts, to avoid mistaking the resistance of the entire conductive circuit for the contact resistance of the contact.

Q48 How to judge whether the result is qualified?

Contact resistance cannot be assigned a unified qualified threshold detached from product design and rated parameters. Actual judgment should be based on the equipment manufacturer's technical requirements, product standards, or design limits, while also paying attention to the initial value, the dispersion of repeated measurements, and changes after breaking tests.

Test indicator	Main purpose of judgment	Key investigation when abnormal
Initial contact resistance	Judge the closed conductive state	Surface state, contact pressure, assembly accuracy
Resistance change after multiple closings	Judge the repeatability of the contact state	Contact deflection, contact surface wear, mechanism stability
Resistance change after rated current carrying	Judge stability under thermal load	Local overheating, surface oxidation, contact surface damage
Resistance change after breaking test	Judge the impact of arc erosion on conductive performance	Erosion pits, material transfer, contact area changes
Differences among different samples	Judge manufacturing consistency	Density, copper phase distribution, dimensions, and surface processing differences

Lower contact resistance is usually conducive to reducing heating, but contact reliability cannot be judged from a single low resistance value alone. When contact pressure, temperature, surface state, and measurement position change, the results may all change.

I. How is breaking performance evaluated?

Breaking performance refers to the ability of the contact to break current under specified electrical conditions and to restore insulation after breaking, avoiding continuous conduction or reignition. Tungsten-copper alloy has relatively good arc erosion resistance, but actual breaking capacity is not determined only by the material; it is also closely related to factors such as the arc-extinguishing medium, contact movement speed, contact gap, breaking current, and breaking voltage.

Key test items

Test item	Evaluation content	Use of results
Rated current breaking test	Whether normal breaking can be achieved under specified working conditions	Verify basic breaking capacity
Short-circuit or specified large-current breaking test	Breaking capacity under high-current conditions	Verify performance under specified fault conditions
Arc duration	Arc maintenance time and variation trend	Judge whether the arc-extinguishing process is stable
Insulation recovery after breaking	Whether reignition, breakdown, or continuous conduction occurs	Judge electrical safety after breaking
Contact erosion amount	Changes in mass, dimensions, and surface morphology before and after breaking	Judge material loss and life trend
Contact resistance after breaking	Whether arc damage affects subsequent current carrying	Evaluate the relationship between breaking and closing performance

Focus on arc energy and material loss

Under simplified conditions, arc energy can be expressed as: arc energy = arc voltage × arc current × arc duration. For actual breaking processes in which arc voltage and current change with time, a more accurate expression is the time integral of the product of arc voltage and current. In engineering, synchronously acquired voltage and current waveforms should usually be used to calculate or analyze arc energy, rather than inferring the degree of erosion only from rated current. After the test, the mass loss, erosion depth, surface pits, molten spatter, and material transfer of the contact should be measured. For contacts that need to maintain a specific contact profile, geometric dimension changes may be more engineering-significant than simple mass loss.

Material tests and complete equipment tests must be distinguished

Arc erosion tests on material specimens can be used to compare different tungsten-copper ratios, densities, and microstructural states, but cannot be directly equated with complete equipment breaking capacity. The breaking performance of actual equipment is also affected by the interrupter structure, contact movement mechanism, magnetic field design, and insulation recovery conditions. For example, medium-voltage vacuum circuit breakers usually give priority to a copper-chromium (Cu-Cr, Copper-Chromium Composite) contact system. Even if tungsten-copper alloy has relatively good burn resistance, it cannot directly replace copper-chromium contacts on that basis; before replacement, vacuum arc characteristics, breaking capacity, and insulation recovery performance must be verified.

II. How is contact reliability evaluated?

Reliability evaluation focuses on whether the contact can continuously complete conductive, closing, and breaking functions during long-term operation. A reasonable plan should include mechanical operation, rated current carrying, repeated breaking, environmental adaptability, and post-test condition inspection.

Recommended reliability verification process

Initial inspection Record baseline data such as contact resistance, contact dimensions, surface state, material density, and hardness. Mechanical operation test Check whether contact travel, contact pressure, and mechanism action are stable after repeated closing and opening.Current-carrying temperature rise test Measure the temperature rise of the contact and connection parts under the specified current, and check whether local hot spots exist.

Electrical life test Perform breaking cycles according to the voltage, current, load type, and operating frequency specified for the equipment, and record failures and performance changes. Post-test re-measurement Re-measure contact resistance, contact dimensions, and erosion morphology to confirm whether technical requirements are still met.

Reliability evaluation should also record the stage at which each abnormality occurs and the failure mode, such as continuous increase in contact resistance, contact welding, severe erosion, contact deformation, insulation recovery failure, or abnormal mechanism action.

Through failure mode classification, it can be determined whether the problem mainly comes from the material, contact structure, manufacturing process, or switch mechanism. If different materials or different supplier batches need to be quantitatively compared, the qualification rate after a specified number of operations, average number of cycles to failure, and failure mode distribution can be counted. However, when the sample size is insufficient, long-term reliability should not be inferred only from average life.

III. What items need to be tested for the tungsten-copper material itself?

Contact material quality directly affects the consistency of contact resistance, temperature rise, and arc erosion. It is recommended to focus on checking the following items:

Material test item	Main function
WCu ratio and composition uniformity	Confirm that the material composition meets design requirements
Relative density and pore conditions	Evaluate the degree of density and identify defects that may cause local heating
Electrical conductivity and thermal conductivity	Evaluate current-carrying capacity and heat transfer capability
Hardness and microstructural uniformity	Judge wear resistance, processing stability, and local performance differences
Copper phase distribution and pore morphology	Investigate uneven copper phase, residual porosity, and local microstructural abnormalities
Dimensions, flatness, and surface roughness	Ensure that contact area, pressure distribution, assembly accuracy meet design requirements

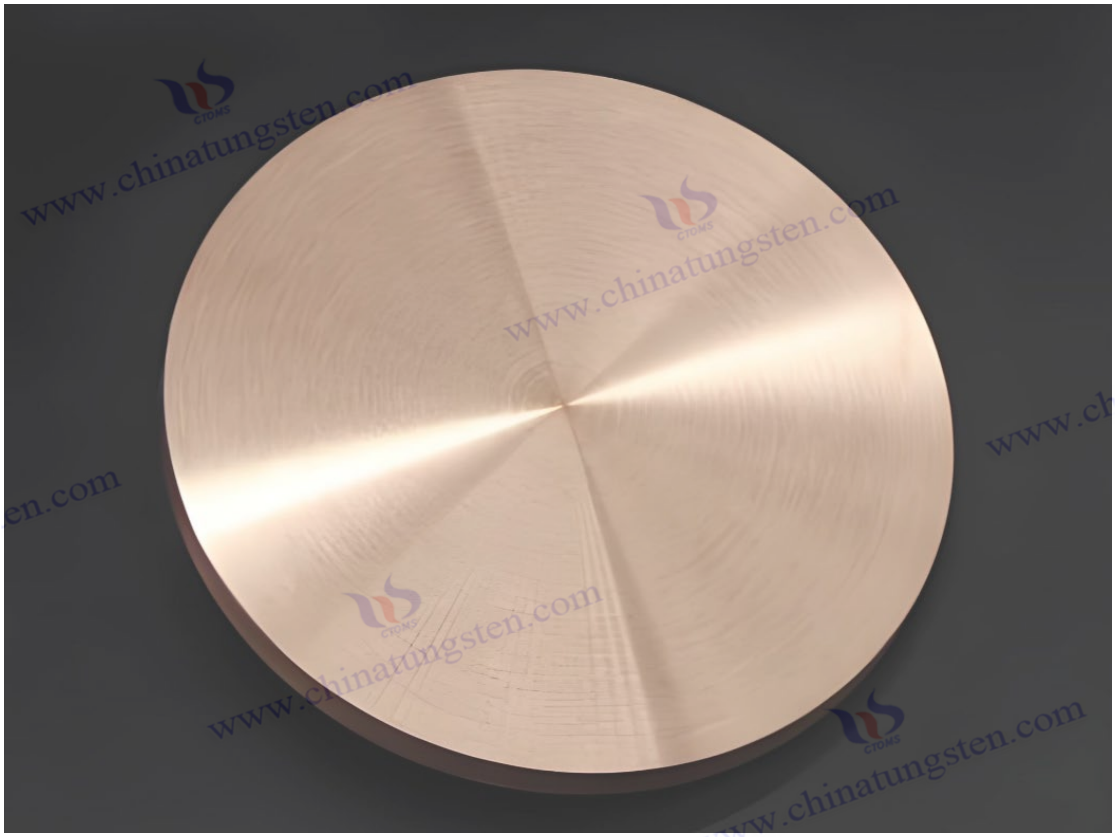
W-Cu alloy is usually manufactured by processes such as powder metallurgy and infiltration. If the pore structure of the tungsten skeleton is unreasonable, copper liquid infiltration is insufficient, or relatively many pores remain inside the material, current distribution and heat dissipation may be uneven, thereby increasing the risk of local temperature rise and arc erosion. Therefore, material test results should be analyzed in association with the electrical test results of the contact assembly, rather than judged in isolation.

IV. How to establish a comparable acceptance standard?

It is recommended to establish unified test conditions and judgment limits for each contact model, including at least the initial contact resistance and its allowable variation range, rated current-carrying temperature rise limit, breaking results under specified breaking conditions, allowable erosion dimensions, mechanical operation requirements, and residual performance requirements after electrical life tests. When comparing different suppliers or different tungsten-copper grades, it should be ensured that the test current, contact pressure, contact geometry, breaking conditions, and measurement methods are consistent. If any one of these changes, it is necessary to distinguish whether the performance change comes from the material itself or from differences in test conditions. In actual application, the evaluation results can be summarized into three levels: material-level testing is used to confirm composition, microstructure, and basic physical properties; component-level testing is used to evaluate contact resistance, temperature rise, and local erosion; complete-equipment-level testing is used to verify rated breaking capacity, electrical life, and operational reliability. Only when the results of the three levels are consistent with each other can a relatively complete judgment be formed on the actual applicability of tungsten-copper alloy contacts.

If the contacts are used in high-voltage circuit breakers, vacuum switches, or high-current contactors, the equipment type and applicable product test standards should also be clarified first, and then specific test currents, breaking times, temperature rise limits, and acceptance thresholds should be formulated, avoiding the use of one set of general indicators to evaluate all contacts.





G. Tungsten-Copper Alloy Semiconductor Heat Dissipation and Electronic Packaging

Q49 Why is tungsten-copper alloy suitable for electronic packaging and thermal management?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) is suitable for electronic packaging and thermal management mainly because it combines relatively good thermal conductivity, an adjustable coefficient of thermal expansion, relatively high dimensional stability, and a certain level of mechanical strength. For power semiconductors, RF devices, microwave components, and high-power electronic modules, these characteristics help conduct away the heat generated by chips while reducing interface stress and packaging deformation caused by thermal expansion mismatch between materials.

I. Why is tungsten-copper alloy suitable for electronic packaging?

Adjustable coefficient of thermal expansion

Chips, ceramic substrates, and metal baseplates expand to different degrees when heated. If the expansion difference is too large, it may lead to solder layer fatigue, interface delamination, or ceramic cracking. The coefficient of thermal expansion of tungsten-copper alloy can be designed by adjusting the tungsten-copper ratio so that it better matches a specific chip or ceramic material.

Balancing thermal conductivity and structural stability

The copper phase of tungsten-copper alloy helps conduct heat, while the tungsten phase provides relatively high stiffness and high-temperature stability. For electronic packaging baseplates and heat spreader components with high heat flux density and strict dimensional requirements, this combination helps balance heat dissipation performance and structural reliability.

Suitable for precision packaging structures

Tungsten-copper alloy can be machined into components such as baseplates, heat sinks, local structures of packaging housings, and heat spreader sheets. For devices requiring dimensional stability, interface matching, and hermetic packaging, further machining, surface treatment, and connection process verification can be carried out according to design requirements.

II. Main advantages of tungsten-copper alloy in thermal management

Relatively good thermal conductivity

Electronic chips generate Joule heat and other loss heat during operation. If heat cannot be transferred from the chip to the heat sink in time, the junction temperature will rise, thereby affecting device efficiency, performance, and life. Tungsten-copper alloy can undertake the heat conduction and heat diffusion tasks between the chip and the heat dissipation structure. Its thermal conductivity depends on the tungsten-copper ratio, material density, porosity, and microstructural uniformity. Increasing copper content usually helps improve thermal conductivity, but also changes the coefficient of thermal expansion, stiffness, and other properties, so comprehensive optimization is required.

The coefficient of thermal expansion can be adjusted according to requirements

The coefficient of thermal expansion describes the degree of dimensional change of a material when temperature changes. For a component with length L, when the temperature change is small and material parameters are approximately constant, the dimensional change can be estimated by the following formula: dimensional change = original length × linear expansion coefficient × temperature change. Here, the dimensional change is related to the original length, linear expansion coefficient, and temperature change. The coefficient of thermal expansion of tungsten-copper alloy is usually between those of tungsten and copper and can be adjusted by changing the composition. This enables it to be used for heat sinks and baseplates that need to match ceramic substrates, semiconductor chips, or other packaging materials. However, the specific matching effect should be determined based on actual material grades and temperature ranges, and cannot be inferred solely from the tungsten-copper ratio.

Helps reduce thermal cycling stress

Power electronic devices repeatedly experience temperature cycles during startup, shutdown, and load changes. The expansion differences of different materials generate cyclic stress at solder layers, braze layers, and interfaces, and long-term action may cause fatigue cracks or delamination. Reasonable selection of tungsten-copper alloy can reduce the thermal expansion difference between it and adjacent materials, thereby reducing some interface stress. However, packaging reliability also depends on solder or braze performance, connection layer thickness,

structural design, surface treatment, and thermal cycling range; the baseplate material alone cannot solve all thermal fatigue problems.

III. How does the tungsten-copper ratio affect packaging performance?

type	General performance trend	Possible application direction
W70Cu30	Higher Cu, more conducive to thermal & electrical conductivity, & coefficient of thermal expansion is also relatively higher	Components with high heat dissipation requirements & tolerance for a certain thermal expansion
W75Cu25	Achieves a compromise among thermal conductivity, thermal expansion matching, and structural performance	Packaging baseplates and heat sinks with relatively high comprehensive performance requirements
W80Cu20	Higher tungsten content, lower coefficient of thermal expansion and higher stiffness, but reduced thermal conductivity	Packaging structures emphasizing thermal expansion matching and dimensional stability

The above are only general trends. Actual thermal conductivity, coefficient of thermal expansion, and mechanical properties are also related to manufacturing process, relative density, pore distribution, and test temperature; measured data for specific grades should be used in design.

IV. In which electronic devices are tungsten-copper alloys mainly used?

Application field	Typical components	Main requirements
Power semiconductors	Power chip packaging baseplates, heat sinks	Thermal conductivity, thermal expansion matching, thermal cycling reliability
RF and microwave electronics	High-frequency power device heat sinks, packaging bases	Heat diffusion, dimensional stability, reliable connection
High-power electronic modules	Metal substrates, heat spreader components	Control of hot spot temperature rise, reduction of packaging stress
High-reliability electronic packaging	Precision packaging baseplates, local metal structures	Dimensional stability, interface matching, and connection reliability
Special thermal management components	Heat spreader sheets, thermally conductive support components	Balancing thermal conductivity and structural strength in limited space

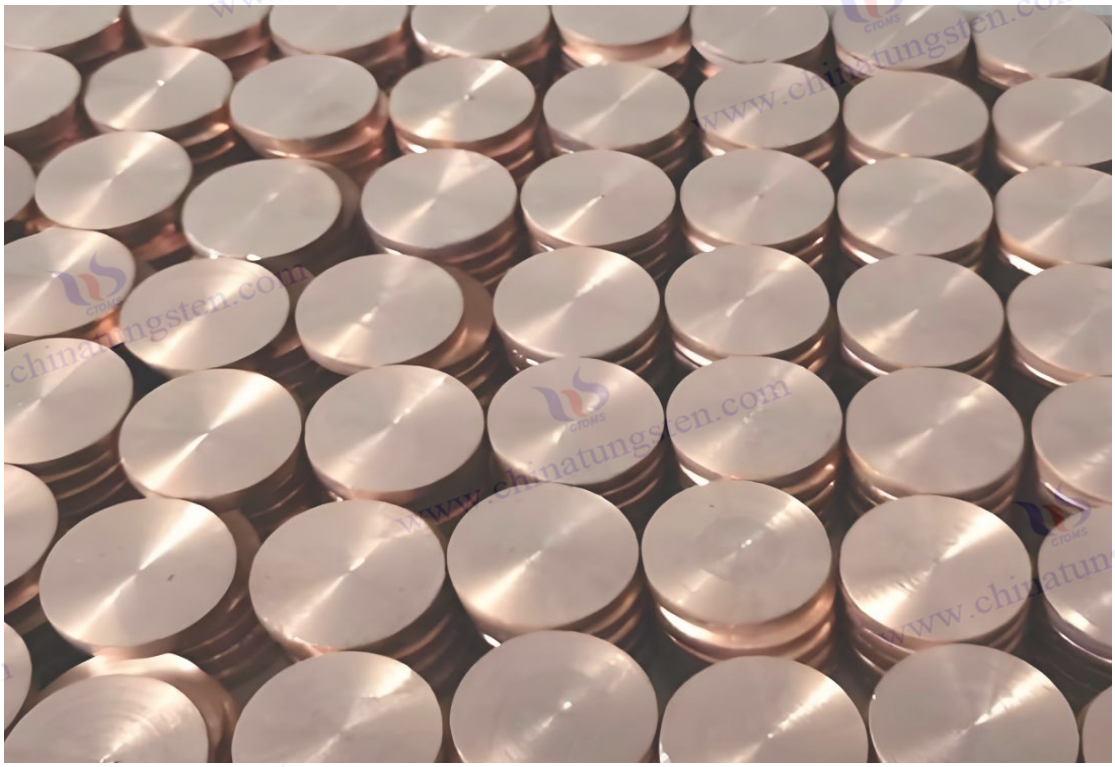
Not all electronic packaging requires tungsten-copper. For cost-sensitive structures with low thermal expansion matching requirements, copper or copper-based materials may be more economical; for heat spreader components requiring extremely high thermal conductivity, pure copper or other high-thermal-conductivity materials may also be more suitable. The advantages of tungsten-copper are mainly reflected in occasions where thermal conductivity, thermal expansion matching, and structural stability need to be satisfied simultaneously.

V. What should be mainly verified when selecting tungsten-copper alloy?

For electronic packaging applications, it is recommended to focus on thermal conductivity, coefficient of thermal expansion, relative density, flatness, surface roughness, connection layer compatibility, and interface integrity after thermal cycling. For hermetic packaging, the hermeticity and structural integrity after material processing, welding, or brazing should also be verified.

Tungsten-copper alloy is often manufactured by processes such as powder metallurgy and copper infiltration. If residual porosity or uneven copper phase distribution exists inside the material, the effective thermal conductivity may be reduced and local heat flux concentration may be caused. Therefore, material density and microstructural quality not only affect the performance of individual parts but also affect batch consistency. When tungsten-copper packaging baseplates and thermal management components are involved, relevant material and processing information from CTIA GROUP can be consulted, and suppliers should be required to provide thermal conductivity, coefficient of thermal expansion, and reliability test data for the corresponding grades.

In short, the value of tungsten-copper alloy is not only thermal conductivity, but the ability to comprehensively design among thermal conductivity, thermal expansion matching, and dimensional stability. For electronic packaging with high power, high heat flux density, and frequent thermal cycling, only by reasonably selecting the tungsten-copper ratio and controlling material density and connection processes can its thermal management advantages be fully brought into play.



Q50 What is a tungsten-copper alloy heat sink? For which electronic devices is it mainly used?

A tungsten-copper alloy heat sink (W-Cu Heat Sink, Tungsten-Copper Heat Sink) is a heat conduction and heat dissipation component made of tungsten-copper composite material, mainly used for power semiconductors, radio frequency (RF) devices, microwave components, high-power lasers, and high-reliability electronic packaging. Its core function is to conduct the heat generated during chip operation to a heat sink or cooling system, and at the same time, by adjusting the coefficient of thermal expansion of the material, reduce the thermal stress generated by different packaging materials during temperature changes. Compared with ordinary copper heat sinks, the outstanding feature of tungsten-copper alloy heat sinks is not necessarily higher thermal conductivity, but a balance among thermal conductivity, thermal expansion matching, structural stability, and packaging reliability, especially suitable for occasions where there is a large thermal expansion difference between the chip and the ceramic substrate or semiconductor material.

I. Basic structure and working principle of tungsten-copper alloy heat sinks

Tungsten-copper alloy heat sinks are usually installed at the bottom of heat-generating chips, ceramic substrates, or electronic packages, serving as a key component in the heat transfer path. A typical heat transfer path is: the chip generates heat, which is transferred through the chip connection layer to the packaging substrate or heat sink, then conducted to an external heat sink, and finally discharged through air cooling, liquid cooling, or other heat dissipation methods. Tungsten-copper alloy is composed of a tungsten phase and a copper phase and is not a single melted alloy in the ordinary sense. Its material is usually prepared by powder metallurgy; a common route is to first prepare a tungsten skeleton with connected pores, and then fill the pores by copper infiltration to form a composite material with a certain density and microstructure. Among them, the tungsten phase mainly provides a lower coefficient of thermal expansion, higher stiffness, and good dimensional stability; the copper phase mainly undertakes heat conduction and improves the electrical and processing properties of the material. The final performance depends on the tungsten-copper ratio, porosity, copper phase continuity, interface quality, and processing technology.

II. Main advantages of tungsten-copper alloy heat sinks

Thermal conductivity and thermal expansion matching can be balanced

Electronic chips generate heat during operation; after the temperature rises, the chip, ceramic substrate, and metal baseplate all undergo thermal expansion. If the coefficients of thermal expansion of different materials differ too much, repeated heating and cooling may cause connection layer fatigue, interface delamination, ceramic cracking, or chip connection failure. The coefficient of thermal expansion of tungsten-copper alloy can be adjusted by changing the tungsten-copper ratio. When tungsten content increases, the coefficient of thermal expansion usually tends to decrease; when copper content increases, thermal conductivity usually improves, but the coefficient of thermal expansion often increases accordingly. Therefore, heat sink design needs to determine the appropriate composition according to the chip and substrate materials, rather than simply pursuing the highest thermal conductivity.

Helps reduce packaging stress generated by thermal cycling

High-power electronic devices often experience startup, shutdown, load changes, and ambient temperature fluctuations. During these processes, packaging materials continuously expand and contract, and the connection layer bears cyclic shear stress. If the tungsten-copper heat sink has good thermal expansion matching with adjacent materials, it helps reduce interface stress and improve the stability of solder layers, braze layers, or other connection structures under thermal cycling conditions. However, thermal expansion matching does not equal completely eliminating thermal stress. Connection layer thickness, elastoplasticity of connection materials, heat sink dimensions, temperature change amplitude, and structural constraints also affect reliability.

Relatively good dimensional stability

Some electronic packages have high requirements for flatness, mounting dimensions, and chip position accuracy. The tungsten phase has relatively high stiffness and good high-temperature stability, and a reasonably designed tungsten-copper heat sink can balance structural strength and dimensional stability to a certain extent. This is especially important for multi-chip power modules, RF packaging bases, and precision microwave components, because obvious warpage of the heat sink may affect chip connection, substrate stress, interface thermal resistance, and overall packaging reliability.

Can adapt to different applications through material ratios

Different electronic devices have different requirements for heat sinks. Some devices focus more on heat dissipation capability, some focus more on thermal expansion matching, and others need to balance thermal cycling life, dimensional stability, and weight. Tungsten-copper alloy can adjust material properties by changing the tungsten-copper ratio. Common grades and their general trends are as follows.

grade	Composition	General performance tendency	Applicable design direction
W70Cu30	Tungsten 70%, copper 30%	Thermal conductivity is usually relatively high, & the coefficient of thermal expansion is also relatively high	Packaging heat sinks focusing more on thermal conductivity
W75Cu25	Tungsten 75%, copper 25%	Compromise among thermal conductivity, thermal expansion matching, and structural performance	Electronic packaging with relatively high comprehensive performance requirements
W80Cu20	Tungsten 80%, copper 20%	Coefficient of thermal expansion is usually lower & stiffness is higher, but thermal conductivity may somewhat reduced	Packaging emphasizing thermal expansion matching and dimensional stability

The above are only general trends; specific values are affected by material density, microstructure, and test temperature. Actual selection should be based on the data for the corresponding grade provided by the supplier, rather than being determined solely by nominal composition.

III. For which electronic devices are tungsten-copper alloy heat sinks mainly used?

Power semiconductor devices

Typical devices: insulated-gate bipolar transistors (IGBTs), power metal-oxide-semiconductor field-effect transistors (Power MOSFETs), power diodes, and power modules. Power semiconductors generate heat during conduction, switching, and energy conversion. Tungsten-copper heat sinks can be used for packaging baseplates of some power devices, chip heat spreader structures, or metal components connected to ceramic substrates, to improve heat transfer and control packaging thermal stress. Actual application needs to be determined in combination with chip materials, ceramic substrate types, and connection processes.

RF and microwave power devices

Typical devices: RF power amplifiers, microwave power modules, radar transmitting components, and high-frequency communication devices. RF and microwave devices often have relatively high local heat flux density and also have high requirements for packaging dimensions, structural stability, and connection reliability. Tungsten-copper heat sinks can be used for device bases and heat spreader components to help transfer heat to external cooling structures and reduce the impact of thermal expansion mismatch between packaging materials.

High-power lasers and optoelectronic devices

Typical devices: semiconductor lasers, laser diode modules, photodetectors, and some high-power optoelectronic components. Lasers are relatively sensitive to operating temperature and thermal stability; local temperature changes may affect output power, wavelength, and service life. Tungsten-copper heat sinks can be used for mounting bases or heat spreader components of some laser chips to help stabilize the thermal environment. Whether they are applicable also depends on the device's heat flux density, optical alignment accuracy, and packaging connection method.

High-reliability and hermetic electronic packaging

Typical devices: high-reliability microelectronic modules, ceramic packaging, some aerospace electronic components, and special communication modules.

Such devices usually have strict requirements for thermal cycling life, dimensional stability, connection integrity, and hermeticity. Tungsten-copper alloy can be used as packaging baseplates, local heat sinks, or thermal matching components, but the material itself cannot directly guarantee hermeticity; ultimately, the connection structure, welding or brazing process, and the overall hermetic performance of the package must also be verified.

IV. What are the differences between tungsten-copper heat sinks and pure copper and molybdenum-copper heat sinks?

Tungsten-copper is not the optimal solution for all thermal management applications. During material selection, it should be compared with materials such as pure copper and molybdenum-copper.

Material	Main characteristics	More suitable direction	Main limitation
copper	High thermal conductivity; usually advantageous in cost and processing technology	Heat dissipation components with low thermal expansion matching requirements and priority on thermal conductivity	Relatively high coefficient of thermal expansion, which may not match some chips or ceramic substrates
W-Cu	Thermal conductivity and coefficient of thermal expansion are adjustable; relatively good dimensional stability	Components that simultaneously focus on thermal conductivity, thermal expansion matching, and packaging reliability	Cost is usually higher, and thermal conductivity may be lower than that of pure copper
Mo-Cu	Has a relatively low coefficient of thermal expansion and can be used for thermally matched packaging structures	Electronic packaging with relatively high thermal expansion matching requirements	Thermal conductivity and processing economy need to be evaluated in combination with specific grades

If the design goal is to minimize thermal resistance as much as possible, pure copper or other high-thermal-conductivity materials may be more advantageous; if the thermal expansion mismatch between the chip and the ceramic substrate is the main reliability risk, then tungsten-copper, molybdenum-copper, and other thermally matched materials should be mainly compared.

V. How should the performance of tungsten-copper heat sinks be evaluated?

Tungsten-copper heat sinks cannot be evaluated only by material thermal conductivity. Actual performance depends on the complete heat transfer path formed by the heat sink body, connection interface, and external cooling conditions. First, the material thermal conductivity and coefficient of thermal expansion should be measured to confirm the degree of matching with the chip and substrate. Second, material density, porosity, flatness, surface roughness, and machining dimensions should be checked, because these factors may affect actual thermal conductivity and connection quality. Finally, thermal cycling, thermal shock, or thermal reliability tests under specified conditions should be carried out to check whether cracks, delamination, warpage, or connection failure appear at the interface. For actual devices, thermal resistance is an important evaluation indicator. Under steady-state conditions, the following simplified formula can be used to estimate thermal resistance:

Thermal resistance = temperature difference ÷ heat transfer power. Here, the unit of thermal resistance is kelvin per watt (K/W), the unit of temperature difference is kelvin (K), and the unit of heat transfer power is watt (W). Under otherwise identical conditions, the lower the thermal resistance, the smaller the temperature difference generated when transferring the same amount of heat. However, the temperature measurement points and heat boundaries must be clarified during measurement; the thermal resistance of the entire package cannot be directly regarded as the thermal resistance of the tungsten-copper material itself.

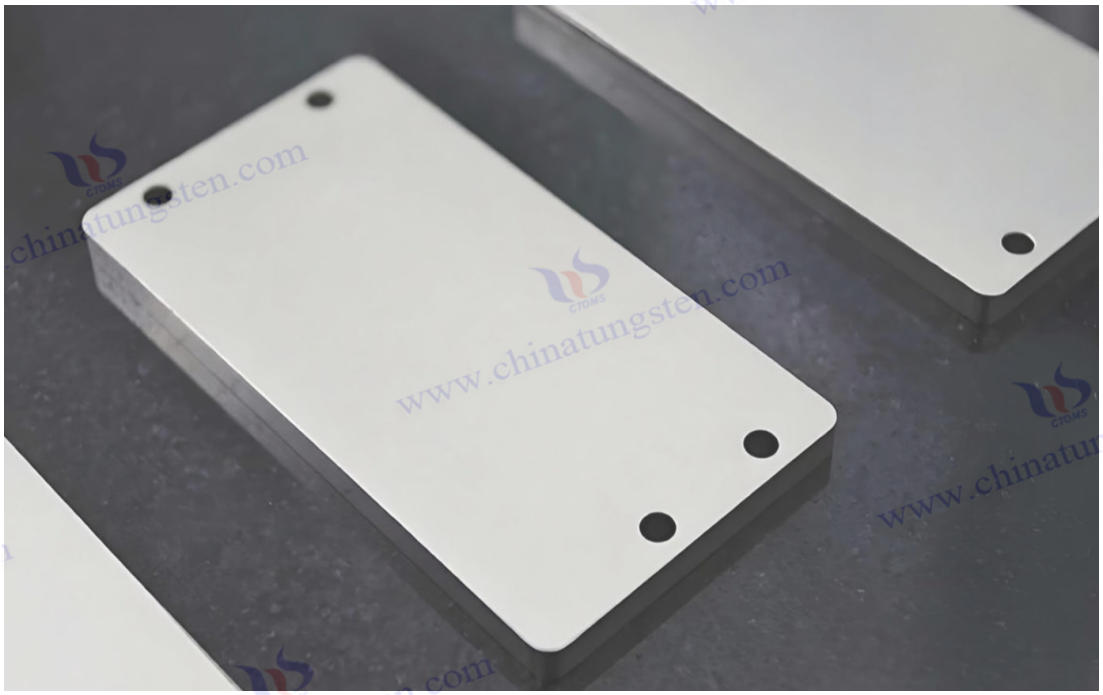
The manufacturing process is equally important. Tungsten-copper alloy is usually prepared by powder metallurgy and infiltration; if there is relatively much residual porosity inside, uneven copper phase distribution, or insufficient surface processing quality, local thermal resistance may increase and packaging connection reliability may be reduced. When tungsten-copper heat sinks, packaging baseplates, and precision thermal management parts are involved, relevant

material and processing information from CTIA GROUP can be consulted, and suppliers should be required to provide thermal conductivity, coefficient of thermal expansion, density, and reliability test data for specific grades.

VI. Key points in actual material selection

When selecting tungsten-copper alloy heat sinks, it is recommended to first determine the chip's maximum power dissipation, allowable junction temperature, heat flux density, packaging substrate material, thermal cycling range, and external cooling method, and then determine the heat sink dimensions, tungsten-copper ratio, and connection process. For example, if the power chip is mounted on a ceramic substrate and the main problem is solder layer fatigue caused by thermal cycling, priority should be given to thermal expansion matching and connection layer stress; if the main problem is local hot spots on the chip, the overall thermal resistance, heat diffusion capability, and cooling system should be mainly analyzed, rather than simply increasing tungsten content.

In short, tungsten-copper alloy heat sinks are electronic packaging components that balance heat conduction, thermal expansion matching, and structural stability, mainly used in power semiconductors, RF and microwave devices, high-power lasers, and high-reliability electronic modules. Their core value lies in adjusting material properties for specific packaging structures, rather than replacing pure copper or other high-thermal-conductivity materials in all cases.



Q51 What are the differences between tungsten-copper alloy and molybdenum-copper heat sinks?

The core differences between tungsten-copper alloy heat sinks and molybdenum-copper heat sinks lie in material composition, coefficient of thermal expansion, thermal conductivity, density, mechanical properties, and applicable temperature range. Both are metal composite materials, mainly used for heat dissipation and thermal management of power semiconductors, radio frequency (RF) devices, microwave devices, and high-reliability electronic packaging, but each has its own emphasis in specific applications.

I. Basic differences between tungsten-copper heat sinks and molybdenum-copper heat sinks

Tungsten-copper (W-Cu, Tungsten-Copper Composite) is composed of a tungsten phase and a copper phase, and molybdenum-copper (Mo-Cu, Molybdenum-Copper Composite) is composed of a molybdenum phase and a copper phase. Both are usually manufactured by processes such as powder metallurgy and infiltration, and balance thermal conductivity and thermal expansion matching by adjusting the ratio of refractory metal to copper.

Comparison item	Tungsten-copper heat sink	Molybdenum-copper heat sink
Main composition	Tungsten (W) and copper (Cu)	Molybdenum (Mo, Molybdenum) and copper (Cu, Copper)
Matrix metal characteristics	W has a high melting point, high density, and relatively high stiffness	Molybdenum has a high melting point, lower density than tungsten, and a relatively low coefficient of thermal expansion
Thermal expansion adjustment	Can be adjusted by tungsten-copper ratio	Can be adjusted by molybdenum-copper ratio
Thermal conductivity	Affected by tungsten content, copper phase continuity, and density	Affected by molybdenum content, copper phase continuity, and density
Density	Usually relatively high	Usually lower under the same volume conditions
Stiffness & structural stability	Usually has relatively high stiffness and good dimensional stability	Also has good dimensional stability, depending on ratio and microstructure
Processing characteristics	Materials with high tungsten content are more difficult to process	Also has a certain degree of processing difficulty, depending on ratio, microstructure, and processing method
Typical application focus	Packaging components with high thermal load, relatively high stiffness requirements, and thermal expansion matching	Components with requirements for thermal expansion matching, weight control, and packaging reliability

It cannot simply be concluded that the thermal conductivity of tungsten-copper is necessarily higher than that of molybdenum-copper, or that molybdenum-copper is necessarily easier to process. Actual performance is closely related to material ratio, porosity, density, copper phase distribution, manufacturing process, and test temperature.

II. Coefficient of thermal expansion: an important parameter determining packaging matching capability

When electronic devices operate, chips, ceramic substrates, connection layers, and heat sinks expand and contract to different degrees due to temperature changes. If the coefficients of

thermal expansion of the layers differ greatly, repeated heating and cooling may cause interface stress, solder layer fatigue, cracks, or packaging warpage. Both tungsten-copper and molybdenum-copper can change the coefficient of thermal expansion by adjusting the ratio of refractory metal to copper. Generally speaking, under similar material design conditions, the coefficient of thermal expansion of molybdenum is lower than that of tungsten, so molybdenum-copper has relatively good thermal expansion matching potential in some packaging solutions. However, the final result still depends on the composite ratio and actual microstructure and cannot be judged only by the parameters of the metal elements themselves. During material selection, the coefficient of thermal expansion of the heat sink should be compared with that of the chip, aluminum nitride (AlN) ceramic, aluminum oxide (Al_2O_3) ceramic, or other packaging substrates, rather than simply pursuing the lowest value.

III. Thermal conductivity: cannot be judged only by material name

The function of a heat sink is to conduct the heat generated by the chip to an external heat dissipation structure. The higher the material thermal conductivity, the lower the heat conduction thermal resistance inside the heat sink is usually, under otherwise identical conditions. The heat conduction thermal resistance of the heat sink body can be approximately expressed as: thermal resistance = thickness ÷ (thermal conductivity × effective heat transfer area), where the greater the thickness, the greater the thermal resistance is usually; the greater the thermal conductivity and effective heat transfer area, the smaller the thermal resistance is usually. The actual thermal conductivity of both tungsten-copper and molybdenum-copper is closely related to copper content and copper phase continuity. When the copper phase content is relatively high and the distribution is continuous, heat conduction is usually more favorable; increasing the refractory metal content helps reduce the coefficient of thermal expansion but may reduce overall thermal conductivity. Therefore, both materials need to achieve a balance between thermal expansion matching and thermal conductivity.

In addition, the total thermal resistance of actual packaging also includes the chip connection layer, interface contact, substrate, and external heat sink. Even if the thermal conductivity of the heat sink material itself is relatively high, if there are voids in the soldering interface, poor contact, or an excessively thick connection layer, the overall heat dissipation effect may still be unsatisfactory.

IV. For which electronic devices are the two materials respectively suitable?

Tungsten-copper heat sink

Suitable for power semiconductor packaging, RF power devices, high-power lasers, and high-reliability electronic components that have requirements for thermal expansion matching, stiffness, dimensional stability, and comprehensive thermal load performance. For designs requiring relatively high stiffness or relatively high-density metal structures, tungsten-copper can be evaluated first.

Molybdenum-copper heat sink

Suitable for power electronic devices, microwave devices, ceramic packaging, and high-

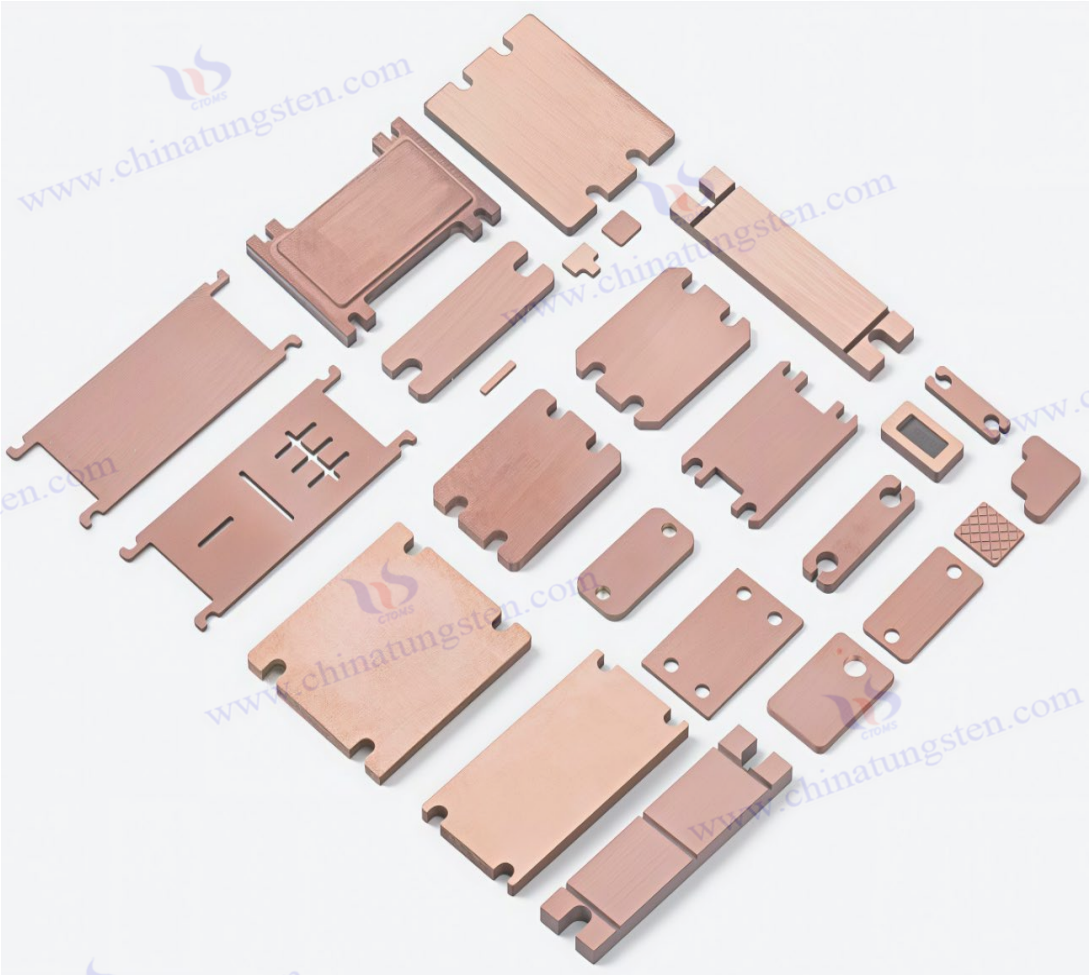
reliability electronic modules that need to control packaging thermal expansion, reduce component weight, and simultaneously balance thermal conductivity. For occasions with obvious weight constraints and where the thermal expansion parameters of molybdenum-copper better meet the packaging design requirements, molybdenum-copper can be evaluated first. The above are general material selection directions and do not mean that a certain material can only be used for a certain type of device. Both can adapt to different packaging requirements by adjusting the ratio, thickness, and structural design.

V. How to judge during actual material selection?

Design requirement	Suggested evaluation direction
Priority on reducing thermal expansion mismatch	Compare the actual coefficients of thermal expansion of tungsten-copper, molybdenum-copper, chips, and substrates
Priority on improving heat dissipation capability	Compare the measured thermal conductivity, heat sink thickness, and interface thermal resistance of specific grades
Relatively sensitive to weight	Evaluate molybdenum-copper first and calculate the mass of the entire component
High requirements for stiffness and dimensional stability	Compare elastic modulus, strength, deformation after thermal cycling, and actual structural constraints
High requirements for long-term reliability	Carry out verification of thermal cycling, interface bonding, warpage, and thermal resistance stability
Sensitive to cost and batch consistency	Simultaneously evaluate raw materials, processing, yield, and the supplier's batch testing capability

For example, when a power chip is mounted on a ceramic substrate, if the main failure risk comes from interface stress caused by thermal cycling, the thermal expansion matching requirements of the chip, substrate, and connection layer should be determined first, and then tungsten-copper or molybdenum-copper grades should be screened. If the main problem is that the chip temperature is too high, the thermal conductivity, thickness, effective area, interface quality, and cooling conditions of the heat sink should be calculated at the same time, and the problem cannot be solved only by changing materials.

During the product development stage, candidate grades of tungsten-copper and molybdenum-copper can be tested in parallel, with focus on comparing thermal conductivity, coefficient of thermal expansion, density, flatness, machining accuracy, interface bonding strength, and performance changes after thermal cycling. If batch manufacturing is involved, performance consistency between different batches should also be verified. For tungsten-copper heat sinks and other tungsten-copper precision components, CTIA GROUP can be consulted for relevant materials and processing directions. Tungsten-copper heat sinks are more suitable for scenarios where comprehensive design is carried out among stiffness, structural stability, and thermal expansion matching; molybdenum-copper heat sinks are worth focusing on in packaging with prominent weight control and thermal expansion matching requirements. The final choice should be based on the measured data of specific grades, packaging structure, and reliability test results, rather than being determined solely by the material name tungsten-copper or molybdenum-copper.



Q52 How does tungsten-copper alloy match the coefficient of thermal expansion of ceramic substrates or semiconductor chips?

The core of matching tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) to the coefficient of thermal expansion of ceramic substrates or semiconductor chips is to adjust the ratio of tungsten to copper so that the thermal expansion behavior of the heat sink is as close as possible to that of the chip, ceramic substrate, and connection layer, while controlling the interfacial stress caused by working temperature changes and reducing problems such as solder layer fatigue, substrate cracking, and package warpage. Actual design cannot pursue only equal coefficient of thermal expansion values; thermal conductivity, connection process, component thickness, temperature range, and thermal cycle life must also be comprehensively considered.

I. Why must the coefficient of thermal expansion be matched?

Different materials change dimensions to different degrees when heated. The coefficient of thermal expansion (CTE, Coefficient of Thermal Expansion) is usually expressed as the relative length change caused by a unit temperature change, and the common unit is μm/(m·K).

When the temperature change range is not large and the coefficient of thermal expansion is approximately constant, the free thermal strain of a material can be estimated as follows: thermal strain = coefficient of thermal expansion × temperature change. The free thermal strain

difference between two materials is: thermal strain difference = difference in coefficient of thermal expansion × temperature change.

For example, assuming that the coefficients of thermal expansion of a tungsten-copper heat sink and a ceramic substrate differ by 2 μm/(m·K) and the working temperature change is 100 K, then the free thermal strain difference between the two is approximately 200 microstrain, i.e., 0.02%. If the interface length is 20 mm, the corresponding free expansion/contraction difference is approximately 4 μm. This dimensional difference may seem very small, but when the chip, ceramic, solder, or metal connection layer are firmly connected, the materials cannot expand and contract completely freely, and interfacial stress will be generated. After repeated heating and cooling, the stress may cause solder layer fatigue, interfacial delamination, ceramic cracking, or chip damage.

II. How to match different materials through the tungsten-copper ratio?

Tungsten-copper is a composite material, and its coefficient of thermal expansion can be designed by adjusting the tungsten content and copper content. Generally speaking, increasing tungsten content usually helps reduce the coefficient of thermal expansion and increase stiffness, but may reduce the overall thermal conductivity; increasing copper content usually helps improve thermal conductivity, while also increasing the coefficient of thermal expansion. The following is a qualitative comparison of common ratios; actual values must be based on specific material grades and test data.

Tungsten-copper ratio/mass fraction	Thermal expansion matching characteristics	Thermal conductivity trend	Applicable design direction
W70Cu30	Coefficient of thermal expansion relatively high	Usually more favorable for thermal conductivity	Components with high heat dissipation requirements and tolerance for relatively high thermal expansion
W75Cu25	Relatively balanced between thermal expansion and thermal conductivity	A compromise design direction	Applications requiring both heat dissipation and packaging matching
W80Cu20	Coefficient of thermal expansion usually lower	Thermal conductivity relatively reduced	Applications with higher requirements for thermal expansion matching and structural stability
Higher tungsten content grades	Can further reduce the coefficient of thermal expansion	Thermal conductivity must be checked emphatically	Packaging with special requirements for low thermal expansion and high stiffness

W70Cu30 in the table means a tungsten mass fraction of 70% and a copper mass fraction of 30%, and other ratios follow the same pattern. The ratio is only the starting point for material selection; the actual coefficient of thermal expansion is also affected by material density, porosity, microstructural uniformity, and manufacturing process.

III. What are the differences in matching strategies for different ceramic substrates or chips?

Aluminum nitride ceramic substrate

Aluminum nitride (AlN, Aluminum Nitride) has relatively high thermal conductivity and is often used in power semiconductor packaging. Its coefficient of thermal expansion is relatively low, so tungsten-copper or molybdenum-copper (Mo-Cu, Molybdenum-Copper Composite) grades with relatively low coefficients of thermal expansion usually need to be selected for matching. During design, the coefficient of thermal expansion of the substrate within the actual working temperature range should be compared first, and then the ratio should be determined in combination with the thickness of the tungsten-copper heat sink, the connection layer material, and the packaging structure. If the heat sink is thick and the connection area is large, the constraint stress caused by thermal expansion mismatch may be more prominent.

Aluminum oxide ceramic substrate

The coefficient of thermal expansion of aluminum oxide (Al_2O_3, Aluminum Oxide) ceramic is usually higher than that of aluminum nitride ceramic. At this time, the design goal is not necessarily to select the tungsten-copper material with the highest tungsten content; instead, a grade with a coefficient of thermal expansion closer to the actual substrate parameters should be selected according to the actual substrate parameters, while verifying whether the thermal conductivity meets the requirements. If the tungsten content is excessively increased to reduce the coefficient of thermal expansion, thermal conductivity may decrease, which may not be beneficial to the thermal performance of the entire package.

Silicon chip

The coefficient of thermal expansion of silicon (Si, Silicon) chips is relatively low, usually lower than that of metal heat sinks with relatively high copper content. Therefore, in cases where the chip is directly connected to the metal base plate and the structural constraint is strong, particular attention should be paid to thermal expansion mismatch. Actual packaging often does not involve the chip being directly connected to the tungsten-copper heat sink; instead, a multilayer structure is formed with the substrate and base plate through solder, sintered silver layer, or other connection materials. During design, the thermomechanical properties of the chip, substrate, connection layer, and heat sink should be considered simultaneously; it is not enough to match only the two components of chip and heat sink.

IV. How to judge whether the coefficient of thermal expansion is matched?

Judgment can be made at three levels.

The first step is to compare material parameters. Obtain the coefficients of thermal expansion of the chip, ceramic substrate, tungsten-copper heat sink, and connection layer, and confirm the temperature range and test direction corresponding to the data. For anisotropic materials, the coefficients of thermal expansion in different directions should also be distinguished.

The second step is to estimate the thermal expansion mismatch. Calculate the free expansion/contraction difference of each material within the specified temperature change range to preliminarily judge the degree of mismatch. For example, if the temperature change is 150 K and the coefficients of thermal expansion of the two materials differ by 1.5 μm/(m·K), then the free expansion/contraction difference per meter of length is approximately 225 μm;

for a connection length of 20 mm, the difference is approximately 4.5 μm.

The third step is to verify the actual structure. A close coefficient of thermal expansion does not necessarily mean that the interfacial stress is low, because the stress is also affected by elastic modulus, connection layer thickness, plastic deformation capacity, structural constraints, and temperature gradient. Important packages should be checked for interfacial stress, warpage, cracks, and thermal resistance changes through finite element thermal stress analysis (FEA, Finite Element Analysis) and temperature cycling tests.

V. How to achieve a balance between thermal expansion matching and thermal conductivity?

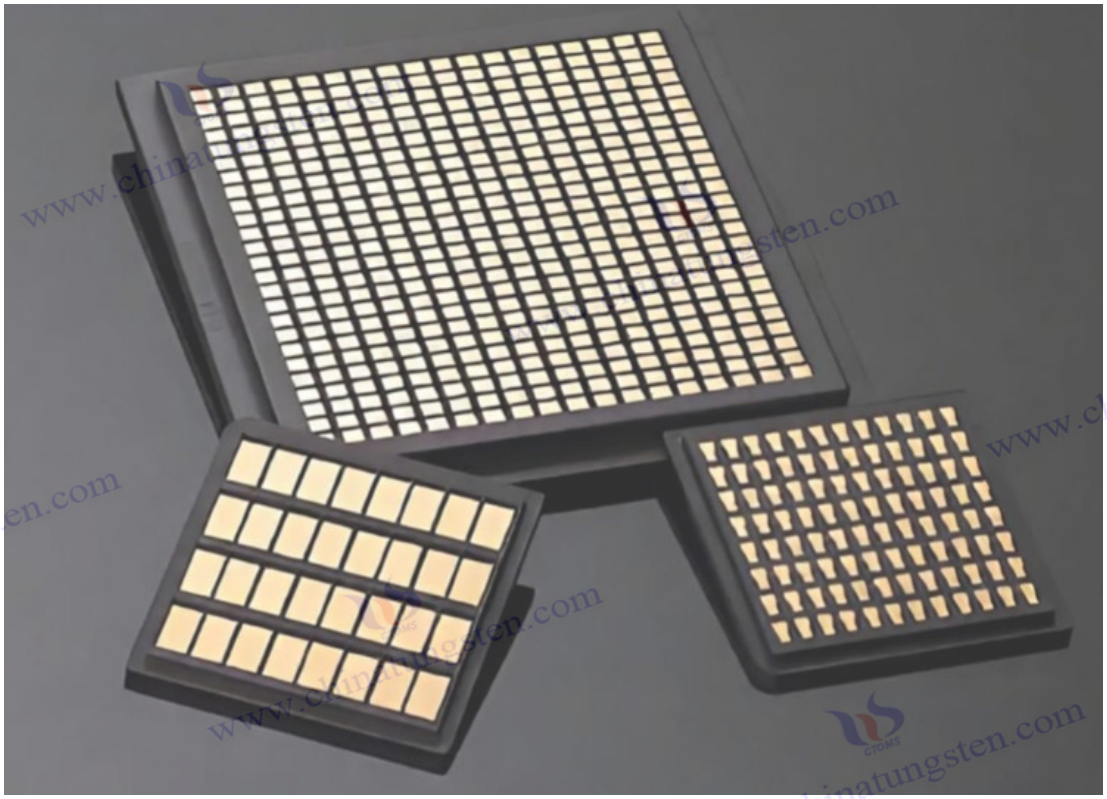
The key to tungsten-copper heat sink design is to simultaneously meet the packaging thermomechanical requirements and heat dissipation requirements, rather than optimizing a single parameter alone.

Design variable	Effect on thermal expansion matching	Effect on heat dissipation capability
Increasing tungsten content	Usually reduces the coefficient of thermal expansion	Thermal conductivity may decrease
Increasing copper content	Usually increases the coefficient of thermal expansion	Usually favorable for thermal conductivity
Reducing heat sink thickness	Can reduce some structural constraints and temperature gradient effects, but the effect depends on the structure	Usually favorable for reducing bulk thermal conduction resistance
Optimizing connection layer thickness and material	Can alleviate or redistribute interfacial stress	A connection layer that is too thick or has many voids will increase thermal resistance
Improving density & microstructural uniformity	Helps improve batch stability	Usually favorable for obtaining stable thermal conductivity

For power semiconductor packaging, it is recommended to first determine the thermal expansion parameters of the chip and ceramic substrate, the maximum working temperature, the temperature cycling range, and the allowable warpage, and then screen candidate grades such as W70Cu30, W75Cu25, and W80Cu20. If thermal expansion matching and thermal conductivity are difficult to satisfy simultaneously, molybdenum-copper materials, optimized connection layers, or multilayer structures can be further evaluated to alleviate the thermomechanical mismatch between materials.

For tungsten-copper heat sinks and related precision components, CTIA GROUP can be consulted for information on material ratios and processing directions.

The thermal expansion matching of tungsten-copper heat sinks should be based on the actual parameters of the chip and ceramic substrate. Preliminary material selection should be carried out by adjusting the tungsten-copper ratio, and then verification should be completed in combination with connection layer design, thermal stress analysis, and temperature cycling tests. Only when thermal expansion matching, thermal conductivity, and interfacial reliability all meet the requirements can a stable package life be obtained.



Q53 How to select tungsten-copper alloy grades based on thermal conductivity, coefficient of thermal expansion, and thermal resistance?

When selecting tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) grades, thermal conductivity, coefficient of thermal expansion, and thermal resistance should be judged together rather than pursuing a single indicator alone. Thermal conductivity determines the material's own ability to conduct heat, the coefficient of thermal expansion determines its thermomechanical matching degree with semiconductor chips or ceramic substrates, and thermal resistance reflects the degree to which the entire heat transfer path obstructs heat flow. For electronic packaging heat sinks, a reasonable material selection sequence is: first determine the thermal expansion matching requirements, then check whether the thermal resistance meets the heat dissipation target, and finally determine the specific grade in combination with mechanical strength, processing accuracy, and cost.

I. What do the three key parameters determine respectively?

Parameter	Meaning and role	Material selection judgment basis
Thermal conductivity (k)	Indicates the material's ability to conduct heat, unit W/(m·K)	Under otherwise identical conditions, the higher the value, the lower the bulk thermal conduction resistance of the material
Coefficient of thermal expansion (CTE)	Indicates the degree of dimensional change of a material when temperature changes, common unit μm/(m·K)	Matches the thermal expansion characteristics of the chip, ceramic substrate, and connection layer to reduce thermal cycling stress
Thermal resistance (Rth)	Indicates the difficulty of generating a temperature difference when heat passes through a certain structure, unit K/W	Calculated according to allowable temperature rise, heat generation power, and the entire heat dissipation path

There are constraint relationships among these three parameters. Increasing tungsten content usually helps reduce the coefficient of thermal expansion but may reduce thermal conductivity; increasing copper content usually helps thermal conduction but may increase thermal expansion mismatch. Therefore, the selection of tungsten-copper grades is essentially multi-objective optimization.

II. Step 1: Determine candidate grades based on the coefficient of thermal expansion

For semiconductor packaging, the coefficient of thermal expansion is often an important indicator for preliminary screening. Assuming that after the tungsten-copper heat sink is connected to the ceramic substrate or chip, temperature changes cause the two to produce different free expansion/contraction amounts, stress may be formed in the solder layer, sintered silver layer, or ceramic interior. When other conditions are similar, common tungsten-copper ratios can be preliminarily screened in the following directions:

grade	Coefficient of thermal expansion trend	Thermal conductivity trend	Preliminary applicable direction
W70Cu30	Relatively high	Usually relatively high	Components with prominent heat dissipation requirements and relatively loose thermal expansion matching requirements
W75Cu25	Intermediate level	Intermediate level	Applications requiring both thermal conductivity and thermal expansion matching
W80Cu20	Relatively low	May be relatively low	Applications with higher requirements for thermal expansion matching and dimensional stability
Higher W	Usually further reduced	Needs to be verified emphatically	Packaging with special requirements for low thermal expansion

The above trends are only for preliminary screening and do not mean that the corresponding grades of all suppliers have the same parameters. Actual thermal conductivity and coefficient of thermal expansion are also affected by material density, porosity, microstructural uniformity, and manufacturing process. In specific operations, the measured coefficients of thermal expansion of the chip, ceramic substrate, and candidate tungsten-copper grades should first be obtained, and then their differences within the actual working temperature range should be compared. If the thermal expansion mismatch is too large, priority should be given to adjusting the material ratio or packaging structure rather than directly selecting the material with the highest thermal conductivity.

III. Step 2: Calculate heat dissipation capability based on thermal resistance

Thermal conductivity is a material property, while thermal resistance is related to both material properties and structural dimensions. Even if two tungsten-copper materials have the same thermal conductivity, differences in thickness, effective heat transfer area, or interface quality may still lead to significant differences in actual thermal resistance.

For one-dimensional steady-state heat transfer in a homogeneous material, the bulk thermal resistance of the heat sink can be calculated using the following formula that is easy to copy: thermal resistance Rth = thickness L ÷ (thermal conductivity k × effective heat transfer area A).

Here, the unit of Rth is K/W, the unit of L is m, the unit of k is W/(m·K), and the unit of A is m^2. The lower the thermal resistance, the smaller the temperature difference generated under the same heat transfer power. For example, if a tungsten-copper heat sink has a thickness of 2 mm, an effective heat transfer area of 10 mm × 10 mm, and an assumed thermal conductivity of 200 W/(m·K), then the bulk thermal resistance is approximately 0.1 K/W. If the heat transfer power through the heat sink is 50 W, then its bulk temperature difference is approximately 5 K. This calculation only reflects the idealized heat conduction of the heat sink body and does not include the thermal resistance generated by the chip connection layer, ceramic substrate, contact interface, and external heat sink.

In actual design, the total thermal resistance should be calculated: total thermal resistance = chip connection layer thermal resistance + ceramic substrate thermal resistance + tungsten-copper heat sink thermal resistance + interface thermal resistance + external heat dissipation path thermal resistance. When these parts are in series, they can be approximately added; if parallel heat transfer paths exist, calculation should be made according to the actual structure. For three-dimensional diffusion heat transfer, local heat sources, or complex packaging, the results of simple formulas should be corrected through thermal simulation or actual measurement.

IV. Step 3: Judge whether the grade is qualified using the temperature rise target

If the heat generation power and allowable temperature rise of the device are known, the allowable total thermal resistance of the entire heat transfer path can be calculated first.

Upper limit of total thermal resistance = allowable temperature rise ÷ heat generation power. For example, if the heat generation power of a device is 80 W and the allowable temperature rise from the chip to the specified reference position is 20 K, then the upper limit of the total thermal resistance of this path is: 20 K ÷ 80 W = 0.25 K/W.

The 20 K here must correspond to a clear temperature measurement position and temperature boundary. For example, if the allowable temperature rise is the difference between the chip junction temperature and the coolant temperature, the thermal resistance inside the package and related to the cooling system must be included in the calculation, and 0.25 K/W cannot all be used as the thermal resistance budget of the tungsten-copper heat sink body. If the thermal resistance budget occupied by the heat sink body is too high, consideration can be given to increasing the material thermal conductivity, reducing the heat sink thickness, increasing the effective heat transfer area, or improving the interface connection. If the thermal resistance of the heat sink body is already very low but the overall temperature rise is still too high, then solder voids, contact thermal resistance, substrate thickness, and external cooling capability should be checked.

V. How to comprehensively judge and select the grade?

The following are material selection directions under different design objectives.

Design scenario	Indicators to be prioritized	Grade screening direction
High-power semiconductors with limited temperature rise	Total thermal resistance, thermal conductivity	Among candidate grades meeting thermal expansion matching, prioritize materials with high measured thermal conductivity
Aluminum nitride ceramic packaging	Coefficient of thermal expansion, thermal resistance, interface reliability	Focus on evaluating low thermal expansion grades and verify connection layer and thermal cycle life
Silicon chip connected to metal base plate	Thermal expansion mismatch between chip and base plate	Match according to the overall structure of chip, substrate, connection layer, and base plate
High-temperature cycling conditions	Coefficient of thermal expansion, interface fatigue, dimensional stability	Prioritize ensuring thermomechanical reliability while verifying thermal conductivity at high temperature
Miniaturized packaging	Thermal resistance, thickness, effective heat transfer area	Compare the thermal resistance of different grades at actual dimensions rather than only comparing thermal conductivity
Mass production	Parameter consistency, processing accuracy, cost	Require suppliers to provide batch inspection data and verify performance after processing

In actual projects, W70Cu30, W75Cu25, and W80Cu20 can be used as initial candidates, but the final material should not be determined directly based on the ratio. A more reliable approach is to require suppliers to provide the thermal conductivity, coefficient of thermal expansion, density, porosity, and test conditions of the corresponding grade, and then calculate the thermal resistance using actual dimensions. For tungsten-copper heat sinks and precision packaging components, CTIA GROUP can be consulted for information on material ratios and processing solutions.

VI. Recommended engineering material selection process

It is recommended to complete material selection according to the following process: first clarify the working temperature range and coefficient of thermal expansion of the chip, ceramic substrate, and tungsten-copper heat sink; second, calculate the total thermal resistance budget of the entire heat dissipation path according to the device heat generation power and allowable temperature rise; then screen tungsten-copper grades that meet the thermal expansion matching requirements and calculate the thermal resistance of candidate materials at actual thickness and effective heat transfer area; finally determine the final grade through thermal stress analysis, temperature cycling tests, thermal resistance testing, and packaging reliability verification.

The coefficient of thermal expansion determines whether the material is suitable for the packaging structure, thermal conductivity determines the material's own heat transfer capability, and thermal resistance determines whether the entire structure can meet the temperature rise requirements. Thermomechanical matching constraints should be satisfied first, then thermal resistance budget should be used to screen thermal conductivity performance, and finally the results should be confirmed by actual packaging tests.

Q54 What thermal cycling and reliability tests are required for tungsten-copper alloy electronic packaging components?

The core of reliability testing for tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) electronic packaging components is to verify whether the material can maintain stable thermal conductivity, dimensional accuracy, interfacial bonding strength, and electrical performance under repeated heating, cooling, power changes, and mechanical loads. For tungsten-copper heat sinks, packaging base plates, and heat spreader components used in power semiconductors, radio frequency (RF, Radio Frequency) devices, microwave components, and high-power lasers, it is not enough to test only the tungsten-copper material itself; the complete package composed of the chip, ceramic substrate, solder layer, or sintered silver connection layer should also be included in the verification. Many failures do not originate from the tungsten-copper body but occur at the connection interfaces between dissimilar materials.

I. What core tests are required for tungsten-copper electronic packaging components?

Test item	Main verification content	Key observed failures
Temperature cycling test	Structural stability after repeated low-temperature and high-temperature transitions	Interfacial cracks, delamination, solder layer fatigue, warpage
High/low temperature storage test	Performance changes during long-term high-temperature or low-temperature environments	Oxidation, microstructural changes, dimensional drift, connection performance degradation
Power cycling test	Reliability during repeated alternating device power-on heating and cooling	Local thermal fatigue, chip connection layer damage, thermal resistance increase
Thermal shock test	Effect of rapid temperature transitions on packaging structure	Ceramic cracking, interfacial peeling, local stress concentration
Thermal resistance & thermal conductivity performance test	Whether heat dissipation capability is stable before and after thermal cycling	Thermal resistance increase, interface void expansion, heat conduction path degradation
Thermal expansion & warpage test	Dimensional change and flatness during temperature changes	Base plate deformation, substrate warpage, assembly offset
Interfacial bonding strength test	Mechanical reliability of brazed, soldered, or sintered connection areas	Delamination, connection layer cracking, interfacial strength decrease
Nondestructive testing	Internal defects and defect propagation after testing	Porosity, cracks, delamination, and connection layer voids
Electrical performance test	Insulation and conduction performance of packaged components	Insulation decrease, short circuit, abnormal contact resistance
Vibration & mechanical shock test	Reliability under mechanical loads during transportation, installation, and operation	Crack propagation, connection loosening, solder layer damage

Not every product must perform all of these items. The test combination and acceptance criteria should be determined according to packaging application, working environment, failure risk, and customer specifications.

II. What are the differences among temperature cycling, thermal shock, and power cycling?

These three are the most important tests in reliability verification of tungsten-copper electronic packaging, but they cannot replace each other.

Temperature cycling test

The temperature cycling test (TC) repeatedly switches between set high and low temperatures to examine the cumulative damage caused by thermal expansion mismatch of materials. Common failures include ceramic substrate cracking, delamination at the interface between tungsten-copper and the connection layer, solder fatigue, and packaging warpage. For semiconductor packaging, reference can be made to JEDEC (Joint Electron Device Engineering Council) JESD22-A104 temperature cycling test method. The specific high/low temperature range, dwell time, transition time, and number of cycles should be determined according to the product working environment and applicable specifications. In engineering development, the following conditions can be used as a preliminary test plan rather than a general acceptance standard:

Item	Preliminary verification suggestion
Temperature range	Determined according to the product use environment, for example −40°C to +125°C
Number of cycles	First perform 200–500 cycles with staged inspection, then decide whether to extend to 1000 cycles or more according to risk and product specifications
Process monitoring	Record key dimensions, thermal resistance, warpage, and electrical parameters
Inspection points	Before testing, after staged cycling, and after testing
Key failure locations	Tungsten-copper/ceramic connection interface, chip connection layer, solder edges, and geometric transition areas

The above temperatures and cycle numbers are only for reference in plan design. Actual qualification should adopt the conditions specified in the corresponding product specification; a specific service life cannot be inferred merely from passing a certain number of cycles.

Thermal shock test

The thermal shock test emphasizes rapid temperature transitions, causing the material to experience a large temperature change rate in a relatively short time. Compared with temperature cycling, thermal shock focuses more on transient stress and brittle damage caused by rapid temperature changes. For packaging structures composed of tungsten-copper and ceramic, key inspection should be given to ceramic edges, metallized areas, connection layer edges, and locations with local thickness changes. The test can refer to applicable methods such as JESD22-A106, but whether a thermal shock test is needed should be confirmed according to the actual product, because not all packages will experience such severe temperature transitions during use.

Power cycling test

The power cycling test repeatedly powers the device on and off, causing the chip itself to generate heat and cool periodically, simulating the temperature changes during actual

operation. Its difference from environmental temperature cycling is that environmental temperature cycling mainly changes the ambient temperature of the entire sample, while power cycling may form an obvious local temperature gradient between the chip and the base plate. Therefore, power cycling is particularly suitable for life verification of high-power semiconductor modules, power device base plates, and chip connection structures. Reference can be made to JEDEC JESD22-A105 power and temperature cycling related test methods. During testing, the chip junction temperature or an appropriate temperature proxy parameter, on-state voltage, thermal resistance, and number of cycles should be recorded, and the heating and cooling stages should be set according to the actual power curve of the product.

III. What other material and interface tests should be carried out?

Temperature cycling can only show the performance of the sample under specified stress and cannot explain the cause of failure alone. It is recommended to combine thermal performance, interface integrity, and dimensional stability tests.

Test category	Recommended method	Key evaluation indicator
Thermal performance	Thermal resistance test, thermal conductivity test	Thermal resistance change rate, thermal conductivity change
Thermal expansion performance	Thermomechanical analysis (TMA, Thermomechanical Analysis)	Coefficient of thermal expansion and its change with temperature
Dimensional stability	Flatness, parallelism, and warpage measurement	Deformation amount, dimensional deviation
Internal defects	Ultrasonic scanning, X-ray inspection, computed tomography (CT)	Void rate, cracks, delamination area
Connection strength	Shear, tensile, or interfacial bonding strength test	Strength and retention rate after thermal cycling
Microstructure	Metallographic cross-section, scanning electron microscope (SEM) observation	Crack path, interfacial reaction, porosity, and microstructural changes

The testing means should be selected according to the connection method. For example, when tungsten-copper and ceramic are connected by brazing, focus should be on voids in the brazing layer, brittle reaction layers, and interfacial cracks; when sintered silver connection is used, focus should be on porosity in the sintered layer, crack propagation, and changes in thermal conductivity after thermal cycling.

IV. Do high-temperature, high-humidity, and mechanical reliability tests need to be performed?

If the packaging component is used in outdoor power equipment, automotive electronics, aerospace, or high-humidity environments, temperature cycling alone is usually not enough, and other reliability items should be added according to the use conditions. The high-temperature storage life test (HTSL) is used to evaluate changes in materials and connection structures after long-term high-temperature exposure; the temperature-humidity-bias test (THB) and highly accelerated stress test (HAST) are mainly used to evaluate moisture, corrosion, ion migration, and moisture resistance of packaging materials. The tungsten-copper body is not necessarily the main weak link in such tests; the actual risk may come from the surface

metallization layer, solder, sealing material, or other connection structures. Vibration, mechanical shock, and bending tests are used to examine structural integrity under mechanical loads during transportation, installation, and operation. For packaging components mounted on a printed circuit board (PCB, Printed Circuit Board), board-level temperature cycling and solder joint reliability can be evaluated according to the assembly form; for a separate tungsten-copper heat sink, priority should be given to actual installation loads, fastening methods, and structural resonance risks.

V. How to formulate a complete test process?

It is recommended to proceed at three levels: material level, component level, and system level.

Material level: confirm the stability of the tungsten-copper grade

Test thermal conductivity, coefficient of thermal expansion, density, porosity, dimensional accuracy, and microstructural uniformity to establish a batch baseline.

Component level: verify packaging connection reliability

Carry out temperature cycling and, where necessary, thermal shock and power cycling on samples composed of the tungsten-copper heat sink, ceramic substrate, and connection layer, and retest thermal resistance, warpage, and interfacial defects at each stage.

System level: confirm actual working performance

Install the packaging component into the target device or module to verify actual power conditions, temperature rise, insulation performance, electrical parameters, and long-term operational reliability.

The initial state should be recorded before testing begins, and performance changes should be compared after testing, rather than only judging whether obvious cracks appear in the sample. For example, an increase in thermal resistance may occur earlier than visible cracks; interfacial delamination found by ultrasonic scanning may not affect conduction in the short term but will weaken long-term reliability. Acceptance criteria should specify the maximum allowable increase in thermal resistance, interfacial delamination limit, dimensional change, connection strength retention rate, and allowable drift range of electrical parameters. Specific limits should be determined jointly by product design requirements, customer specifications, and applicable test standards, and it is not appropriate to set uniform thresholds for all tungsten-copper packaging components. Reliability verification of tungsten-copper electronic packaging components should be based on temperature cycling, with power cycling or thermal shock added according to actual working conditions, and combined with thermal resistance testing, interfacial nondestructive testing, connection strength, and dimensional stability evaluation.

A truly effective test plan should not only confirm whether the product can pass the specified stress but also identify the location where damage occurs, its evolution pattern, and its impact on heat dissipation performance and service life.



H. Processing and Customization of Tungsten-Copper Alloy

Q55 Can tungsten-copper alloy be turned, milled, drilled, and tapped?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) can be turned, milled, drilled, and tapped, and can be used to manufacture electronic packaging heat sinks, semiconductor base plates, electrodes, contacts, and precision structural parts. However, tungsten-copper alloy is a composite material composed of a tungsten phase and a copper phase, and its machinability differs from that of pure copper, pure tungsten, and ordinary steel. The actual difficulty mainly depends on the tungsten-copper ratio, density, microstructural uniformity, part size, and precision requirements.

I. Applicability of four common machining methods

Machining method	Feasible?	Main difficulties	Process recommendations
Turning	Yes	Tungsten phase is hard and tool wear is relatively fast; copper phase causes built-up edge and burrs	Use machine tools with good rigidity, sharp tools, and stable cutting parameters
Milling	Yes	Interrupted cutting easily causes tool impact and micro-chipping edge defects	Use cemented carbide or suitable coated tools, and control radial depth of cut and cutting vibration
Drilling	Yes	Difficult chip removal in deep holes; burrs or micro-chipping may appear at hole openings	Use drill bits suitable for hard composite materials, and reasonably arrange feed, cooling, and chip removal
Tapping	Requires caution	Small internal threads are prone to thread chipping, wear, or dimensional out-of-tolerance	Prioritize evaluation of pilot hole accuracy and thread engagement length; use thread milling or threaded inserts

The above processes can all be implemented, but this does not mean that all tungsten-copper grades are suitable for the same tools and parameters. Especially for high-tungsten-content materials, cutting force, tool wear, and edge damage risk usually require key control.

II. Effect of different tungsten-copper ratios on machinability

The higher the tungsten content of tungsten-copper, the higher the hardness and wear resistance usually are, and the greater the difficulty of traditional cutting machining often is; when the copper content is relatively high, the material may be more prone to built-up edge, chip accumulation, and burrs. Therefore, machining difficulty cannot be judged only by material hardness; tungsten phase particle size, copper phase distribution, and material density should also be considered.

Material type	Turning and milling	Drilling and tapping	Key processing control points
W70Cu30	Relatively easy to cut, but copper phase adhesion still needs control	Can be machined; focus on controlling burrs and hole wall quality	Tool sharpness, chip removal, and surface quality
W75Cu25	Cutting performance and wear resistance are in a compromise state	Can be machined, but attention should be paid to small hole and internal thread quality	Tool wear, dimensional stability
W80Cu20	Usually requires stricter control of tool wear	Drilling and tapping difficulty may increase	Tool material, cutting parameters, edge chipping
High tungsten content	Traditional cutting machining difficulty further increases	Small holes, deep holes, and fine internal threads especially require caution	When necessary, compare alternative processes such as grinding and EDM

The table shows general trends; actual machining performance should be based on specific grades and trial cutting results.

III. Turning and milling: how to improve machining quality?

Turning is mainly used to machine outer diameters, end faces, steps, and cylindrical structures; milling is suitable for machining planes, grooves, steps, contours, and mounting surfaces. For tungsten-copper precision parts, it is recommended to focus on controlling the following factors.

First, tools should balance wear resistance and edge stability.

Cemented carbide tools can usually serve as the starting point for conventional machining; for high-tungsten-content, batch machining, or high-precision working conditions, suitable coated cemented carbide tools can be further evaluated. It cannot simply be assumed that the harder the coating, the better; tool substrate, edge geometry, and coating compatibility are equally important.

Second, cutting vibration and excessive instantaneous loads should be avoided.

The tungsten phase and copper phase in tungsten-copper materials have different mechanical properties. When cutting conditions are unstable, local edge chipping, surface micro-defects, or dimensional fluctuations may occur. When machining thin-walled structures, clamping force should also be controlled to avoid workpiece deformation.

Third, rough machining and finish machining should preferably be arranged separately.
After rough machining, an appropriate stabilization process can be arranged according to part structure and precision requirements before finish machining, to reduce the impact of residual stress release and clamping changes on dimensions.

IV. Drilling and tapping: what needs the most attention?
The main problems in drilling are tool wear, hole diameter deviation, poor chip removal, and exit burrs. During deep hole machining, special attention should be paid to chip evacuation and cooling conditions to avoid cutting heat accumulation and tool sticking. For thin-walled heat sinks or holes close to edges, the distance between hole positions and edges should be controlled to reduce the risk of local defects. Tapping is usually more sensitive than ordinary drilling, especially for small threads, short engagement lengths, and high-tungsten-content materials. The tungsten-copper composite microstructure may cause local chipping of the thread profile, and the copper phase may also cause chip adhesion. Before machining, confirm whether the pilot hole size, pitch, effective engagement length, and fastening load are reasonable.

For parts that withstand relatively high preload, repeated disassembly and assembly, or long-term vibration, three options can be compared: directly tapping internal threads in tungsten-copper, using thread milling, or installing metal threaded inserts. If the part wall thickness is small or the thread size is very fine, the latter two options may more easily achieve stable assembly performance, but they need to be verified in combination with structural space and connection load.

V. When should grinding or EDM be considered?
When tungsten-copper parts have high-precision planes, strict flatness requirements, micro-holes, complex narrow grooves, or relatively high tungsten content, traditional cutting may not be the most economical or stable solution.

Machining requirement	Processes that can be evaluated
High-precision planes and relatively low surface roughness	Precision grinding, lapping
Micro-holes or complex narrow grooves	Electrical discharge machining (EDM, Electrical Discharge Machining)
Complex contours of high-tungsten-content materials	Combination of mechanical machining and EDM
Flatness and thickness control of precision heat sinks	Finish machining, lapping, and flatness inspection

EDM is suitable for conductive tungsten-copper alloy, but machining efficiency, surface recast layer, microcrack risk, and electrode wear still need to be evaluated. For electronic packaging parts, if the machined surface serves heat conduction or connection functions, surface integrity and compatibility with subsequent welding, brazing, or metallization processes should also be verified.

VI. What inspections should be carried out after machining?
After tungsten-copper parts are machined, it is recommended to check dimensional and geometric accuracy, hole diameter and thread gauge conformity, surface roughness, burrs, and

edge chipping according to the application. When used for electronic packaging heat sinks, flatness, parallelism, surface defects, and cleanliness of the connection interface should also be considered; when used for electrodes or electrical contacts, electrical conductivity, contact performance, or arc resistance-related verification should be added according to actual functions. For tungsten-copper heat sinks, precision electrodes, and other complex structural parts, CTIA GROUP can be consulted for information on related materials and precision machining directions.

We believe that tungsten-copper alloy can fully be turned, milled, drilled, and tapped, but high tungsten content, small-size holes, fine internal threads, and high-precision packaging surfaces require stricter process control. Actual production should first conduct trial cutting according to the grade to verify tool life, dimensional stability, and surface quality, and then determine batch machining parameters.



Q56 Is tungsten-copper alloy suitable for EDM and wire cutting?

Tungsten-copper alloy is suitable for EDM and wire cutting. Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) is electrically conductive and contains a high-melting-point, high-hardness tungsten phase. Traditional turning, milling, and drilling may face problems such as relatively fast tool wear and difficulty in machining micro-structures. Therefore, for complex contours, narrow grooves, micro-holes, and high-precision structures, EDM and wire cutting are both processes worth considering. However, the applicable ranges of the two processes are different: die-sinking EDM is suitable for complex cavities and non-through structures, while wire cutting is suitable for contours and precision two-dimensional shapes that can be cut through by a wire electrode.

I. What is the difference between EDM and wire cutting?

Comparison item	Die-sinking EDM	Wire EDM
English name	Electrical Discharge Machining (EDM)	Wire Electrical Discharge Machining (Wire EDM)
Machining principle	Pulse discharge occurs between a shaped electrode and the workpiece, gradually eroding the material	Pulse discharge occurs between a fine metal wire and the workpiece, cutting along a set path
Main uses	Cavities, blind grooves, complex concave structures, special hole shapes	Through holes, narrow grooves, outer contours, precision two-dimensional contours
Whether a dedicated shaped electrode is required	Usually required	Usually no shaped electrode is required; a continuously traveling wire electrode is used
Typical advantages	Can machine complex cavities and non-through structures	Relatively high contour accuracy, suitable for complex shapes and narrow slits
Main limitations	Electrode manufacturing, wear, and discharge gap need to be controlled	The workpiece needs a wire threading hole or a starting position where the wire electrode can enter
Typical W-Cu application scenarios	Complex grooves, blind holes, special-shaped structures	Precision outer shapes, narrow grooves, through contours, and thin plate cutting

Both belong to non-traditional machining methods and do not rely on ordinary cutting tools to directly cut the material, but machining quality is still affected by discharge parameters, material microstructure, flushing conditions, and equipment accuracy.

II. Why is tungsten-copper alloy suitable for EDM?

Tungsten-copper alloy is electrically conductive and can establish pulse discharge between the electrode and the workpiece. The local high temperature generated by the discharge melts or vaporizes the workpiece surface material, which is then carried away by the working fluid, gradually forming the required shape. The machining characteristics of tungsten-copper alloy mainly include three points.

First, it is suitable for machining high-hardness material structures.

The tungsten phase has high hardness and a high melting point, and traditional tool machining may cause wear and reduced machining efficiency. EDM does not rely on tool hardness to directly cut the workpiece, so it can machine structures that are difficult to handle by traditional

mechanical machining.

Second, it is suitable for complex geometric shapes.
For structures such as narrow grooves, special-shaped holes, and local grooves in precision heat sinks, electronic packaging components, and electrodes, EDM can reduce the limitations of dedicated cutting tools.

Third, it is suitable for fine machining, but the heat effect needs to be controlled.
EDM forms a recast layer and heat-affected zone; if the discharge energy is too large or the machining parameters are unsuitable, microcracks, increased surface roughness, or local microstructural damage may occur. Therefore, for high-reliability electronic packaging parts, reasonable setting of rough machining, finish machining, and necessary post-processing procedures is usually required.

III. Is tungsten-copper alloy suitable for wire cutting?
Yes. Wire cutting is especially suitable for tungsten-copper parts that require high-precision outer contours, through narrow grooves, thin sheet contours, and complex two-dimensional shapes. For example, tungsten-copper alloy can be wire-cut to machine electrode contours, precision shims, special-shaped metal sheets, and some packaging structural parts. However, wire cutting requires the workpiece to have a starting channel through which the wire electrode can pass, and it usually cannot directly machine closed blind cavities like die-sinking EDM. The quality control points of wire cutting include cutting speed, pulse energy, wire travel state, working fluid conditions, and multi-pass trimming strategy. For thin-walled or precision parts, residual stress release and workpiece deformation during cutting should also be controlled.

IV. What effect does different tungsten-copper ratios have on EDM?
The tungsten-copper ratio affects EDM efficiency, surface quality, and machining stability, but machining performance cannot be judged only by tungsten content. The tungsten phase and copper phase in tungsten-copper alloy differ in electrical conductivity, thermal conductivity, and erosion behavior, and material density, porosity, and microstructural uniformity also affect the discharge process.

Material type	Characteristics that may appear during machining	Key process control points
W70Cu30	Higher copper content; thermal and electrical conductivity characteristics are usually more favorable for heat conduction	Optimize discharge energy, flushing, and surface quality
W75Cu25	Can serve as a candidate material for comprehensive performance comparison	Determine stable parameters through trial machining
W80Cu20	Higher tungsten content; local discharge response and material microstructure affect uniformity	Control discharge energy, surface defects, and dimensional deviation
Higher tungsten grades	Key evaluation of discharge stability, machining efficiency, and surface integrity	Determine pulse parameters and finish machining strategy through process tests

These are preliminary judgment directions, not fixed machinability rankings. Different

equipment, electrode materials, working fluids, and pulse parameters may change actual machining results.

V. How to improve machining accuracy and surface quality?

For tungsten-copper alloy, it is recommended to adopt a strategy of separating rough machining and finish machining. The rough machining stage mainly focuses on stable material removal, while the finish machining stage reduces single-discharge energy and uses multiple fine trimming passes to reduce surface roughness, recast layer, and dimensional error. In actual production, the following factors should be controlled:

Discharge parameters: Reasonably adjust pulse width, pulse interval, peak current, and discharge energy to avoid excessive concentrated heat input.

Working fluid and chip removal: Maintain sufficient flushing and a stable discharge gap to reduce secondary discharge caused by retained machining debris.

Electrode and wire travel conditions: For EDM, electrode wear and electrode size compensation should be controlled; for wire cutting, stable wire travel and appropriate tension should be ensured.

Post-processing and inspection: Remove burrs and surface residues as required, inspect dimensions, contours, and roughness, and evaluate the recast layer and microcracks for critical parts.

If the machining object is an electronic packaging heat sink, special attention should also be paid to the quality of the connection surface. Even if the dimensions are qualified, surface recast layer, microcracks, or local thermal damage may affect subsequent brazing, sintered connection, or thermal conduction performance.

VI. How should the process be selected?

Machining requirement	Process to be prioritized
Complex blind grooves, concave cavities	Die-sinking EDM
Precision outer contours, through narrow grooves	Wire EDM
High-precision planes and low-roughness surfaces	Precision grinding or lapping
Both complex contours and high surface quality	Wire cutting or die-sinking EDM rough machining, followed by finish machining
Critical packaging surfaces or high-reliability connection surfaces	Select EDM according to structure, and verify surface integrity and connection performance

For tungsten-copper alloy precision electrodes, heat sinks, and packaging structural parts, CTIA GROUP can be consulted for information on related materials and machining directions.

Tungsten-copper alloy is suitable for both die-sinking EDM and wire EDM. The former mainly solves the machining problems of complex cavities and non-through structures, while the latter is mainly used for precision contours and through cutting. The final process should be determined jointly according to the tungsten-copper grade, part geometry, dimensional tolerances, surface quality requirements, and subsequent connection processes.

Q57 How to control dimensional tolerances, flatness, and parallelism in precision machining of tungsten-copper alloy?

To stably control dimensional tolerances, flatness, and parallelism in precision machining of tungsten-copper alloy, the key is not only to improve machine tool accuracy, but also to simultaneously control material microstructure, machining allowance, clamping deformation, cutting heat, residual stress, and inspection methods. For tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) heat sinks, semiconductor packaging base plates, electrodes, and precision structural parts, it is especially necessary to prevent deformation after rough machining, local edge chipping during finish machining, and errors caused by measurement temperature and clamping methods.

I. What are the differences among the three precision indicators?

Indicator	Control object	Common influencing factors	Main inspection methods
Dimensional tolerance	Dimensions such as length, thickness, hole diameter & groove width	Tool wear, thermal deformation, machine tool positioning error, measurement error	Micrometer, coordinate measuring machine, bore gauge, etc.
Flatness	Deviation of a single surface from an ideal plane shape	Clamping deformation, internal stress release of material, uneven machining heat	Flatness meter, coordinate measuring machine, precision platform with dial indicator
Parallelism	Directional relationship between two surfaces or datums	Unreasonable datum selection, clamping tilt, inconsistent surface machining datums	Coordinate measuring machine, precision platform and dial indicator, etc.

Dimensional tolerance focuses on whether the actual size is within the specified range; flatness evaluates the flatness of a surface itself; parallelism evaluates the directional relationship between two surfaces. Even if the thickness of a part is qualified, its flatness may be out of tolerance; two surfaces that are each flat are not necessarily parallel to each other.

II. How to control dimensional tolerances?

Adopt staged rough machining, semi-finish machining, and finish machining

It is not recommended to directly complete all dimensions in one clamping or one operation. A more reliable way is to first remove most of the allowance, then release part of the machining stress through semi-finish machining, and finally complete finish machining with stable clamping and cutting conditions. For example, when a tungsten-copper heat sink needs to control the final thickness, two datum surfaces can be machined first, then one datum surface is used for positioning to machine the other surface, and finally precision grinding is performed to the target thickness. The specific allowance should be determined according to part size, material state, machine tool capability, and final tolerance, and a fixed ratio should not be applied to all parts.

Control tool wear and cutting parameters

The tungsten phase in tungsten-copper has relatively high hardness, which may accelerate tool wear; the copper phase may cause adhesion, burrs, and local material dragging. Tool wear will gradually change the actual cutting dimensions, especially affecting hole diameter, groove width, step height, and precision outer shapes. In production, cutting speed, feed rate, and cutting depth should be determined through trial machining, the relationship between tool life and dimensional deviation should be established, and tool inspection or replacement cycles should be set. For high-tungsten-content grades, edge wear and micro-chipping should be monitored emphatically.

Control temperature and measurement conditions

Precision parts expand due to heat during machining, and their dimensions change after cooling. If the temperature during machining and measurement differs, systematic deviation may occur in the measurement results. For high-precision parts, it is recommended to complete final inspection in a temperature-stable environment and record the part temperature, measuring equipment status, and measurement datum. If drawing dimensions are based on the standard reference temperature, judgment should be made according to the corresponding metrological requirements to avoid mistaking thermal expansion during machining for permanent dimensional deviation.

III. How to control flatness?

The flatness of tungsten-copper alloy heat sinks and packaging base plates is usually affected jointly by clamping, internal stress of the material, and machining heat.

First, excessive clamping force or uneven force should be avoided. Thin plates and large-area parts may temporarily deform when clamped, and after machining, although the clamp is released, warpage may occur due to elastic recovery. Uniform support, low-deformation fixtures, or appropriate vacuum adsorption schemes can be used according to the structure, but it must be confirmed that the fixture itself will not cause local adsorption deformation.

Second, the machining amount on both sides should be reasonably distributed. If material removal on both sides of the part is uneven, bending may occur after residual stress is redistributed. For heat sinks requiring high flatness, flatness can be checked after rough machining, and then necessary stabilization processes and two-sided finish machining can be arranged.

Finally, for packaging surfaces with strict flatness requirements, precision grinding, lapping, or other applicable finish machining methods can be used. During machining, grinding heat, grinding wheel condition, and cooling conditions should be controlled to avoid local burns, microcracks, or thermal deformation. The specific process should be determined in combination with the material grade and surface function requirements.

IV. How to control parallelism?

The core of parallelism control is to establish a reliable machining datum and ensure that the relative directional relationship between the two measured surfaces remains stable during the

process. For the upper and lower surfaces of a tungsten-copper heat sink, it is recommended to first machine and inspect one datum surface, and then use that datum surface as the positioning basis for subsequent machining and inspection. If the positioning datum is repeatedly changed during machining, errors may gradually accumulate, causing the two surfaces to be non-parallel or the thickness distribution to be uneven.

Control measure	Role
Unify the machining datum	Reduce datum conversion errors caused by multiple clampings
Use reliable positioning and support	Avoid part tilting or force deformation
Control the removal amount during two-sided finish machining	Reduce directional deviation caused by stress redistribution
Measure thickness at multiple positions after machining	Judge the thickness variation trend and assist in identifying parallelism problems
Use a coordinate measuring machine or precision measurement system	Evaluate results according to drawing datums and specified geometric tolerances

Thickness measurement at multiple positions can help judge parallelism trends, but it cannot replace standardized geometric tolerance inspection in all cases. For high-precision parts, acceptance should be carried out according to the datum system and geometric tolerance requirements specified in the drawing.

V. How do different machining processes cooperate?

Machining process	Applicable tasks	Precision control points
Turning	Outer diameters, end faces, steps, and shaft-type features	Tool wear, clamping coaxiality, cutting heat
Milling	Planes, grooves, steps, and contours	Machine tool rigidity, tool runout, cutting vibration
Grinding	High-precision planes, thickness, and dimensional finish machining	Grinding heat, grinding wheel condition, clamping deformation
Lapping	Functional surfaces with high flatness and relatively low surface roughness	Lapping pressure, contact uniformity, and material removal consistency
EDM	Complex cavities, narrow grooves, and difficult-to-cut structures	Discharge gap, recast layer, heat effect, and post-machining dimensional compensation
Wire EDM	Precision through contours and narrow slits	Wire travel stability, cutting deformation

EDM and wire cutting are suitable for complex shapes, but if the final functional surface requires very high flatness, low roughness, or stable connection performance, subsequent grinding, lapping, or other finish machining processes usually still need to be evaluated.

VI. How to establish an executable quality control process?

For tungsten-copper alloy precision parts, it is recommended to link machining and inspection rather than performing only one dimensional inspection at the end.

Process stage	Main control content	Inspection focus
Raw material acceptance	Grade, ratio, density, and material state	Material certificate, density, necessary microstructure inspection
Rough machining	Remove main allowance, control clamping force and heat input	Blank dimensions, initial warpage, obvious defects
Semi-finish machining	Stabilize datum, release part of stress, correct shape	Dimensional allowance, flatness trend
Finish machining	Control tool or grinding wheel condition, machining temperature, and clamping	Final dimensions, flatness, parallelism
Cleaning & final inspection	Remove burrs, residues, and surface contamination	Key dimensions, surface quality, geometric tolerances
Batch verification	Check repeatability and process stability	Batch deviation, process capability, and nonconforming rate

For high-reliability electronic packaging parts, final inspection should also be combined with actual functions. For example, when the heat sink is connected to the ceramic substrate, in addition to geometric tolerances, attention should also be paid to the surface roughness, cleanliness, metallization layer state of the connection surface, and warpage after welding or sintering.

For materials and machining solutions for tungsten-copper heat sinks and precision structural parts, CTIA GROUP can also be consulted. When actually formulating the process, it is best to first clarify the dimensional tolerances, flatness, parallelism, surface roughness, and inspection datums in the part drawing, and then determine the machining route and inspection method.

Only when the machining datum, clamping method, material state, finish machining process, and measurement conditions match each other can the dimensions and geometric accuracy of tungsten-copper alloy precision parts be stably controlled.



Q58 Can tungsten-copper alloy be ground, polished, and surface-coated?

Tungsten-copper alloy (W-Cu, Tungsten-Copper Composite) can be ground, polished, and surface-coated. These processes are commonly used for electronic packaging heat sinks, semiconductor base plates, electrodes, electrical contacts, and precision structural parts to improve dimensional accuracy, surface roughness, soldering performance, corrosion resistance, and electrical contact performance. However, the three processes solve different problems: grinding mainly controls dimensions and geometric accuracy, polishing mainly improves surface quality, and coating mainly adjusts surface functions. The specific process needs to be determined in combination with the tungsten-copper ratio, surface state, part application, and subsequent connection method.

I. What are the differences among grinding, polishing, and coating?

Process	Main purpose	Typical application	Main control indicators
Grinding	Remove material, correct flatness and dimensions	Heat sink base plates, precision mounting surfaces, packaging substrates	Flatness, parallelism, thickness tolerance, surface roughness
Polishing	Reduce surface roughness, improve surface uniformity	Precision packaging surfaces, electrode working surfaces, connection surfaces	Surface roughness, scratches, microcracks, local pits
Coating	Improve wettability, electrical contact, corrosion resistance, or connectivity	Soldering base plates, electrical contact parts, electronic packaging surfaces	Coating thickness, adhesion, porosity, coverage uniformity

Grinding and polishing are material removal processes, while coating is a surface modification process. Usually, main dimensional processing should be completed first, followed by grinding

and polishing; if the product requires coating, it should be carried out after the substrate surface reaches the specified dimensions, roughness, and cleanliness, and the coating thickness should be included in the final dimensional tolerance calculation.

II. How is tungsten-copper alloy ground?

Tungsten-copper alloy can be processed by surface grinding, precision grinding, and other processes. For heat sinks and electronic packaging base plates, the focus of grinding is often to control thickness, flatness, and parallelism so that they maintain good contact when connected to ceramic substrates or chips.

The tungsten phase has high hardness, while the copper phase is relatively soft, and the removal rates of the two phases during grinding may differ. If the abrasive, pressure, or processing time is improperly selected, the surface may show copper phase depression, tungsten phase protrusion, edge chipping, or local scratches.

Process control usually includes: selecting abrasives and grinding discs suitable for the material hardness and surface requirements, maintaining uniform pressure and stable motion trajectory, controlling grinding heat and cooling conditions, and inspecting thickness and flatness in stages during processing. For high-precision parts, simply increasing grinding pressure to increase removal speed should be avoided to prevent deformation or surface defects.

III. What should be noted when polishing tungsten-copper alloy?

Polishing can further reduce surface roughness and improve appearance and the microscopic quality of connection surfaces, but longer polishing is not necessarily better. Because the hardness, plasticity, and removal characteristics of the tungsten phase and copper phase differ, tungsten-copper alloy may experience uneven removal of the two phases. When the copper phase is excessively removed, microscopic depressions may form on the surface; when the tungsten phase locally protrudes, it may affect the uniformity of subsequent coatings and the actual contact state of the connection interface. Therefore, the polishing process should set targets according to the part application. If used for electronic packaging heat sinks, priority should be given to controlling flatness, surface roughness, and cleanliness of the connection surface; if used for electrodes or electrical contacts, contact area, surface defects, and actual electrical contact performance should also be considered.

Surface roughness is usually expressed as Ra (Arithmetic Average Roughness), but the Ra value alone is not enough to judge whether the surface is qualified. For welding, brazing, or sintering connection surfaces, evaluation should also be combined with surface morphology, oxidation state, cleanliness, and connection process.

IV. What metals can be plated on tungsten-copper alloy?

Tungsten-copper alloy has electrical conductivity and can undergo appropriate metal electroplating or other surface metallization treatments. Common coatings and their uses are as follows:

Coating	Main function	Common application	Process concerns
Nickel	Provides a barrier layer, improves corrosion resistance and coating bonding conditions	Electronic packaging base plates, electrodes, metallized parts	Adhesion, thickness uniformity, internal stress
Gold	Improves surface oxidation resistance and electrical contact stability	High-reliability electronic contact surfaces, some packaging surfaces	Cost, wear, coating thickness, and underlying layer system
Silver	Provides relatively high electrical conductivity and lower contact resistance potential	Electrical contact parts and specific conductive surfaces	Sulfidation discoloration, wear, coating adhesion
Copper	Facilitates subsequent soldering, brazing, or further metallization	Electronic packaging, connection surfaces	Oxidation, diffusion, subsequent surface protection
Tin	Improves wettability of some soldering processes	Electronic components adapted to specific solder systems	Must evaluate tin whiskers, storage environment, and soldering reliability

Coating is not simply a matter of directly selecting a certain metal. For tungsten-copper composite materials, surface pretreatment, two-phase microstructure differences, and coating adhesion should be evaluated first. If the substrate surface has pores, contamination, oxidation, or a high height difference between the two phases, even if the initial coating appearance is good, blistering, peeling, or local failure may occur after thermal cycling, soldering, or mechanical loading.



V. Key processes of tungsten-copper alloy coating treatment

Typical process route for tungsten-copper alloy coating treatment:

substrate inspection → precision machining → grinding or polishing → degreasing and cleaning → surface activation or appropriate pretreatment → coating deposition → necessary post-treatment → coating and dimensional inspection.

Among these, pretreatment is particularly important. The surface state of tungsten-copper

alloy is affected by the distribution of the tungsten phase and copper phase and the manufacturing process, and conventional cleaning or activation schemes may not be applicable to all grades. During process development, the surface wetting state, coating adhesion, coating thickness uniformity, and stability after heat treatment or soldering should be verified. For high-reliability electronic packaging components, it is recommended to evaluate at least coating thickness, adhesion, porosity or defects, surface roughness, blistering and peeling after thermal cycling, and wetting performance in subsequent soldering or brazing. For electrical contact parts, contact resistance and performance testing after wear should also be added.

VI. How should processes be combined for different applications?

Application scenario	Recommended process approach
Semiconductor packaging heat sink	Precision machining → double-sided grinding or fine grinding → necessary polishing → metallization treatment suitable for soldering or brazing
High-power laser heat sink	Control flatness and roughness → cleaning → select coating system according to connection method
EDM electrode	Machine to shape → necessary surface finishing → decide whether surface treatment is needed according to the use environment
Electrical contact or conductive part	Precision machining → grinding or polishing of contact surface → select coating according to electrical contact requirements and verify contact resistance
High-reliability precision part	Based on drawing dimensions and functional requirements, formulate a complete process for processing, surface treatment, and reliability testing

For tungsten-copper precision components, CTIA GROUP can be consulted for information on materials and processing directions. Tungsten-copper alloy can be ground, polished, and surface-coated. Grinding is used to stabilize dimensions and geometric accuracy, polishing is used to improve surface quality, and coating is used to meet conductive contact, corrosion resistance, or subsequent connection requirements. For electronic packaging components, the most important thing is to ensure substrate surface quality, coating adhesion, and subsequent connection reliability, rather than simply pursuing surface brightness or coating thickness.

Q59 Can tungsten-copper alloy be connected to copper, ceramics, or other metals?

Tungsten-copper alloy can be connected to copper, ceramics, stainless steel, molybdenum, Kovar alloy, and many other materials, and is widely used in electronic packaging, power semiconductor heat sinks, vacuum electrical devices, and high-temperature structural parts. Because tungsten-copper alloy is composed of a tungsten (W, Tungsten) skeleton and a copper (Cu, Copper) phase, combining the high melting point of the tungsten phase and the high thermal conductivity of the copper phase, its connection process needs to simultaneously consider the coefficient of thermal expansion, wettability, connection temperature, and thermal cycle reliability of the materials.

I. Connection methods between tungsten-copper alloy and different materials

Connection object	Recommended connection process	Key control factors
Cu & Cu alloys	Brazing, diffusion welding, electron beam welding, or laser welding, depending on the structure	Risk of copper phase melting, joint strength, thermal deformation, and interfacial microstructure
Ceramics such as Al oxide & Al nitride	Active metal brazing, brazing after metallization	Ceramic brittleness, wettability, thermal expansion mismatch, and residual stress
Mo & moly alloys	Diffusion welding, brazing, local fusion welding, etc.	Thermal expansion matching, interfacial bonding, and high-temperature performance
Stainless steel	Brazing, diffusion welding; laser welding can be used for some structures	Thermal expansion difference between the two materials, interfacial brittle phases, & heat affected zone
Kovar alloy (Fe-Nil-Co alloy)	Brazing, diffusion welding, often used in combination with ceramic packaging structures	Sealing temperature, thermal expansion matching, and airtightness
Nickel-based alloys	Brazing, diffusion welding; fusion welding used in some working conditions	High-temperature strength, interfacial reaction, and corrosive environment

The above processes are not applicable to all grades and structures. The tungsten content, porosity, copper phase continuity, surface state, and part thickness of tungsten-copper alloy all affect the connection effect.

II. Connection between tungsten-copper alloy and copper

The connection of tungsten-copper to pure copper or copper alloy is often used for power device base plates, heat sinks, and conductive heat dissipation components. For thin-layer, planar, or large-area joints, brazing or diffusion welding is usually evaluated first. Brazing forms a connection through an intermediate brazing filler metal, and the process window is relatively flexible; diffusion welding relies on temperature, pressure, and interfacial diffusion to form a bond, and is suitable for structures with requirements for joint density and dimensional stability. If laser welding or other fusion welding processes are used, heat input needs to be carefully controlled. The melting point of the copper phase in tungsten-copper alloy is much lower than that of the tungsten phase, and local overheating may cause copper phase melting, spattering, porosity, or microstructural non-uniformity. Processing cannot simply follow the welding parameters for pure copper.

III. Connection between tungsten-copper alloy and ceramics

When tungsten-copper is connected to aluminum oxide (Al_2O_3, Aluminum Oxide) or aluminum nitride (AlN, Aluminum Nitride) ceramics, the main difficulty is not simply achieving adhesion, but simultaneously obtaining reliable interfacial bonding, relatively low residual stress, and good airtightness or thermal conductivity. Two processes are commonly used:

Active metal brazing uses brazing filler metals containing active elements such as titanium to promote wetting and reaction bonding of the filler metal to the ceramic surface, and is suitable for direct connection between ceramic and metal.

Brazing after ceramic metallization first forms a weldable metal layer on the ceramic surface, and then connects the tungsten-copper alloy through brazing filler metal. It is suitable for products that require control of the metallization layer, joint thickness, and packaging process.

Ceramics themselves are relatively brittle, so the brazing filler layer thickness, connection area, edge structure, and cooling rate must be controlled. The closer the coefficients of thermal expansion of tungsten-copper and ceramic, the more favorable it is usually to reduce interfacial stress caused by temperature changes, but evaluation is still needed in combination with the ceramic grade, joint dimensions, and actual temperature range.

IV. Process selection when connecting tungsten-copper alloy to other metals

In addition to copper and ceramics, tungsten-copper alloy can also be connected to molybdenum, stainless steel, Kovar alloy, and nickel-based alloys. During selection, judgment can be made according to the following principles.

Process	Applicable characteristics	Main limitations
Brazing	Suitable for dissimilar materials, complex structures, and relatively large contact surfaces	The brazing filler layer may become a thermal resistance or weak interface
Diffusion welding	Suitable for high-quality, low-porosity joints and precision structures	High requirements for surface quality, pressure, temperature, and fixturing
Laser welding	Concentrated heat input, suitable for local connections	High requirements for copper phase distribution and heat input control of tungsten-copper materials
Electron beam welding	Can achieve local connection with high energy density, suitable for specific precision structures	High requirements for equipment and vacuum conditions, and process development is relatively difficult
Mechanical connection	Convenient for disassembly and maintenance, can avoid overall heating	Contact thermal resistance, fastening force decay, and thermal cycle loosening need to be evaluated

For electronic packaging heat dissipation components, brazing and diffusion welding should usually be compared first; for detachable structures, bolts, clamping, or other mechanical connection methods can be considered; for local complex contours, processes such as laser welding need to be evaluated according to the material combination and joint geometry.

V. How to improve connection reliability

The connection quality of tungsten-copper alloy mainly depends on the following aspects.

The first is thermal expansion matching. When the difference in coefficient of thermal

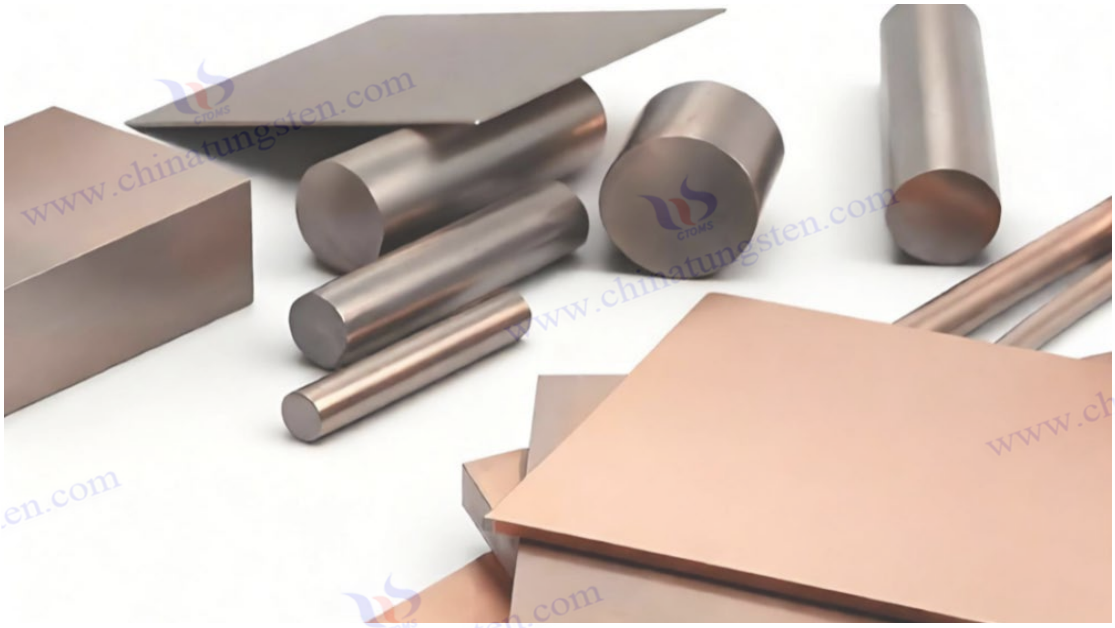
expansion (CTE, Coefficient of Thermal Expansion) of the connected materials is too large, heating and cooling will generate relatively high thermal stress at the joint, and in severe cases may cause ceramic cracking, brazing filler fatigue, or interfacial peeling.

The second is surface treatment. The connection surface should have appropriate flatness, roughness, and cleanliness, and oil stains, oxides, and processing residues should be removed. For structures requiring nickel, gold, or other metal layers, the coating adhesion, thickness uniformity, and compatibility with the brazing filler metal should also be verified.

The third is joint structure. The brazing filler gap, overlap area, fillet, and edge transition should be reasonably designed to avoid stress concentration caused by sharp corners and local stiffness. For high thermal conductivity packaging components, joint thermal resistance should also be evaluated to avoid a situation where the connection is firm but heat dissipation performance decreases.

The last is inspection after connection. Shear or tensile tests, ultrasonic or other applicable nondestructive testing, thermal resistance testing, temperature cycling tests, and airtightness testing can be arranged according to the application. If the product is used for power semiconductors or vacuum packaging, material-level performance and actual component-level reliability should be verified separately.

For the connection of tungsten-copper alloy to copper, the focus is on controlling heat input and joint thermal resistance; for connection to ceramics, the focus is on wetting, thermal expansion matching, and residual stress; for connection to other metals, selection should be made among brazing, diffusion welding, fusion welding, and mechanical connection according to the material combination, service temperature, and structural requirements.



Q60 What drawings, dimensions, and technical parameters are required to customize tungsten-copper alloy parts?

When customizing tungsten-copper alloy parts, it is recommended to provide part drawings, key dimensions and tolerances, tungsten-copper alloy grade or performance requirements, processing and surface treatment requirements, service conditions, and inspection standards. The more complete the information, the more conducive it is to accurately evaluating material selection, processing feasibility, production cost, and delivery cycle. If a complete drawing is not available temporarily, a 3D model, hand-drawn sketch, or physical dimensions can be provided first, and the supplier can further confirm the technical details.

I. Drawings and dimensional information to be provided

Information item	Specific content	Importance
2D engineering drawing	Part front view, top view, section view, detail view	Required
3D model	STEP, STP, IGES, and other formats, describing complex surfaces and internal structures	Recommended for complex parts
Overall dimensions	Length, width, height, diameter, thickness, step height, etc.	Required
Holes and threads	Hole diameter, hole depth, hole spacing, thread specification, pitch, effective depth	Provided according to structure
Dimensional tolerance	General dimensional tolerance, key fit dimensional tolerance	Required
Geometric tolerance	Flatness, parallelism, perpendicularity, coaxiality, position tolerance, etc.	Recommended for precision parts
Surface roughness	For example, Ra 0.8 μm, Ra 1.6 μm, marked separately according to functional surfaces	Recommended
Datum & measurement requirements	Datum surface, positioning holes, inspection datum, and assembly datum	Recommended for precision parts

The drawing should indicate as much as possible all key dimensions that affect assembly, heat conduction, sealing, or positioning, and avoid providing only the overall length, width, and height. For parts with blind holes, deep grooves, thin walls, special-shaped surfaces, or complex internal cavities, it is recommended to provide section views and 3D models at the same time.

II. Tungsten-copper alloy material parameters to be determined

Different tungsten contents of tungsten-copper alloy will change density, thermal conductivity, coefficient of thermal expansion, processing difficulty, and cost. If the grade has been determined, it should be directly indicated; if not yet determined, performance targets can be proposed according to the application, and the supplier can recommend the material.

Technical parameter	Common filling method	Main function
Material grade	W70Cu30, W75Cu25, W80Cu20	Determine the tungsten-copper ratio & material performance range
Tungsten content	For example, 70%, 75%, 80%	Adjust thermal expansion, density & comprehensive performance
Density	g/cm³, indicating the min.value	Check material quality and density
Thermal conductivity	W/(m·K), min. requirement	Used for heat dissipation design
Coefficient of thermal expansion	μm/(m·K) or $\times 10^{-6}$/K, with temperature range indicated	Used to match chips, ceramics, and other metals
Electrical conductivity	MS/m, % International Annealed Copper Standard (IACS), etc.	Used for electrodes, conductive structures, and electronic packaging
Hardness	Specify the test method and required range	Used to evaluate wear resistance and processing performance
Material state	Sintered, infiltrated, and other agreed process states	Affect microstructure, density, and performance consistency

W70Cu30 usually leans toward higher thermal conductivity requirements, and W80Cu20 usually leans toward lower thermal expansion requirements, but specific performance depends on the material manufacturing process and the supplier's measured data, and all performance indicators cannot be inferred solely from the grade. If the part is used for semiconductor packaging, ceramic substrates, or precision heat sinks, it is best to also provide the grade, coefficient of thermal expansion, working temperature, and allowable temperature rise of the mating materials so as to evaluate material matching.

III. Processing and surface treatment requirements to be clarified

Tungsten-copper alloy parts may involve turning, milling, drilling, tapping, grinding, lapping, EDM, and wire cutting. Special processing requirements should be indicated in drawings or technical agreements, especially for deep holes, small threads, thin-walled areas, and precision fitting surfaces. In terms of surface treatment, it should be stated whether grinding, polishing, nickel plating, gold plating, silver plating, or other coatings are required, and the coating thickness, coverage area, surface roughness, and adhesion requirements should be clarified. If the part needs brazing, welding, or connection with ceramics, the connection area, connection method, brazing filler or coating requirements, and dimensional and performance acceptance standards after connection should also be indicated.

IV. Service conditions and quality requirements to be provided

The actual application of the part often determines the final material solution. It is recommended to provide the following information: working temperature and temperature change range, heat flow or heat generation power, mechanical load borne, whether current is carried, whether in a vacuum or corrosive environment, whether airtightness is required, whether frequent temperature cycling occurs, and expected service life. Inspection requirements should also be clarified as much as possible, such as full inspection or sampling inspection of dimensions, key dimension inspection reports, material composition or performance reports, nondestructive testing, thermal resistance testing, temperature cycling tests, and surface coating inspection. For high-reliability parts, inspection methods, sampling ratios, acceptance limits, and report formats should be agreed in advance.

V. Customization information list that can be sent directly to the supplier

Tungsten-Copper Alloy Part Inquiry Information Form
Customer Filling Form for CTIA GROUP

Item	Content
Part/component name and application	
Part/component application	
Drawing or 3D model/image	
Whether a sample is available	
Overall dimensions	
Tolerance/geometric tolerance	
Material grade (content)	
Various performance requirements	
Processing requirements	
Surface treatment	
Service conditions and application	
Required quantity	
Delivery requirements	
Inspection and documents	
Supplementary notes	

After filling in, the organized information can be sent to the supplier CTIA GROUP (sales@chinatungsten.com) for preliminary technical evaluation and quotation. Projects involving tungsten-copper material selection, precision machining, dimensional inspection, and surface treatment can also consult CTIA GROUP for relevant manufacturing solutions. During actual inquiry, the most critical thing is to first clarify the part application, outline drawing, key tolerances, material grade or performance target, and purchase quantity. Other parameters can be gradually supplemented according to the product application, and it is not necessary to determine all of them at the initial stage.

Q61 How to control processing deformation, surface defects, and material loss in complex tungsten-copper alloy parts?

The processing quality of complex tungsten-copper alloy parts mainly depends on residual stress control, processing heat management, tool and process matching, material microstructural uniformity, and machining allowance design. For thin-walled parts, deep-hole parts, special-shaped heat sinks, and high-precision packaging parts, it is not enough to rely only on a single measure of improving machining accuracy; a complete process flow should be established from blank preparation, rough machining, semi-finish machining, finish machining to final inspection.

I. How to control processing deformation

Tungsten-copper alloy is composed of a tungsten phase and a copper phase, and the thermophysical properties of the two phases differ. During processing, cutting force, local temperature rise, release of clamping stress, and material microstructural non-uniformity may all cause dimensional drift, warpage, or flatness out of tolerance.

Source of deformation	Common manifestation	Control method
Blank residual stress	Warpage after processing, gradual dimensional change	Select blanks with stable quality, remove material in stages, and evaluate stress relief processes when necessary
Excessive clamping force	Thin-wall deformation, springback after clamping release	Use uniform clamping, soft jaws, and dedicated positioning fixtures to avoid local excessive pressing
Cutting heat accumulation	Dimensional drift, local deformation	Optimize cutting parameters, cooling method, and processing sequence
Excessive one-side removal	Flatness change, structural bending	Symmetrical machining, alternating machining of both sides, control allowance differences in each area
Non-uniform blank microstructure	Fluctuation of local machining allowance and surface quality	Select materials with stable microstructure and density, and accept key performance

For thin-walled structures, it is recommended to prioritize staged processing. During rough machining, an appropriate allowance should be retained so that the part can release part of the processing stress; then release the clamp to check deformation, reposition if necessary, and then perform semi-finish and finish machining. For symmetrical structures, both sides can be machined alternately to avoid stress imbalance caused by excessive material removal on one side. Precision planar parts can be corrected for flatness and parallelism by fine grinding or lapping. If heat treatment or other stress relief processes are required, their impact on the microstructure, dimensional stability, and copper phase state of tungsten-copper material should be confirmed first; the heat treatment system for ordinary steel cannot be directly applied.

II. How to reduce surface defects

Tungsten-copper alloy is a typical two-phase composite material; the tungsten phase has high hardness, and the copper phase is relatively soft. When processing parameters are unsuitable, tools are worn, or pores exist inside the material, problems such as copper phase smearing,

tungsten phase micro-chipping, pull-out pits, burrs, scratches, and uneven surface roughness may occur.

Surface defect	Main cause	Improvement direction
Scratches, tool marks	Tool wear, chip scratching, poor chip removal	Use sharp tools suitable for the material, improve chip removal and cooling
Micro-chipping, particle detachment	Local fracture of tungsten phase, excessive cutting impact	Reduce impact load, optimize feed rate and tool geometry parameters
Copper phase smearing or smearing	Copper phase softening, tool dulling, excessive local temperature rise	Reduce friction and heat accumulation, control tool wear
Pull-out pits, exposed holes	Blank porosity, poor phase interface bonding, or processing tear	Improve blank density and microstructural consistency, optimize finish machining process
Burrs	Insufficient material support at the exit, poor tool condition	Optimize tool entry and exit paths, add support, use appropriate deburring process
Uneven roughness	Different removal rates of the two phases, unstable processing parameters	Fine grinding, lapping, or polishing, and control allowances of each process

In the finish machining stage, focus should be on tool condition, feed stability, cooling, and workpiece support. For surfaces with high requirements, suitable cutting parameters can be determined first through trial processing, and then whether to use fine grinding, lapping, or polishing can be decided. More polishing is not necessarily better; excessive treatment may cause copper phase depression, tungsten phase protrusion, or edge dimensional loss. If the part subsequently requires nickel plating, brazing, or connection with ceramics, surface cleanliness, roughness, and processing damage layer should also be controlled to avoid a situation where the surface looks smooth but interfacial bonding performance is unstable.

III. How to reduce material loss and processing cost

Tungsten-copper alloy contains a relatively high proportion of tungsten, and the material cost is usually relatively high; moreover, high-tungsten-content materials often have more obvious tool wear problems. Therefore, reducing loss cannot only reduce cutting volume; comprehensive optimization is also needed from blank shape, processing route, tool life, and rework rate.

First, the blank dimensions should be optimized. The blank dimensions should not only leave sufficient machining allowance but also avoid excessive enlargement. For complex contours, near-net-shape blanks or pre-machined blanks can be evaluated according to material supply capability to reduce large-volume removal.

Second, the allowance of each process should be reasonably allocated. Rough machining is responsible for quickly removing excess material, semi-finish machining corrects the shape and leaves space for dimensional changes after stress release, and finish machining removes only a small amount of material to achieve final dimensions and surface requirements. Excessive finish machining allowance easily increases tool load, while too small an allowance may not eliminate defects from the previous process.

Third, tool wear and rework should be controlled. High-tungsten-content grades may require tools, grinding, or other special processing methods suitable for hard composite materials. For complex deep grooves, special-shaped holes, and narrow slits, EDM, wire cutting, or grinding can be evaluated according to the geometry to avoid forcibly using unsuitable traditional cutting methods.

Material loss can be calculated simply as follows: material utilization rate = mass of qualified finished parts ÷ mass of input blank × 100%. For example, if the blank mass is 1.0 kg and the qualified part mass is 0.65 kg, the material utilization rate is 65%. This indicator is suitable for comparing different blank schemes, but actual cost should also be judged in combination with chip recovery value, tool consumption, processing hours, and scrap rate.

IV. Recommended processing flow for complex parts

Blank acceptance and material confirmation → check grade, dimensions, density, and appearance defects → rough machining → prioritize machining datum surfaces, remove allowance in stages → clamp release inspection and necessary stress relief → measure warpage, dimensional changes, and datum stability → semi-finish and finish machining → precisely control clamping, cutting heat, tool condition, and allowance → fine grinding, lapping, or special processing → correct flatness, hole and groove accuracy, and surface quality → final inspection and quality records → dimensions, geometric tolerance, roughness, and necessary nondestructive testing

The actual process does not necessarily need to adopt all the above steps. Simple parts can combine some processes; for thin-walled, deep-hole, high-flatness, or high-reliability packaging parts, process measurement and trial processing verification should be added.

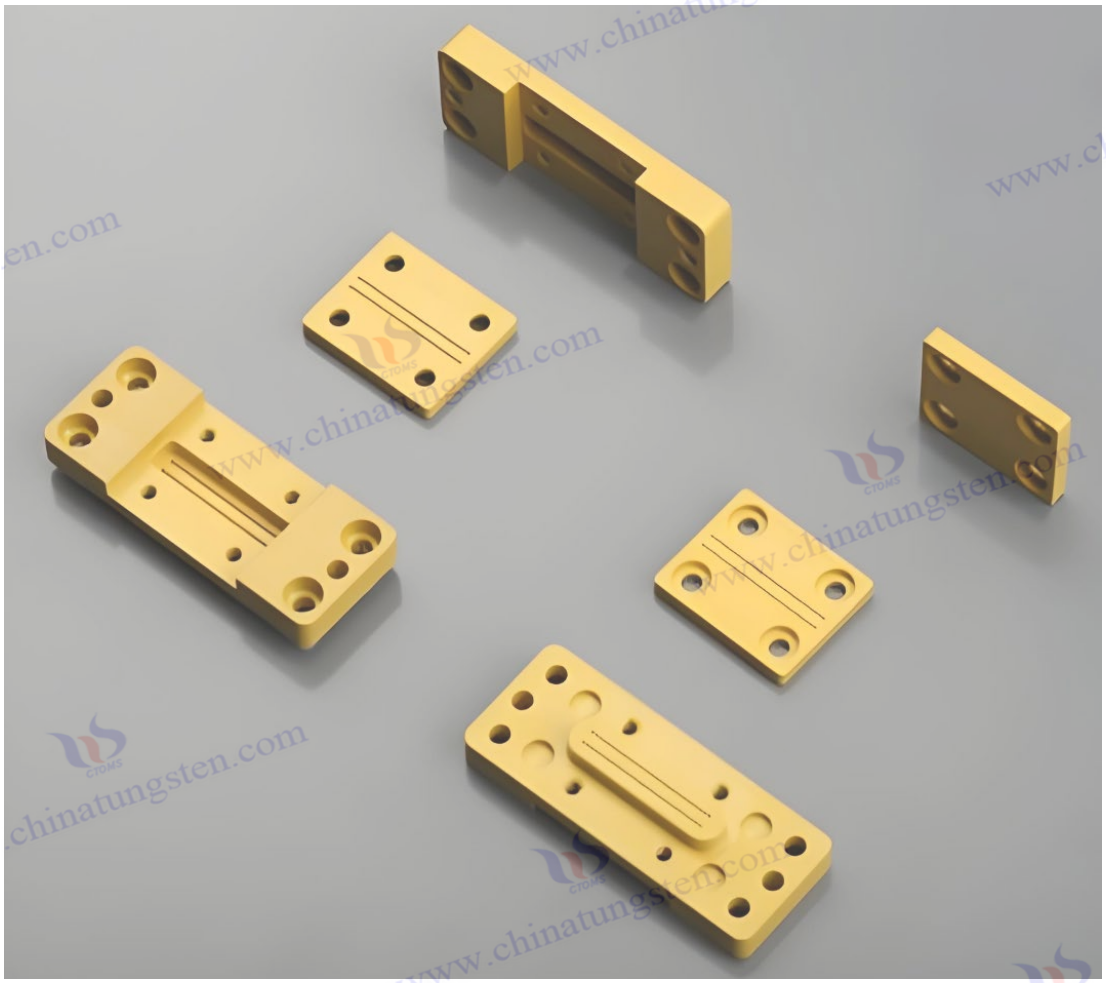
V. Establish quantifiable quality control standards

The acceptance indicators of the processing plan should be determined before production, not judged after processing is completed. It is recommended to control at least the following items:

Control item	Recommended control method
Dimensional accuracy	Use coordinate measuring machines, micrometers, inner diameter gauges, etc. with appropriate accuracy
Flatness and parallelism	Measure according to drawing datums, use precision platforms and dedicated measuring equipment when necessary
Surface roughness	Use a surface roughness meter to measure functional surfaces
Surface defects	Use microscopic observation and applicable nondestructive testing methods
Processing deformation	Record key dimensions after rough machining, after clamp release, and after final machining
Material utilization rate	Count blank mass, qualified product mass, scrap amount, and recyclable chips
Batch consistency	Record material batch, tool life, key parameters, and inspection results

For high-precision parts, it is best to establish process records for key dimensions and observe whether dimensions drift systematically with tool wear, processing time, or clamping method. In this way, the process can be adjusted before batch processing to reduce the risk of scrapping

the entire batch. To control processing deformation of complex tungsten-copper alloy parts, reliance should be placed on reasonable allowance allocation, stable clamping, and staged processing; to control surface defects, attention should be paid to two-phase microstructure, tool wear, and local heat; to reduce material loss, blank, processing route, and process allowance should be optimized. The three need to be designed simultaneously to balance dimensional accuracy, surface quality, material utilization rate, and production cost.



Q62 What factors determine the production cycle and processing cost of custom tungsten-copper alloy products?

The production cycle and processing cost of custom tungsten-copper alloy products are mainly determined by the material grade and blank supply, part structural complexity, dimensional tolerances, surface treatment, special processing operations, inspection standards, and order quantity. For high-precision tungsten-copper parts, the cost comes not only from the tungsten-copper alloy raw material but also from material preparation, precision machining, tool wear, quality inspection, and the risk of nonconforming products.

I. Main factors affecting production cycle and processing cost

Influencing factor	Effect on production cycle	Effect on processing cost
Material grade and tungsten content	Specific grades or specifications may require additional material preparation	Tungsten content, raw material specifications, and supply conditions affect material cost
Blank size and shape	Non-standard blanks may require additional preparation time	The larger the blank and the greater the material removal volume, the higher the material cost and processing cost
Part structural complexity	Deep holes, special-shaped grooves, thin-walled structures increase operations and setup time	Complex structures require more processing hours and dedicated tooling
Dimensional and geometric tolerances	High-precision requirements usually require additional finishing and inspection operations	Fine grinding, lapping, and precision measurement increase cost
Surface roughness and coating	Grinding, polishing, and coating treatment extend the process flow	Increase post-processing, outsourcing, and inspection costs
Processing method	Special processes such as EDM and wire cutting may increase scheduling time	Equipment hours, consumables, and subsequent surface finishing may all increase costs
Quality and reliability requirements	Material re-inspection, nondestructive testing, and reliability testing extend delivery time	Testing equipment, test hours, and quality documents generate additional costs
Order quantity	Small-batch orders may require separate scheduling and setup	Mass production can spread programming, clamping, and tooling costs
Supply chain and logistics	Raw material procurement, outsourced operations, transportation	Expedited procurement, special packaging, and transportation increase costs

II. Material grade and blank are the starting point of cost accounting

Common tungsten-copper alloy grades include W70Cu30, W75Cu25, and W80Cu20. Among them, W70Cu30 means a tungsten mass fraction of approximately 70% and a copper mass fraction of approximately 30%. Different grades have different material properties and processing performance, and the final quotation cannot be judged only by tungsten content; blank manufacturing process, material density, dimensional specifications, and performance acceptance requirements must also be considered. If the part shape is complex and the machining allowance is large, material cost may account for a relatively high proportion. If a blank closer to the finished shape can be used, material removal volume and processing hours can usually be reduced. However, whether a near-net-shape blank is economical also depends on order quantity, blank supply capability, and dimensional accuracy.

III. Part precision and structure determine processing difficulty

For tungsten-copper alloy, there may be a significant cost difference between ordinary shape processing and precision complex processing. For example, simple rectangular blocks or cylindrical parts mainly involve sawing, milling, or turning, with relatively few operations; parts with deep holes, small threads, narrow grooves, and thin walls may require dedicated fixtures, staged processing, fine grinding, or EDM. The stricter the dimensional tolerance, the more consideration must be given to post-processing deformation, datum unification, tool wear, and measurement uncertainty. When surface roughness requirements increase, grinding, polishing, and other operations may also need to be added. Therefore, when quoting, key dimensional tolerances, flatness, parallelism, and surface roughness should be specified, rather than providing only overall dimensions.

IV. How do different processing operations affect cost?

Processing operation	Main use	Possible added cost
Turning, milling, drilling	Basic shape, hole and groove, and thread processing	Tool wear, programming, and clamping hours
Grinding and lapping	Improve dimensional accuracy, flatness, and surface quality	Precision equipment hours, consumables, and measurement time
Electrical discharge machining (EDM)	Complex cavities, narrow grooves, and difficult-to-machine contours	Electrodes or consumables, EDM time, and post-processing
Wire EDM	Precision through contours and narrow kerfs	Cutting time, clamping, and surface finishing
Coating treatment	Improve soldering wettability, electrical contact, or surface performance	Pretreatment, coating processing, thickness inspection
Brazing or other connection	Assembly with copper, ceramics, or other metals	Brazing filler, connection tooling, process verification, and joint inspection

For complex products, the most economical solution is not necessarily the one with the lowest cost for a single operation. For example, using EDM to form complex groove shapes may be more stable than repeatedly using traditional cutting; and for high-precision planes, fine grinding or lapping may be easier to meet tolerance requirements than multiple fine milling passes.

V. What stages usually make up the production cycle?

The delivery time of custom tungsten-copper alloy products generally consists of material preparation, process design, processing and manufacturing, surface treatment, and final inspection. Technical confirmation and process design Confirm drawings, grade, dimensional tolerances, processing route, and acceptance standards. Incomplete information or changes in technical requirements will delay the start of production.

Raw material and blank preparation Verify inventory, procurement cycle, blank specifications, and material inspection requirements. Special grades or non-standard dimensions may become the main waiting link.

Processing and in-process inspection Complete rough machining, semi-finish machining, finish machining, and necessary in-process measurement. When the structure is complex, precision is high, or multiple setups are required, processing hours will increase significantly.

Surface treatment and connection Perform grinding, polishing, coating, brazing, or other post-processing as required, and consider outsourcing schedules.

Final inspection and delivery Complete dimensional, geometric tolerance, surface quality, and agreed material or reliability inspections, organize inspection documents, and deliver.

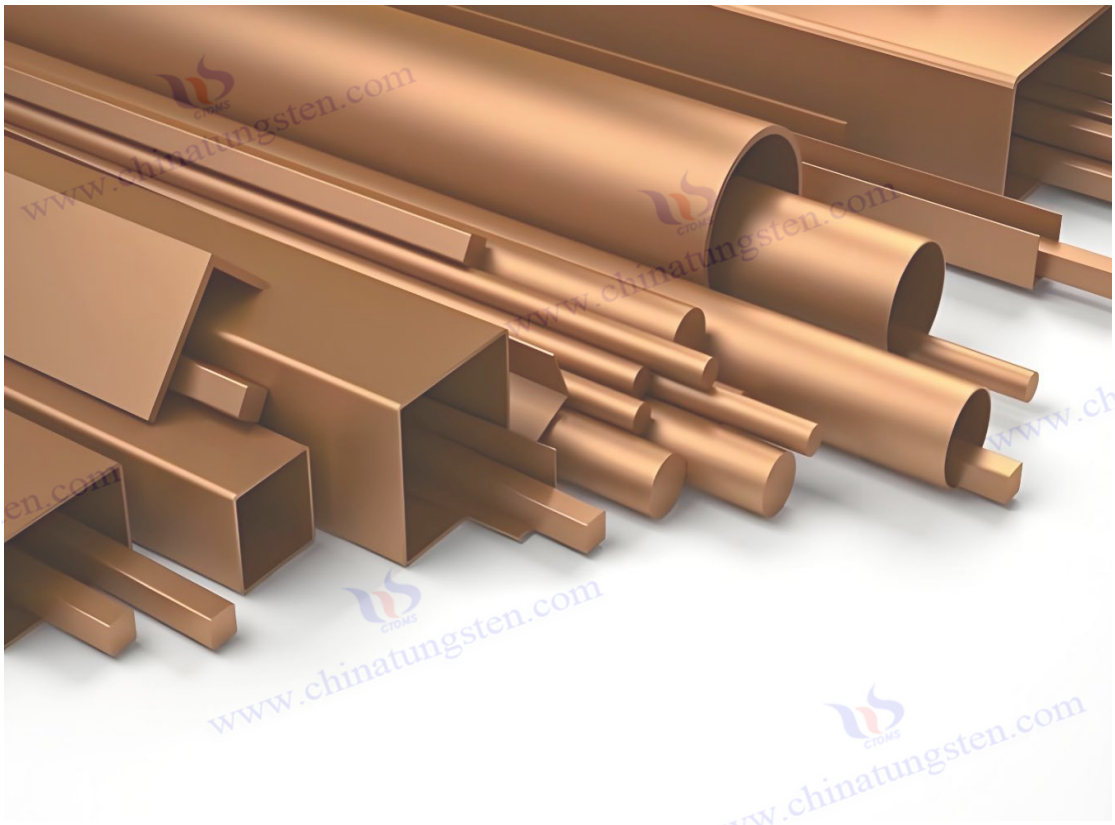
The specific delivery time needs to be evaluated in combination with supplier inventory, equipment scheduling, and outsourcing arrangements, and a fixed number of days cannot be given based only on material grade. The cycles for sample parts, small-batch parts, and repeat batch orders may also differ.

VI. How to reduce cost while ensuring quality?

It is recommended to optimize from both design and process ends. In the design stage, unnecessary high-precision dimensions, complex surfaces, and excessively deep holes and grooves can be reduced, non-critical dimensional tolerances can be unified, and the functional surfaces that truly affect assembly and heat conduction can be clarified. In the process stage, blank dimensions can be optimized, repeated clamping reduced, operations that can be combined can be merged, and dimensional stability can be verified through first-article processing before mass production.

For products requiring coating, brazing, or ceramic connection, interface requirements should be determined at the early stage of design to avoid discovering after the part is processed that the structure needs to be modified or post-processing needs to be added. If there is no clear requirement for material grade yet, targets such as thermal conductivity, coefficient of thermal expansion, and working temperature can be proposed first, and then the comprehensive cost of different material solutions can be compared.

During actual inquiry, providing the supplier with 2D engineering drawings or 3D models, material grade or performance targets, key tolerances, surface treatment requirements, order quantity, service environment, and inspection standards can usually significantly improve the accuracy of quotation and delivery evaluation. For tungsten-copper precision parts, CTIA GROUP can also be consulted for material selection, precision machining, and custom manufacturing solutions.



Part III

Standards, Quality, Procurement, and Industry Analysis of Tungsten-Copper Alloy

I. Quality Inspection and Standards of Tungsten-Copper Alloy

Q63 How to test the chemical composition, density, and porosity of tungsten-copper alloy?

The chemical composition, density, and porosity of tungsten-copper alloy are three important indicators for evaluating material quality. Chemical composition is used to confirm whether the actual content of tungsten (W, Tungsten) and copper (Cu, Copper) meets the grade requirements; density is used to judge the degree of densification and batch stability of the material; porosity is used to evaluate the impact of internal pores, sintering, or infiltration defects on strength, thermal conductivity, and airtightness. During actual testing, it is recommended to test the three indicators separately and verify each other. Especially for tungsten-copper alloy prepared by powder metallurgy or infiltration, it cannot be assumed that there are no pores inside the material simply because the density is qualified, nor can the internal density be judged only by surface observation.

I. How to test chemical composition

The composition testing of tungsten-copper alloy mainly focuses on the mass fractions of tungsten and copper, as well as other impurity elements specified in the contract or material standards. Common methods are as follows.

Test method	Main use	Advantages and limitations
X-ray fluorescence spectrometry (XRF)	Rapid determination of major elements such as W & Cur	Fast detection speed & little damage to samples; results are affected by instrument calibration, surface state, matrix effects
Inductively coupled plasma optical emission spectrometry (ICP-OES)	Quantitative analysis of major elements & some impurity elements	Good quantitative capability, but usually requires sampling, dissolution, or validated sample preparation process
Scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDS)	Analysis of local areas & elemental distribution of W & Cur phases	Suitable for microstructure and local composition analysis, but not suitable to directly replace overall chemical composition testing of the entire batch
Chemical analysis method	Determination of specific elements according to specified standards	Can serve as an arbitration or high-accuracy analysis method, but the specific method depends on the test item

If it is only necessary to quickly confirm whether the material roughly conforms to grades such as W70Cu30 or W80Cu20, XRF calibrated with standard samples can be used for screening first; if used for procurement acceptance, dispute arbitration, or strict composition control, the standard chemical analysis method specified in the contract should be used first, and methods such as ICP-OES can be used for rechecking when necessary. The test report should indicate the mass fractions of tungsten and copper, impurity element requirements, test method, sampling location, and measurement uncertainty. For materials with non-uniform microstructure, sampling locations should also be reasonably selected to avoid mistaking local test results for the average composition of the entire part.

II. How to test density

The density of tungsten-copper alloy is usually measured by the mass-volume method. For parts with regular shapes and dimensions that are easy to measure accurately, the volume can be calculated from geometric dimensions; for samples with irregular shapes or requiring higher measurement reliability, the Archimedes method can be used.

Archimedes method

The Archimedes method calculates the volume and density of a sample by measuring its mass in air and in liquid, and is suitable for many dense tungsten-copper alloy specimens. The calculation formula is: density = mass in air ÷ (mass in air − apparent mass in liquid) × liquid density. Among these, the mass in air and the apparent mass in liquid should use the same mass unit, and the liquid density should be determined according to the actual measurement temperature. If the sample has open pores, liquid may enter the pores and affect the results, so the drying, immersion, saturation, and surface bubble treatment methods of the sample must be carried out according to the applicable standard.

Geometric dimension method

For regular rectangular cuboid, cylindrical, and other parts, the mass and geometric dimensions can be measured, the volume calculated first, and then the density calculated. For example, rectangular cuboid volume = length × width × height; density = mass ÷ volume. This method is convenient to operate, but when the part has chamfers, complex surfaces, tiny holes and grooves, or large dimensional tolerances, the volume error may be significantly amplified, so it is not necessarily suitable for high-precision density acceptance.

What to focus on in density testing

Inspection item	Main purpose
Measured density	Judge whether the material meets the agreed density requirements
Theoretical density or reference density	Serve as a comparison basis for material ratio and degree of densification
Batch density difference	Evaluate manufacturing consistency among different batches
Density difference at different positions of the part	Under appropriate sampling conditions, assist in identifying local density non-uniformity

Theoretical density should be determined according to actual composition and applicable material models, and the same fixed value cannot be used for all tungsten-copper grades. Acceptance should be based on the requirements in drawings, procurement technical agreements, or specified material standards.

III. How to test porosity

Pores in tungsten-copper alloy may come from powder pressing, sintering, insufficient copper infiltration, residual gas, or other defects in the manufacturing process. During testing, total porosity, open porosity, and closed porosity should be distinguished because the material characteristics they reflect are not the same.

Test method	Test object	Applicable scenarios and limitations
Density comparison method	Estimate porosity from measured & theoretical density	Fast and suitable for overall density evaluation, but depends on the accuracy of theoretical density and material uniformity
Metallographic microscopic analysis	Area proportion of pores on a polished cross-section	Can observe pore shape, distribution, and local microstructure, but results are affected by sampling location
X-ray computed tomography	Three-dimensional distribution of internal pores	Suitable for locating internal defects; detection capability is limited by equipment resolution, material attenuation, and scanning parameters
Archimedes method combined with saturation treatment	Evaluate indicators related to open pores	Suitable for samples meeting test conditions, but cannot alone completely measure all closed pores
Ultrasonic testing	Internal discontinuities & some defects	Used for screening specific sizes and structural defects; capability needs to be verified for material and defect types

Estimating porosity from density

When the material composition is clear, the theoretical density calculation is reliable, and the

measured density can represent the overall material, the following approximate relationship can be used: porosity (%) ≈ [1 – measured bulk density ÷ theoretical pore-free density] × 100%. For example, assuming that the theoretical pore-free density of a specimen is 15.0 g/cm³ and the measured bulk density is 14.85 g/cm³, the estimated porosity is approximately 1.0%. This is only a demonstration of the calculation method and does not represent the actual standard value of a certain tungsten-copper grade. This method is suitable for preliminary evaluation of overall density, but if the actual composition of the material deviates from the nominal ratio, other phases exist, or the composition distribution is uneven, the theoretical density may deviate, resulting in inaccurate porosity estimation.

Observing pores through metallographic analysis

Metallographic analysis usually requires cutting a representative sample, mounting, grinding, and polishing, and then observing the cross-section with a microscope. By statistically analyzing the area proportion of pores through image analysis, the local porosity on that cross-section can be evaluated. The advantage of the metallographic method is that it can simultaneously observe tungsten phase distribution, copper phase continuity, interface state, and pore morphology; the limitation is that it is local sampling testing, and a single cross-section may not represent the entire complex part. For important parts, samples should be taken from multiple representative positions, and the image analysis method and statistical rules should be clarified.

Detecting internal pores through industrial computed tomography

Industrial computed tomography (CT) can reconstruct the internal three-dimensional structure of a part and locate pores, internal cracks, and local defects, and is particularly suitable for complex parts that should not be damaged. However, the high atomic number of tungsten and strong X-ray attenuation increase scanning difficulty. Before testing, the imaging capability should be verified according to part dimensions, material thickness, equipment energy, and target defect size; it cannot be assumed that all tiny pores can be identified.

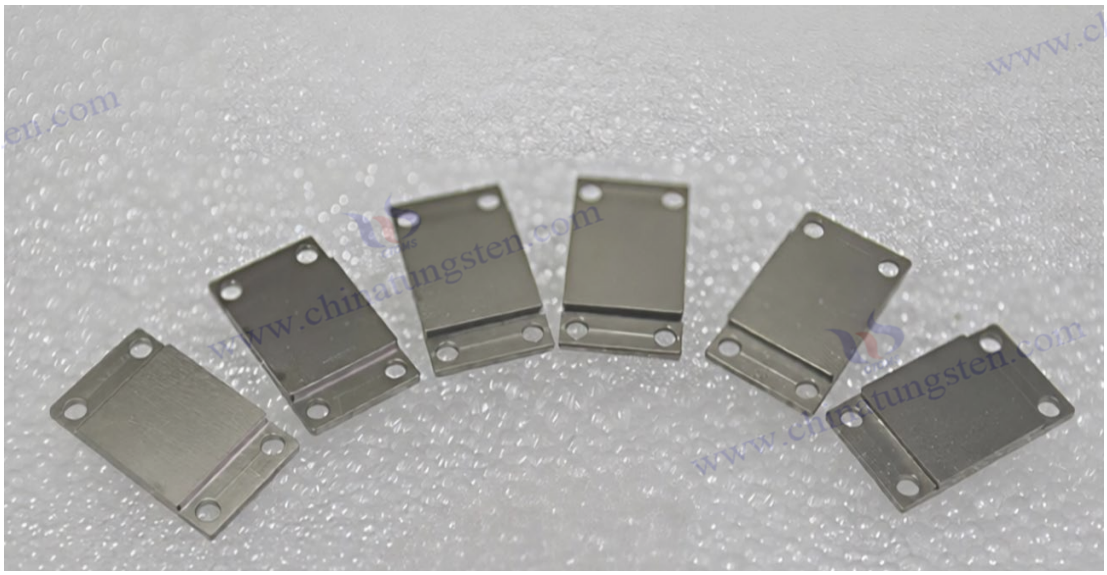
IV. How to combine the three tests

For ordinary incoming material acceptance, composition screening and density testing can be performed first, and then whether to carry out porosity testing can be decided according to risk and technical agreement. For high thermal conductivity heat sinks, semiconductor packaging components, vacuum devices, and high-reliability parts, a more complete combination scheme is recommended.

Application requirement	Recommended test combination
Conventional material incoming acceptance	Composition testing, density testing, appearance inspection
High density requirement	Composition testing, density testing, metallographic porosity analysis
Complex internal structure or critical load-bearing parts	Composition testing, density testing, validated CT, nondestructive testing
High thermal conductivity electronic packaging components	Composition, density, porosity, and microstructure analysis, with thermal conductivity testing added when necessary
Parts with high airtightness requirements	Composition and density testing, internal defect inspection, and airtightness testing according to product requirements

It should be distinguished that material porosity testing and part airtightness testing are not the same item. Even if the overall porosity is low, through channels may exist; conversely, a material with a small number of isolated pores does not necessarily leak.

For custom tungsten-copper alloy parts, it is recommended to specify in the procurement technical agreement the material grade, composition range, minimum density or allowable deviation, porosity limit, test method, sampling location, and inspection report requirements. This can not only improve the consistency of supplier acceptance but also avoid the situation where results from different test methods cannot be directly compared.



Q64 How to test the electrical conductivity, thermal conductivity, and hardness of tungsten-copper alloy?

The electrical conductivity, thermal conductivity, and hardness of tungsten-copper alloy reflect the material's electrical transmission capability, thermal transmission capability, and ability to resist local plastic deformation, respectively. The test methods for the three indicators are different, and special instruments are usually required, with measurement carried out according to unified specimen preparation conditions, test temperature, and testing standards. For tungsten-copper alloys such as W70Cu30, W75Cu25, and W80Cu20, it is recommended to check the material grade, density, specimen surface state, and manufacturing process at the same time, because the tungsten-copper ratio, porosity, and two-phase microstructure all affect the final test results.

I. How to test electrical conductivity

The electrical conductivity of tungsten-copper alloy is usually measured with an eddy current conductivity meter, or with the four-terminal resistance method. The former is suitable for rapid, nondestructive testing, while the latter is suitable for calculating the conductivity of the material through resistance measurement.

Test method	Principle and use	Main precautions
Eddy current conductivity method	Measure conductivity according to the response of conductive materials to an alternating electromagnetic field	Affected by specimen thickness, surface state, probe frequency, and temperature
Four-terminal resistance method	Measure specimen resistance and calculate resistivity and conductivity in combination with geometric dimensions	High requirements for specimen dimensions, contact arrangement, temperature, and voltage measurement accuracy
Resistivity tester	Obtain material resistivity through a dedicated resistivity measurement system	The applicable resistance range and test standard of the equipment should be confirmed

The four-terminal resistance method can reduce the influence of contact resistance of current leads and voltage leads. For regular specimens, the resistivity calculation method is: resistivity = resistance × cross-sectional area ÷ measured length; conductivity = 1 ÷ resistivity. The common unit of resistivity is Ω·m, and the common unit of conductivity is S/m (Siemens per meter). If the test report uses %IACS (International Annealed Copper Standard), the conversion basis and test temperature should be indicated to avoid direct comparison of data under different units or temperature conditions.

II. How to test thermal conductivity

The thermal conductivity of tungsten-copper alloy is usually tested by the laser flash method or the steady-state heat flow method. The measurement principles of the two methods are different, and the applicable specimen shapes and data processing methods are also different.

Test method	Measurement principle	Applicable situation
Laser flash method (LFA)	Obtain thermal diffusivity from the temperature rise response on the back side of the specimen after pulse heating	Suitable for measuring material thermal diffusivity and calculating thermal conductivity in combination with density and specific heat capacity
Steady-state heat flow method	Establish a stable temperature gradient and calculate thermal conductivity through heat flow and temperature difference	Suitable for specimens meeting standard geometry and boundary conditions
Dedicated thermal conductivity test system	Determine thermal conductivity according to a specific heat flow measurement principle	Should be selected according to material thermal conductivity range, specimen thickness, and test temperature

The laser flash method usually measures thermal diffusivity rather than directly obtaining thermal conductivity. The thermal conductivity calculation relationship is: thermal conductivity = thermal diffusivity × density × specific heat capacity. Among these, the unit of thermal diffusivity is m^2/s, the unit of density is kg/m^3, the unit of specific heat capacity is J/(kg·K), and the unit of thermal conductivity is W/(m·K).

During testing, attention should be paid to specimen thickness, parallelism, surface coating, density input value, and the accuracy of specific heat capacity data. If the laser flash method is used, it should also be confirmed whether the model used by the instrument is suitable for the material and whether necessary corrections such as radiation loss have been made.

For tungsten-copper parts that need to work in high-temperature environments, it is recommended to measure at conditions close to the actual service temperature, or to provide data at multiple temperature points. Room-temperature thermal conductivity cannot directly represent performance over the entire working temperature range.

III. How to test hardness

The hardness of tungsten-copper alloy is usually measured by the Vickers hardness method or the Rockwell hardness method. Because the material has two different microstructures, the tungsten phase and the copper phase, the test results are affected by indentation size, specimen surface quality, and test location.

Test method	Characteristics	Applicable situation
Vickers hardness (HV)	Uses a diamond square pyramid indenter and measures the indentation diagonal	Suitable for most tungsten-copper alloy specimens and convenient for comparison under different loads
Rockwell hardness (HR)	Determines the hardness value according to the change in indentation depth	Suitable for parts meeting specimen thickness, surface state, and hardness scale requirements
Micro-Vickers hardness	Uses a small test force to measure tiny areas	Analyzes hardness differences of tungsten phase, copper phase, or local microstructure, but cannot directly represent overall macroscopic hardness

Before hardness testing, the test surface should be machined flat and properly ground or polished to ensure that the indentation boundary can be clearly identified. The test force, dwell

time, indentation spacing, edge distance, and specimen thickness should be implemented according to the selected standard. If the hardness of the entire tungsten-copper alloy part needs to be evaluated, multi-point measurement should be carried out at representative positions, and the average value and degree of dispersion should be calculated according to the agreed rules. If the hardness difference between the tungsten phase and copper phase is studied, microhardness testing should be used and combined with microstructural observation; the measured value of a single tungsten phase area cannot be used as the hardness of the entire material.

IV. Comparison of test conditions for the three indicators

Item	Recommended method	Typical report unit	Main influencing factors
Electrical conductivity	Eddy current method, four-terminal resistance method	MS/m, S/m, or %IACS	Temperature, material composition, density, specimen thickness, and surface state
Thermal conductivity	Laser flash method combined with density and specific heat capacity, or steady-state heat flow method	W/(m·K)	Temperature, porosity, microstructure, specimen dimensions, and calculation parameters
Hardness	Vickers hardness method, Rockwell hardness method when applicable	HV, HR, etc.	Test force, surface roughness, indentation location, microstructural uniformity

The three indicators should be tested by suitable methods respectively; density or composition test results cannot be used to directly replace electrical conductivity, thermal conductivity, or hardness measurement. For materials of the same grade, if the test method, temperature, or specimen state differ, the obtained data may also differ.

V. How to formulate a testing plan for tungsten-copper alloy

If used for general incoming acceptance, electrical conductivity, thermal conductivity, and hardness can be tested according to the technical agreement, and the grade and density should be confirmed at the same time. If used for power semiconductor heat sinks, electronic packaging base plates, or high-reliability electrodes, it is recommended to add material composition, porosity, and microstructure testing, and to carry out high-temperature performance verification when necessary.

When procuring or commissioning testing, it is recommended to clarify four items: first, the material grade and composition range; second, the target values or allowable ranges of electrical conductivity, thermal conductivity, and hardness; third, the test standards, test temperature, specimen dimensions, and sampling locations; fourth, whether the report needs to provide measured values, average values, measurement uncertainty, and equipment information.

Only by unifying these conditions can the test results of different suppliers be compared fairly and whether the material truly meets the electrical, heat dissipation, and mechanical performance requirements of the part be judged.

Q65 How to perform metallographic microstructure analysis and nondestructive testing of tungsten-copper alloy?

Metallographic microstructure analysis and nondestructive testing of tungsten-copper alloy are used to evaluate the internal microstructural quality of the material and internal defects of the part, respectively. Metallographic analysis mainly observes the distribution of the tungsten phase and copper phase, pores, interfacial bonding, and local microstructural abnormalities; nondestructive testing is used to find internal pores, cracks, inclusions, insufficiently infiltrated areas, and other defects while keeping the part intact as much as possible. For tungsten-copper alloys such as W70Cu30, W75Cu25, and W80Cu20, it is recommended to combine metallographic microscopic analysis, X-ray testing, industrial computed tomography, and ultrasonic testing according to part application, dimensions, defect type, and acceptance requirements, rather than relying on a single method to judge quality.

I. Metallographic microstructure analysis of tungsten-copper alloy

What does metallographic analysis mainly observe?

Tungsten-copper alloy is usually composed of a tungsten phase and a copper phase, and the specific microstructure morphology depends on manufacturing processes such as powder metallurgy, sintering, and copper infiltration. Metallographic analysis mainly focuses on the following items.

Analysis item	Main observation content	Significance of quality evaluation
Tungsten phase distribution	Morphology, size, and distribution uniformity of tungsten particles or skeleton	Judge the degree of microstructural uniformity
Copper phase distribution	Continuity, distribution range, and local enrichment of the copper phase	Affects thermal conductivity, electrical conductivity, and microstructural stability
Pores and micropores	Pore size, shape, quantity, and distribution	Reflects densification or infiltration quality
Phase interface state	Bonding between the tungsten phase and copper phase	Assists in judging local interface defects
Cracks and abnormal areas	Microcracks, local peeling, microstructural abnormalities	Evaluate material integrity
Microstructural size & proportion	Particle size, area fraction, & local microstructural differences	Used for batch consistency analysis

The tungsten phase and copper phase differ in hardness and processing response, and improper sample preparation may produce artifacts such as copper phase smearing, particle pull-out, or edge chipping. Therefore, not all pores in metallographic images necessarily come from original material defects; judgment must be combined with sample preparation quality and other test results.

Basic flow of metallographic analysis

Sampling and position marking: select representative areas and retain records of sampling direction and position.Mounting, grinding, and polishing: reduce scratches, phase pull-out, edge collapse, and copper phase smearing.Microscopic observation and image acquisition: observe the tungsten phase, copper phase, pores, and interface state.

Image quantification and result judgment: statistically analyze pore area fraction, microstructural size, and distribution differences, and judge according to acceptance standards. For batch products, it is recommended to clarify sampling locations, cross-section direction, observation magnification, image analysis method, and defect judgment rules. For large or structurally complex parts, representative sampling can be arranged preferentially from key functional areas, thickness transition areas, and suspected defect areas.

Differences between metallographic microscopes and scanning electron microscopes

Equipment	Main use	Advantages
Optical metallographic microscope	Observe tungsten phase, copper phase, pores, and overall microstructure morphology	Relatively low cost, suitable for conventional microstructure evaluation
Scanning electron microscope (SEM)	Observe fine interfaces, particle morphology, and local defects	Higher resolution, suitable for analyzing microstructure
Energy dispersive X-ray spectroscopy (EDS)	Analyze local elemental composition and distribution	Can assist in confirming elemental characteristics of different areas, but cannot replace overall composition testing

Metallographic analysis is destructive or sampling-based testing and usually requires cutting specimens. If the finished product cannot be destroyed, suitable nondestructive testing methods should be used; representative witness specimens can also be prepared from the same batch of material for metallographic inspection.

II. Main methods of nondestructive testing for tungsten-copper alloy

The goal of nondestructive testing is to find internal or surface defects without damaging the part as much as possible. Different methods have different sensitivities to defect type, size, orientation, and location.

Test method	Main test object	Applicable characteristics and limitations
X-ray digital radiography (DR)	Internal pores, defects with obvious density differences	Can quickly inspect internal structure, but defect overlap, orientation, and material thickness affect detection capability
Industrial computed tomography (CT)	Three-dimensional pores, internal cracks, local defects	Can locate defects and analyze dimensions; equipment resolution, scanning time, and material attenuation constitute limitations
Ultrasonic testing (UT)	Internal cracks, delamination, and discontinuities	Suitable for parts with certain thickness and geometric conditions; high attenuation, microstructural scattering, and coupling issues need to be addressed
Penetrant testing (PT)	Surface-connected cracks and open defects	Suitable for surface open defects, cannot find closed pores completely located inside
Eddy current testing (ET)	Surface or near-surface electromagnetic property anomalies	Suitable for screening specific surface and near-surface defects; detection depth is affected by frequency and material conditions

X-ray testing and industrial CT

X-ray testing displays internal structural differences through the different attenuation of X-rays by the material, and is suitable for screening pores, local density anomalies, and certain internal

defects. Industrial CT reconstructs the internal three-dimensional structure through projection data from multiple angles, and can further determine the location, volume, and spatial distribution of pores. For complex tungsten-copper parts, CT is particularly suitable for analyzing pores around deep holes, at thick-thin transitions, and in internal structures. However, tungsten has a high atomic number, and tungsten-copper alloy as a whole has strong X-ray attenuation. During actual testing, process verification needs to be carried out according to part thickness, equipment energy, detector performance, and target defect size. Without verification, it is not appropriate to directly promise that defects below a certain fixed size can definitely be detected.

Ultrasonic testing

Ultrasonic testing identifies discontinuities through reflection or transmission changes generated when sound waves propagate inside the material, and is suitable for detecting some internal cracks and bonding anomalies. For tungsten-copper alloy, particular attention should be paid to material microstructural scattering, specimen thickness, surface coupling conditions, and defect orientation. Before testing, it is usually necessary to select appropriate probe frequency, beam direction, and reference blocks, and to verify detection sensitivity using known defects or artificial reflectors. If the part is small in size, complex in structure, or has strong acoustic attenuation, ultrasonic testing may be difficult to obtain reliable results, and other methods should be considered as supplements.

Surface and near-surface defect testing

For surface cracks, grinding damage, or local defects that appear after processing, penetrant testing or eddy current testing can be selected according to the surface state. Penetrant testing mainly targets surface open defects; eddy current testing is suitable for surface and near-surface anomalies under specific conditions.

If the part surface has a coating, high roughness, or oil stains and processing residues, it should first be confirmed whether these factors affect the test results. For critical parts, whether testing is needed before and after final surface treatment should also be evaluated separately.

III. How to choose a combination of metallographic analysis and nondestructive testing

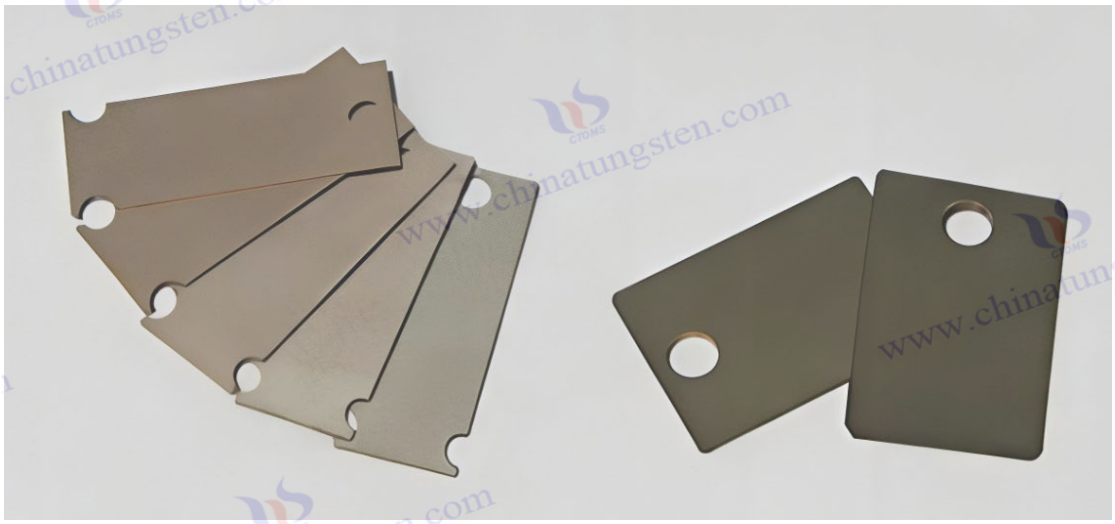
Product application	Recommended test combination	Key focus
Ordinary tungsten-copper machined parts	Metallographic sampling inspection, density testing, appearance inspection	Microstructural uniformity, pores, and surface defects
High thermal conductivity heat sink	Metallographic analysis, density testing, CT when necessary	Pores, copper phase distribution, and density
Precision electronic packaging components	Metallographic witness specimen, CT or applicable X-ray testing, dimensional inspection	Internal defects, interface quality, and structural integrity
Vacuum or airtight packaging parts	Internal defect testing, applicable surface testing, airtightness testing	Through defects, connection interfaces, and leakage risk
High-reliability structural parts	ultrasonic testing, surface testing, & metallographic sampling inspection according to defect risk	Internal cracks, pores, local microstructural abnormalities, and batch consistency

Nondestructive testing results and metallographic analysis can complement each other but cannot completely replace each other. Metallography can observe microstructure and local pores but cannot directly prove that there are no defects inside the entire part; nondestructive testing can cover a larger volume but may not be able to identify all tiny microstructural abnormalities. In addition, porosity testing and airtightness testing also belong to different quality evaluation items. If the part requires vacuum sealing or long-term airtightness, leak testing should be carried out separately according to product requirements.

IV. What should a test report contain?

To ensure comparability of test results among different batches and different suppliers, it is recommended to specify in the technical agreement the material grade, test method, sampling location, equipment conditions, acceptance limits, and defect judgment rules. The test report should at least record the sample number, material batch, test area, specimen preparation method, instrument and parameters, test results, and judgment basis. For CT or X-ray testing, the verifiable minimum defect detection capability should also be specified; for metallographic analysis, data such as observation magnification, image statistical method, and pore area fraction should be recorded.

If used for quality acceptance of custom tungsten-copper products, a more practical approach is: first confirm the basic material quality by composition, density, and metallographic analysis, then select CT, X-ray, ultrasonic, or surface testing methods according to part structure and risk, and finally complete product-level verification in combination with dimensional inspection, thermal performance testing, or airtightness testing. This can control testing costs and avoid excessive judgment of material quality based on a single test result.



Q66 To which tungsten-copper materials does ASTM B702 (Standard Specification for Copper-Tungsten Electrical Contact Material) apply?

ASTM B702 (American Society for Testing and Materials, Standard Specification for Copper-Tungsten Electrical Contact Material) mainly applies to tungsten-copper electrical contacts and assemblies manufactured by powder metallurgy, and covers the tungsten-copper binary alloy composition system usually used for electrical contacts. The current version is ASTM B702-93(2024), where 2024 indicates the year of reapproval of the standard, not the year of first publication.

Applicable tungsten-copper material types

ASTM B702 does not limit its scope to a single fixed tungsten content grade, but covers tungsten-copper alloy compositions selected according to electrical contact use requirements. Therefore, common tungsten-copper electrical contact materials can be confirmed according to this standard for technical specification after agreeing on composition, performance, and inspection requirements with the purchaser.

Material type	Typical W/mass fraction	Applicability description
WCu50	About 50%	Can be used for electrical contacts requiring balanced electrical conductivity and arc erosion resistance
WCu60	About 60%	Can be used for medium- and high-current electrical contacts and related electrical switch components
WCu70	About 70%	Can be used for contacts with higher requirements for arc erosion resistance and anti-welding performance
WCu75	About 75%	Can be used for specific electrical contacts with high burn resistance requirements
WCu80	About 80%	Can be used for high-tungsten-content electrical contacts, but performance needs to be confirmed in combination with actual working conditions
Other W-Cu ratios	As agreed by both supplier & purchaser	As long as it belongs to the tungsten-copper system and is used for electrical contacts, technical requirements can be confirmed according to the agreement of both parties

The ratios listed in the table are examples of common tungsten-copper materials and do not mean that ASTM B702 specifies uniform mandatory grades, chemical composition limits, or all performance indicators for these ratios.

What does ASTM B702 mainly regulate?

The focus of this standard is powder metallurgy tungsten-copper electrical contact assemblies, not tungsten-copper products for all applications. Its main technical content includes material chemical composition determined through negotiation between the manufacturer and purchaser, physical performance and qualification verification tests agreed according to the actual function of the contact, and carrying out corresponding inspections on actual production parts as much as possible. Applicable products include electrical switch contacts, circuit breaker contacts, and other electrical contact assemblies made of tungsten-copper material. For electronic packaging heat dissipation substrates, tungsten-copper counterweights, radiation shielding parts, welding electrodes, and general structural parts, it

cannot be directly assumed that ASTM B702 applies simply because the material is a tungsten-copper alloy; these products need to select more appropriate material specifications and acceptance requirements according to actual use.

How to reference this standard during procurement or customization?

It is recommended to specify ASTM B702-93(2024) in the procurement technical documents, and at the same time clarify the tungsten-copper grade or tungsten and copper content range, key dimensions and tolerances, density and electrical conductivity requirements, inspection methods, sampling rules, and quality certification documents. Because this standard emphasizes that the composition and related performance are determined through negotiation between the manufacturer and purchaser, simply marking ASTM B702 is usually not enough to completely determine product acceptance conditions. ASTM B702 applies to powder metallurgy manufactured tungsten-copper electrical contact materials and assemblies, with the core being electrical contact application and technical requirements agreed by both parties, rather than a certain fixed tungsten-copper ratio.

What standards and test methods should be referenced when procuring tungsten-copper alloy?

When procuring tungsten-copper alloy, it is not enough to check only the material grade or require the supplier to provide a material certificate; the applicable standards should also be determined according to product application, and requirements such as chemical composition, density, electrical conductivity, thermal conductivity, hardness, dimensional tolerance, and internal defects should be converted into executable test items. For electrical contacts, electronic packaging heat dissipation components, EDM electrodes, and other custom tungsten-copper parts, it is recommended to use a combination of product standards, test method standards, and procurement technical agreements for acceptance.

I. What standards should be referenced during procurement?

Standard or specification	Main applicable scope	Use during procurement
ASTM B702-93 (American Society for Testing and Materials standard for copper-tungsten electrical contact material)	PM manufactured W-Cu electrical contact assemblies	Applicable to electrical contact products; chemical composition, physical performance tests, and dimensional requirements need to be agreed by both supplier and purchaser
ASTM B777 (Standard Specification for Tungsten Base, High-Density Metal)	Tungsten-based high-density alloys	Some tungsten-based high-density alloy products; should not directly replace tungsten-copper material standards
ISO (International Organization for Standardization) related test standards	Selected according to specific performance and test items	Used to clarify specimen preparation, measurement methods, and result expression
GB/T (recommended national standard numbering system) related standards	Domestic procurement & inspection	Check the applicable scope of current standards according to test items
Enterprise technical specifications and procurement agreements	Custom tungsten-copper products	Material grade, performance indicators, dimensional tolerances, sampling rules, re-inspection, and judgment

Among these, ASTM B702-93(2024) explicitly applies to copper-tungsten electrical contact assemblies manufactured by powder metallurgy, and its chemical composition limits and

physical performance qualification tests need to be determined through negotiation between the manufacturer and purchaser. Therefore, ordinary tungsten-copper heat sinks, counterweights, and EDM electrodes should not automatically apply this standard.

II. Core test items for tungsten-copper alloy procurement

Test item	Recommended method	Main inspection content
Chemical composition	XRF, ICP-OES	Tungsten and copper content and agreed impurity elements
Density	Archimedes method, geometric dimension and mass calculation method	Whether the measured density meets the material grade or procurement agreement requirements
Porosity	Density comparison method, metallographic microscopic analysis, industrial CT	Pore content, pore distribution, and internal defects
Electrical conductivity	Eddy current conductivity meter, four-terminal resistance method	Whether the electrical conductivity meets the requirements
Thermal conductivity	Laser flash method for thermal diffusivity, combined with density and specific heat capacity calculation	Thermal management performance and batch stability
Hardness	Vickers hardness test, Rockwell hardness test when applicable	Whether the surface or cross-section hardness meets the agreement
Metallographic microstructure	Optical microscope, SEM-EDS	Tungsten phase distribution, copper phase continuity, pores, interface defects
Dimensions & geometric tolerances	Coordinate measuring machine, image measuring instrument, micrometer, roughness tester	Length, width, thickness, hole diameter, flatness, parallelism, position tolerance, roughness
Internal defects	X-ray digital radiography, industrial CT, ultrasonic testing when applicable	Cracks, inclusions, local porosity, and internal discontinuities
Surface quality	Visual inspection, microscopic observation, applicable penetrant testing	Cracks, chipping, burrs, scratches, and processing defects

The test method should be determined according to specimen dimensions, tungsten content, product shape, and acceptance purpose. For example, XRF is suitable for rapid screening of elemental composition, but if higher-accuracy quantitative analysis is required, an appropriate method should be selected according to matrix effects, calibration conditions, and target elements. Industrial CT also cannot necessarily detect all tiny pores, and detection capability needs to be verified in combination with part thickness, tungsten content, and target defect size.

III. How should acceptance priorities be set for different applications?

Electrical contacts and switch contacts

Focus on checking tungsten and copper content, density, electrical conductivity, hardness, dimensions, and surface defects. For important electrical components, contact resistance, arc erosion resistance, anti-welding performance, and actual breaking performance verification should also be carried out according to use conditions.

Electronic packaging and heat dissipation substrates

Focus on checking coefficient of thermal expansion, thermal conductivity, density, flatness, thickness tolerance, and surface roughness. If the product needs to be connected to ceramics, copper, or other metals, interfacial bonding quality, thermal cycle reliability, and airtightness requirements should also be verified.

EDM electrodes

Focus on checking dimensional accuracy, density, electrical conductivity, hardness, surface quality, and microstructural uniformity. For slender, thin-walled, or complex cavity electrodes, attention should also be paid to processing deformation, chipping, and local defects.

Counterweights and other custom structural parts

Focus on checking mass or density, overall dimensions, hole positions, balance accuracy, surface defects, and assembly interfaces. Only when actual use involves thermal conductivity, electrical conductivity, or shielding performance should corresponding special tests be added.

IV. What should be clearly stated in the procurement technical agreement?

It is recommended to specify at least the following: material grade and tungsten and copper content range; standard name, version, and applicable clauses; key indicators such as density, electrical conductivity, thermal conductivity, and hardness and their units; drawing dimensions, geometric tolerances, and surface roughness; test methods, specimen locations, sampling quantity, re-inspection rules, and nonconforming judgment methods; batch traceability, material certificate, and test report requirements. The relationship between density and porosity can also be used for procurement quality verification. For materials with known theoretical pore-free density, total porosity can be estimated as follows: porosity (%) ≈ [1 − measured bulk density ÷ theoretical pore-free density] × 100%. This method is an indirect estimation, cannot separately distinguish open pores and closed pores, and cannot replace special testing of critical internal defects.

If custom tungsten-copper products are procured, relevant material and processing information from CTIA GROUP can be referenced: https://www.ctia.com.cn, and the technical agreement signed by both parties and actual test reports should be used as the final acceptance basis.

My suggestion is: for electrical contacts, prioritize checking ASTM B702 and electrical function test requirements; for electronic packaging, prioritize checking coefficient of thermal expansion, thermal conductivity, and dimensional accuracy; for electrodes and structural parts, formulate an acceptance table around density, electrical conductivity, microstructural quality, and processing tolerances. Do not judge whether the entire batch of tungsten-copper products is qualified based only on material grade or a single density value.

Q67 How to troubleshoot when tungsten-copper alloy products have substandard electrical conductivity, copper bleeding, or internal cracks?

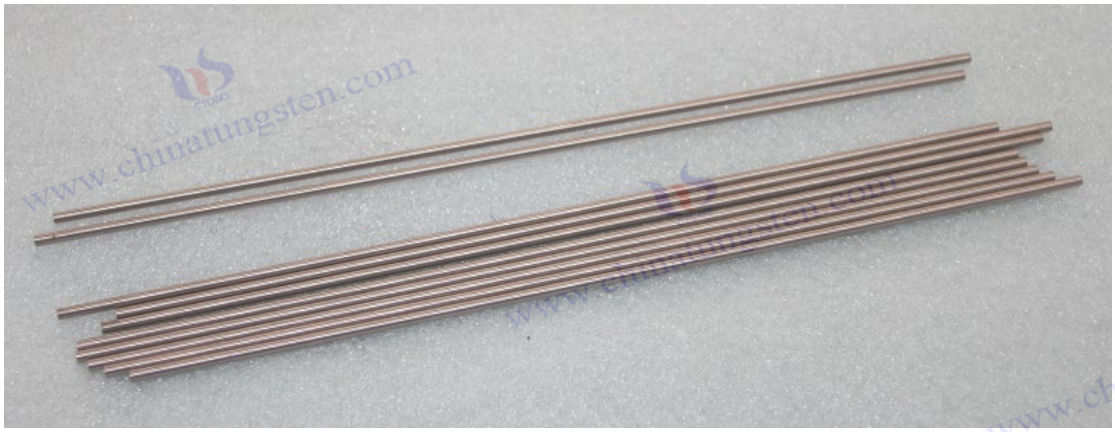
When tungsten-copper alloy products have substandard electrical conductivity, copper bleeding, or internal cracks, a distinction should first be made among problems of the material itself, powder metallurgy manufacturing process problems, defects caused by subsequent processing, and misjudgment caused by inconsistent test methods or test conditions. These three types of abnormalities may appear simultaneously, but their formation mechanisms are different, and they cannot be handled only by increasing copper content, re-polishing, or simple repair welding. It is recommended to troubleshoot in the order of first reviewing test results, then locating defects, then tracing the process, and finally verifying corrective measures, and to temporarily isolate the same batch of products to avoid direct delivery without evaluation.

I. Substandard electrical conductivity: first verify composition, density, and test conditions

The electrical conductivity of tungsten-copper alloy is mainly affected by copper content, copper phase continuity, porosity, impurities, microstructural uniformity, and test conditions. The electrical conductivity of the tungsten phase itself is lower than that of the copper phase, so under otherwise similar conditions, a decrease in copper content usually causes a decrease in electrical conductivity; however, a low electrical conductivity alone cannot directly determine that the copper content is insufficient.

Troubleshooting direction	Possible cause	Recommended inspection method
Chemical composition	Low copper content, tungsten-copper ratio not meeting requirements, excessive impurities	XRF, ICP-OES
Material density	Insufficient sintering or infiltration, more residual porosity	Archimedes method for density measurement, metallographic analysis, industrial CT when necessary
Copper phase distribution	Discontinuous copper phase, local tungsten enrichment, uneven microstructural distribution	Metallographic microscope, SEM-EDS
Measurement conditions	Rough surface, unsuitable thickness or shape, different temperature	Retest with standard specimen, instrument calibration, unified temperature and measurement position
Subsequent processing	Surface contamination, local thermal damage, or microstructural changes caused by processing	Retest after cleaning, compare measurement results at different depths or positions

It is recommended to execute in the following order: first repeat the measurement with a calibrated instrument at the specified temperature and take values at multiple positions; if the result is still low, then check the material composition and density; if both composition and density meet the requirements, further check copper phase continuity, impurities, and local microstructural abnormalities. The electrical conductivity result should also clearly indicate the unit and expression method used, such as percentage of International Annealed Copper Standard (% IACS). Values under different units or different test conditions cannot be directly compared.



II. Copper bleeding: focus on checking the infiltration process, pore channels, and thermal history

Tungsten-copper alloy is usually prepared by the powder metallurgy route, in which a common process is to first form a porous tungsten skeleton and then introduce liquid copper through infiltration. So-called copper bleeding may manifest as surface copper liquid exudation, local copper enrichment, copper spots after processing, or copper migration or leakage during high-temperature use. The actual phenomenon must first be confirmed before judging whether it is a manufacturing defect.

Possible cause	Formation mechanism	Troubleshooting method
Excessive copper content or infiltration amount	Too much copper phase, local copper-rich areas are easily formed	Chemical composition analysis, cross-section metallography
Abnormal pore structure of tungsten skeleton	Uneven pore size or connectivity, leading to uneven copper distribution	Metallographic analysis, density testing, industrial CT when necessary
Improper infiltration temperature or holding time	Uneven copper liquid distribution, local accumulation, or unsuitable process window	Trace furnace temperature curve, holding time, and process records
Residual copper on surface or processing smearing	Mechanical processing smears the copper phase onto the surface, forming an appearance similar to bleeding	Observe after cleaning, cross-section analysis, microscopic inspection
High-temperature service or local overheating	Copper phase softens, migrates, or flows under local temperature and pressure conditions	Check actual temperature, load, contact state, and failure location

During troubleshooting, first confirm whether the copper bleeding occurs before leaving the factory, after processing, or during use. If copper liquid exudation or obvious copper spots appear before the product is in service, priority should be given to checking the infiltration process, material microstructure, and surface processing state; if it appears only after high-temperature use, the actual temperature, local heat flow, contact pressure, and thermal cycling should be included in the analysis. It is not recommended to directly polish away surface copper traces and then judge the product as qualified. If copper bleeding originates from internal connected pores, microstructural abnormalities, or insufficient high-temperature stability, simply treating the surface can only conceal the phenomenon and cannot eliminate the root cause.

III. Internal cracks: distinguish manufacturing cracks, processing cracks, and service cracks

Tungsten-copper alloy is composed of a tungsten phase and a copper phase, and the two differ significantly in thermal expansion and mechanical properties. Powder pressing, sintering, copper infiltration, cooling, mechanical processing, and subsequent thermal cycling may all generate local stress. When the stress exceeds the local load-bearing capacity of the material, microcracks, interfacial cracking, or macroscopic cracks may occur.

Possible source of cracks	Typical cause	Recommended inspection
Powder pressing and sintering stage	Uneven green compact density, pressing defects, uneven sintering shrinkage	Trace process records, inspect cross-section microstructure and crack distribution
Copper infiltration and cooling stage	Large temperature gradient, tungsten skeleton defects, cooling stress	Metallographic analysis, industrial CT, fracture analysis
Mechanical processing stage	Excessive tool load, clamping stress, concentrated cutting heat, brittle tungsten phase chipping	Check crack direction, processing trajectory, and tool and clamping records
Brazing or connection stage	Joint thermal expansion mismatch, brazing thermal cycling, residual stress	Check connection interface, thermal cycling records, and joint cross-section
Actual service stage	Thermal shock, fatigue load, overheating, or local stress concentration	Analyze in combination with failure location, load history, and fracture morphology

The test method should be selected according to crack size and location. X-ray digital radiography is suitable for inspecting some internal defects; industrial CT can provide three-dimensional defect information, but when the tungsten content is high and the part is thick, X-ray attenuation increases significantly, and actual detection capability needs to be verified first. Ultrasonic testing can be used for suitable geometric shapes and defect types; penetrant testing is mainly used for cracks connected to the surface and cannot prove that there are no internal cracks. For high-reliability products, after internal cracks are found, delivery should be stopped first and the crack location, size, orientation, and propagation risk should be evaluated. Whether repair is allowed should be decided according to product application, technical agreement, and risk assessment, and it should not be assumed that the original performance can be restored by repair welding or surface treatment.

IV. How to judge the correlation when the three types of abnormalities appear simultaneously?

If low electrical conductivity, copper bleeding, and internal cracks occur simultaneously, it is recommended to first check the consistency of the material microstructure and manufacturing process, rather than treating the three phenomena separately. The recommended troubleshooting order is basically as follows:

Isolate the abnormal batch and record the defect location, occurrence time, product number, and use conditions.

Review electrical conductivity, density, and dimensional testing, and confirm that the instrument, temperature, specimen state, and measurement method are consistent.

Recheck the tungsten-copper composition, metallographic microstructure, copper phase distribution, and pore conditions to determine whether there is a common material or process cause.

Check the pressing, sintering, infiltration, cooling, and mechanical processing records to locate the abnormal process and process fluctuations.

Formulate corrective measures for the root cause, and verify with retained samples of the same batch, reworked samples, or trial production batches.

Re-inspect all key indicators and form a cause analysis, corrective measures, verification results, and batch disposition record.

For example, if copper bleeding and internal cracks are concentrated in the same local area, it may indicate abnormalities in copper phase distribution, pore structure, or local thermal stress; if electrical conductivity is also low at the same time, the overall copper content, density, and copper phase continuity should also be checked. However, these correlations can only serve as investigation directions and cannot replace metallographic and composition testing evidence.

V. How to prevent the problem from recurring?

The supplier should take measures for the confirmed root cause, rather than only treating the final manifestation. If there is composition deviation, raw material batching and batch review should be improved; if pore or copper phase distribution is abnormal, the pressing, sintering, and infiltration processes should be adjusted and stabilized; if cracks originate from processing, tools, cutting parameters, clamping methods, and machining allowance should be optimized; if defects originate from the use environment, temperature, load, thermal cycling, and structural design need to be re-evaluated.

The purchaser can add the following requirements to the quality agreement: provide measured data of material composition, density, and agreed performance for each batch; retain traceable production batches and process records for key products; specify acceptance limits and rejection conditions for key defects such as internal cracks and copper bleeding; when abnormalities occur, the supplier should submit a root cause analysis and corrective and preventive action report, and complete re-inspection as agreed.

In short, substandard electrical conductivity should first be checked for composition, density, and measurement conditions; copper bleeding should focus on the infiltration process, pore channels, and thermal history; internal cracks should be analyzed for stress sources in combination with defect location and formation stage. Only by combining measured data, metallographic evidence, and production records can surface phenomena be distinguished from the true root cause.

Q68 How to establish a batch traceability and quality control system for tungsten-copper alloy products?

The key to establishing a batch traceability and quality control system for tungsten-copper alloy products is to enable every product to be associated with raw material batches, production processes, test results, processing records, and final delivery information, and to ensure that when substandard electrical conductivity, copper bleeding, internal cracks, or dimensional out-of-tolerance occur, the problem batch can be quickly located, the cause traced, and the scope of impact controlled. It is recommended to adopt a management model with batch coding as the main line, process quality control as the foundation, inspection records as evidence, and closed-loop handling of abnormalities as the guarantee, which is suitable for tungsten-copper electrical contacts, electronic packaging heat dissipation components, EDM electrodes, and other custom products.

I. Establish a complete batch traceability chain

The traceability of tungsten-copper alloy should not only record the finished product number but also cover the entire process from raw material warehousing to product delivery.

Raw material warehousing

Supplier, material grade, tungsten-copper composition, powder batch number, inspection report, warehousing date, and acceptance conclusion.

Manufacturing process

Batching, powder mixing, pressing, sintering, infiltration, heat treatment, or other actual process batches, equipment, process parameters, and operation records.

Processing and in-process inspection

Blank number, machining process, equipment and tool information, key dimensions, appearance inspection, and process release records.

Final inspection and delivery

Composition, density, electrical conductivity, thermal conductivity, hardness, dimensions, and special testing, judgment, packaging identification, and customer order information.

Each stage should retain clear input batches, output batches, and association relationships. If one raw material batch is split into multiple production batches, or multiple blank batches are combined for processing, the splitting, merging, and corresponding quantities must be recorded, and a single general finished product batch number cannot be retained only.

II. Unify batch coding and identification rules

It is recommended to establish a coding rule with uniqueness, readability, and scalability.

For example: WCU-261023-P03-M02

This example can be defined as: WCU indicates the tungsten-copper alloy product category, 261023 indicates the production date, P03 indicates the production batch, and M02 indicates the sub-batch. It is only an example, and the actual code should be determined according to the enterprise's existing system and ensure that it will not be repeated. The traceability system should at least distinguish the following identifications: raw material batch number, manufacturing batch number, machining batch number, inspection batch number, and finished

product batch number. They can be associated through the system and do not all need to be printed on the product surface. For products that are small in size and cannot be directly engraved, the batch number can be marked on the packaging label, turnover box, tray, or accompanying documents; QR codes or barcodes can be used to quickly read batch information. If the product allows permanent marking, the marking location and method should also be verified not to affect function, surface quality, or customer assembly requirements.

III. Establish quality control points divided by process

The traceability system must be combined with actual quality control; otherwise, even if the records are complete, nonconforming products cannot be prevented from flowing into the next process in time.

Process stage	Main quality risk	Recommended control items	Release condition
Raw material acceptance	Composition deviation, powder abnormality, material mixing	Composition, supplier documents, powder batch number, and agreed raw material indicators	Raw materials meet procurement specifications
Batching & powder mixing	Batching error, uneven mixing, impurity contamination	Batching weighing records, equipment status, mixing process records	Ratio & process parameters meet requirements
Pressing & sintering	Uneven green compact density, abnormal shrinkage, cracks	Pressing parameters, sintering temperature curve, holding time, and appearance inspection	Process parameters qualified, no prohibited defects
Copper infiltration	Abnormal Cu distribution, residual porosity, copper bleeding	Infiltration temperature, holding time, copper dosage, density, and microstructure inspection	Infiltration quality meets process requirements
Mechanical processing	Dimensional out-of-tolerance, chipping, cracks, surface damage	Key dimensions, geometric tolerances, roughness, and processing state	Process inspection qualified
Final inspection	Substandard performance, internal defects, missed inspection	Composition, density, electrical conductivity, hardness, dimensions, and agreed special testing	All applicable acceptance items qualified
Packaging & shipping	Mixed batches, wrong shipment, inconsistent identification	Labels, quantity, batch number, documents, and order verification	Physical objects consistent with quality documents

The test items in the table do not mean that every batch of products must repeatedly perform all tests. Enterprises should determine full inspection, sampling inspection, and periodic verification items according to product application, failure risk, customer requirements, and process stability.

IV. Clarify the correspondence between quality documents and traceability records

Each finished product batch should form a set of mutually associated quality files, recommended to include:

Material certificate

material grade, chemical composition, material source, and batch information.

Production process records

batching, pressing, sintering, infiltration, heat treatment, and key equipment parameters.

In-process inspection records

process dimensions, appearance, defects, and release conclusions.

Factory inspection report

key performance, measured dimensions, test methods, units, and judgment results.

Special test records

metallography, nondestructive testing, coefficient of thermal expansion, airtightness, or other applicable items.

Nonconforming product and corrective action records

defect description, cause analysis, disposition method, and re-inspection results.

Shipping records

customer order, finished product batch number, quantity, packaging identification, and accompanying documents.

Taking substandard electrical conductivity as an example, quality personnel should be able to find the corresponding test record through the finished product batch number, and then associate it with material composition, density, production furnace number, infiltration process, and processing records. Only by forming such associations does traceability have practical value.

V. Establish an abnormality handling and batch isolation mechanism

When abnormalities occur, it is recommended to implement a unified closed-loop process: after discovering the problem, immediately identify and isolate the relevant products, determine the affected batches and quantities, trace raw materials and process records, analyze the root cause, formulate corrective measures, and decide whether to release, rework, downgrade, or scrap after re-inspection.

For tungsten-copper alloy, different abnormalities should correspond to different investigation priorities. For example, low electrical conductivity should focus on checking composition, density, and copper phase continuity; copper bleeding should check the infiltration process, pore channels, and thermal history; internal cracks should be judged in combination with crack location, metallographic microstructure, cooling process, and processing stress.

Abnormality handling must retain approval records. After rework, products cannot be re-released simply because the appearance has improved; the performance and dimensions affected by rework should be re-tested; when internal cracks or critical electrical performance are involved, whether rework is allowed should also be decided according to product risk and customer requirements.

VI. Set quantifiable quality management indicators

To judge whether the system is effective, it is recommended to calculate the following indicators monthly or by production batch:

Indicator	Calculation or statistical method	Management purpose
Batch first-pass yield	Batches passing first inspection ÷ total inspected batches × 100%	Evaluate manufacturing process stability
Product defect rate	Number of nonconforming products ÷ total number of inspected products × 100%	Identify main defect types
Traceability completeness rate	Batches with complete traceability records ÷ total number of inspected batches × 100%	Check whether the record chain is complete
Abnormality closure cycle	Time from abnormality registration to completion of corrective action verification	Measure problem handling efficiency
Recurring defect occurrence rate	Number and trend of abnormalities with repeated same root cause	Judge whether corrective measures are effective
Supplier batch qualification rate	Qualified incoming material batches ÷ total incoming material batches × 100%	Evaluate supplier quality stability

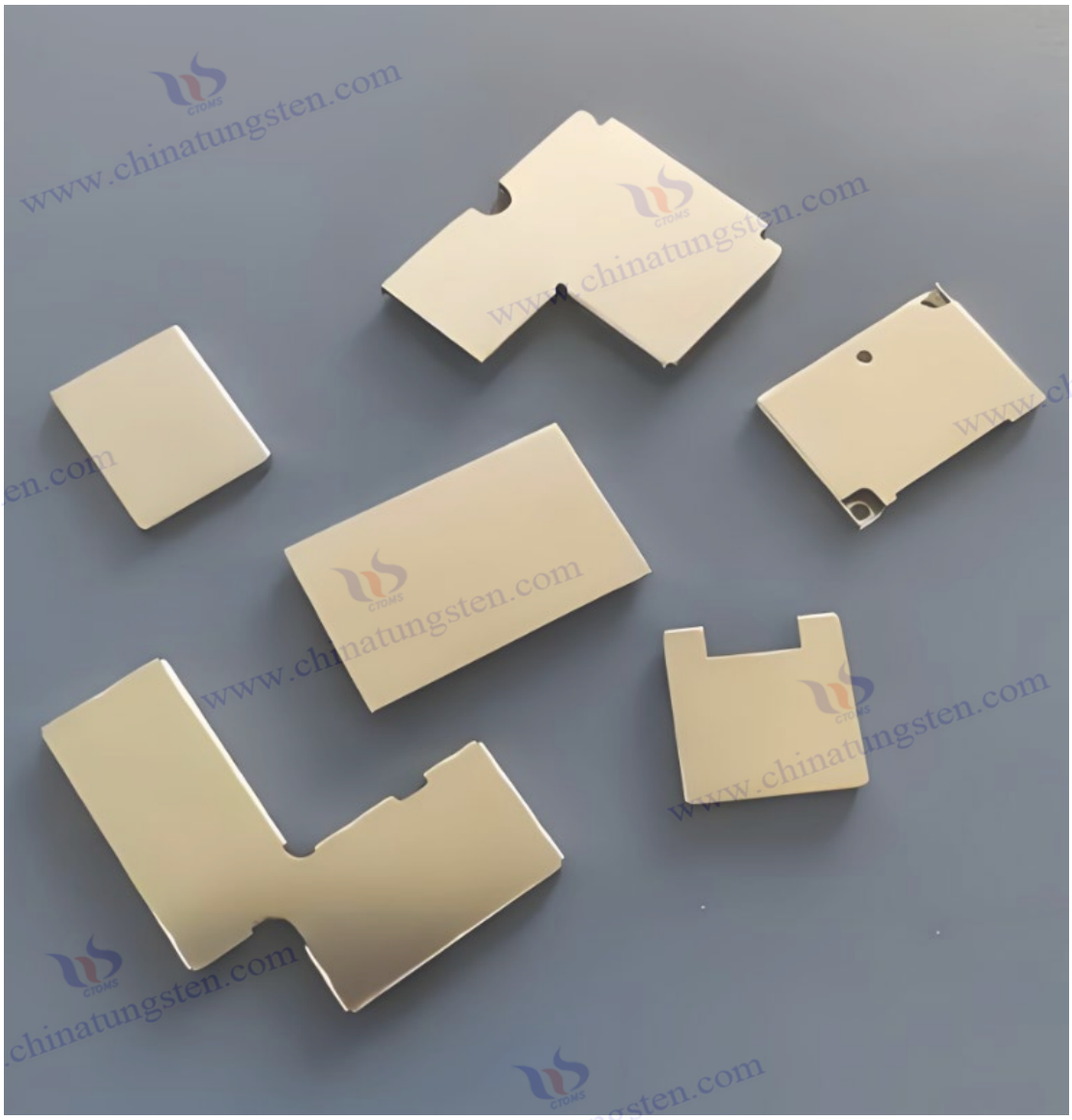
Indicators should be statistically stratified by product category, supplier, and defect type to avoid mixing tungsten-copper products of different applications and risk levels for comparison.

VII. Gradually upgrade from spreadsheets to digital traceability

Small and medium-sized enterprises can first use controlled spreadsheets or quality management systems to establish a unified batch ledger, ensure consistent fields, clear permissions, records that cannot be arbitrarily overwritten, and good backups. When there are many product varieties, frequent batches, or complex processes, then gradually connect to a manufacturing execution system (MES) and enterprise resource planning (ERP) system to realize the association of production, inspection, inventory, and delivery data.

Regardless of which system is used, the most important thing is not the technical form, but ensuring that records are authentic, batches are unique, data are traceable, changes leave traces, and abnormalities can be closed in a loop. When critical electrical contacts or high-reliability electronic packaging products are involved, the record retention period, data review authority, and customer audit requirements should also be clearly specified.

In summary, batch traceability and quality control of tungsten-copper alloy should form a complete chain from raw materials, production processes, processing inspection to finished product delivery, and ensure that the system truly operates through clear release standards, abnormality isolation, and corrective measures. It is recommended to start with four basic tasks: batch coding, key quality control points, factory inspection records, and closed-loop abnormality handling, and then gradually improve digital management.



X. Tungsten-Copper Alloy Procurement and Supplier Evaluation

Q69 What factors determine the price of tungsten-copper alloy?

The price of tungsten-copper alloy is mainly determined by the cost of tungsten and copper raw materials, the tungsten-copper ratio, the manufacturing process, product dimensions and machining accuracy, performance requirements, order quantity, and inspection standards. Among these, raw materials determine the cost basis, the manufacturing process and processing difficulty determine processing costs, and quality requirements and yield affect the final quotation. For buyers, even if two suppliers both quote WCu80 (tungsten-copper 80, i.e., tungsten mass fraction of approximately 80% and copper mass fraction of approximately 20%), the final price may differ significantly if the blank state, dimensional tolerances, density requirements, and inspection items are different.

I. Main factors affecting the price of tungsten-copper alloy

Influencing factor	Effect on price	Specific reason
Tungsten and copper raw material prices	Directly affect material cost	Changes in tungsten powder prices, copper material prices, and raw material procurement cycles all affect quotations
Tungsten-copper ratio	Usually an important cost factor	Higher tungsten content usually means more tungsten powder is needed, and material cost increases accordingly
Material purity and powder quality	May increase cost	Raw materials with high purity, controlled particle size distribution, and low impurity content usually require stricter procurement and process control
Manufacturing process	Affects manufacturing cost and yield	Equipment, energy consumption, and number of processes differ among powder pressing, sintering, copper infiltration, and other process routes
Product dimensions and structure	Material utilization rate and processing hours	Thin walls, deep holes, narrow grooves, complex surfaces, and small-size features increase processing difficulty
Dimensional tolerances and surface requirements	Higher precision means higher cost	Fine grinding, slow wire cutting, precision machining, and multiple measurements increase labor hours and quality control costs
Density and performance indicators	Process control and inspection costs	The stricter the requirements for density, electrical conductivity, thermal conductivity, hardness, and microstructural uniformity, the more complex process control usually is
Order quantity	Affects unit cost	Batch production can amortize programming, tooling, setup, and inspection costs; small-batch customization usually has higher unit costs
Inspection and delivery requirements	Increases quality and fulfillment costs	Metallographic analysis, nondestructive testing, third-party testing, special packaging, and expedited delivery may all increase costs

II. Why does the tungsten-copper ratio affect price?

Tungsten-copper alloy is usually expressed in terms of the mass fractions of tungsten and copper. Common grades include WCu50, WCu60, WCu70, WCu75, WCu80, and WCu90, where the number usually indicates the mass fraction percentage of tungsten.

Common grade	Tungsten content	Copper content	General trend of price impact
WCu50	50%	50%	Copper cost changes are relatively more important
WCu70	70%	30%	The impact of tungsten powder cost further increases
WCu80	80%	20%	Usually more sensitive to tungsten powder prices
WCu90	90%	10%	Tungsten raw material cost usually occupies a more important position

The above ratios are all mass fractions, and specific products should still be based on the material certificate and procurement agreement. Under otherwise similar conditions, materials with higher tungsten content are usually more expensive, but the final quotation of two products cannot be judged solely by tungsten content. Different grades may also differ in manufacturing process, density, microstructural requirements, and processing difficulty. For electronic packaging components requiring high thermal conductivity, or precision parts requiring a specific coefficient of thermal expansion, performance requirements should be determined first, and then an appropriate tungsten-copper ratio should be selected, rather than simply pursuing high tungsten content.

III. How do manufacturing process and machining accuracy affect quotations?

Tungsten-copper alloy is usually manufactured by the powder metallurgy route, which may specifically include tungsten powder preparation and pressing, sintering, copper infiltration, blank shaping, and subsequent precision machining. The process routes for different products are not completely the same.

Blank prices and finished product prices also need to be distinguished. Purchasing standard plates, rods, or blocks usually mainly considers material specifications, supply state, and machining allowance; purchasing finished products with precision holes, complex contours, or strict geometric tolerances also requires including costs for programming, clamping, cutting, grinding, wire cutting, deburring, and final inspection.

For example, for the same WCu80:

Standard-size blank: mainly affected by material cost, blank specifications, and supply quantity

Simple turned or milled part: adds machining hours and dimensional inspection costs

Part with deep holes, narrow grooves, or complex cavities: may require multiple clampings, dedicated tooling, and special processing equipment

High-precision electronic packaging component: in addition to processing fees, may add costs for flatness, parallelism, surface roughness, and thermal performance verification

Therefore, when inquiring, it should be clarified whether the quotation object is raw material, blank, or final finished product, to avoid directly comparing prices of different delivery states.

IV. Why do raw material market fluctuations transmit to tungsten-copper quotations?

The raw material cost of tungsten-copper alloy is affected by changes in the prices of tungsten concentrate, ammonium paratungstate (APT, Ammonium Paratungstate), tungsten powder, and copper materials. Tungsten raw materials are also affected by factors such as mine supply, production quotas, inventory, processing costs, and trade policies, and price fluctuations may be significantly different from those of copper materials. In addition, there is usually a time lag in the transmission of raw material prices to finished product quotations. Suppliers may use raw material inventory purchased earlier or organize production according to long-term procurement contracts, so the current quotation is not necessarily synchronized with the raw material market price of the day. If the purchase volume is large or the delivery period is long, it is recommended to clarify in the contract the quotation validity period, raw material price adjustment mechanism, prepayment and material preparation rules, to reduce the impact of raw material price changes on the project budget.

V. How to judge whether a supplier's quotation is reasonable?

It is recommended to require suppliers to quote according to the same product conditions and, as far as possible, break down material costs, manufacturing costs, precision machining costs, inspection costs, and packaging and transportation costs. At least the following information should be unified: material grade and tungsten-copper ratio, blank or finished product state, product drawings and dimensional tolerances, density and other key performance requirements, surface treatment, inspection standards, purchase quantity, and delivery cycle.

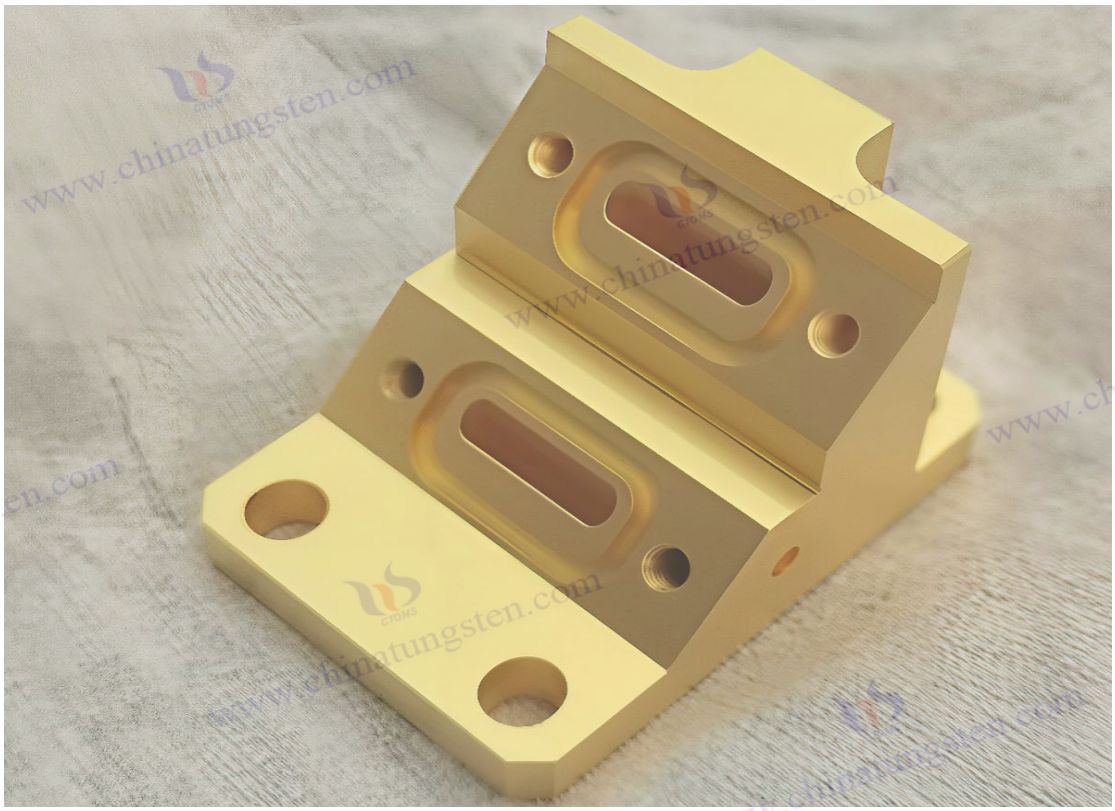
If two quotations differ greatly, priority should be given to checking whether the same material grade, manufacturing process, and acceptance standards are used, and then comparing unit prices. For schemes with significantly lower prices, it should also be confirmed whether they include necessary precision machining, performance testing, and quality traceability documents. For custom tungsten-copper products, relevant material and processing information from CTIA GROUP can also be consulted, and the quotation range can be determined in combination with drawings and actual working conditions.

VI. How can the price of tungsten-copper alloy be estimated?

Before obtaining a formal supplier quotation, the cost composition can be understood using the following simplified method: finished product price ≈ raw material cost + manufacturing and processing fee + precision machining fee + inspection fee + packaging and transportation fee + reasonable management and profit margin. Among these, raw material cost is not only related to the unit material price but also depends on blank weight, finished product weight, machining allowance, and material utilization rate. For complex parts requiring a large amount of material removal, even if the finished product volume is not large, higher costs may arise due to a larger blank and longer processing time.

To obtain a more valuable estimate, the most important thing is to provide the material grade, product dimensions or drawings, purchase quantity, and key requirements such as density, electrical conductivity, thermal conductivity, and dimensional accuracy. The tungsten-copper ratio or price per kilogram alone is usually insufficient to judge the actual cost of a custom finished product.

For any needs or questions, you can contact CTIA GROUP to calculate the cost and economic feasibility of your design.



Q70 How do tungsten content, product dimensions, and machining accuracy affect procurement cost?

The procurement cost of tungsten-copper alloy is mainly affected by three aspects: tungsten content, product dimensions, and machining accuracy. Tungsten content determines the baseline level of material cost, product dimensions affect blank usage, material utilization rate, and processing hours, and machining accuracy determines equipment, tools, number of processes, and inspection investment. The three interact, so the final quotation cannot be judged solely by grade or finished product weight.

I. How does tungsten content affect material cost?

Tungsten-copper alloy is usually classified by tungsten mass fraction, such as WCu50, WCu70, WCu80, and WCu90, where the number usually indicates the mass fraction percentage of tungsten. Because the prices of tungsten powder and copper raw materials differ, changing the tungsten-copper ratio directly changes raw material cost.

Material grade	W mass fraction	Cu mass fraction	Cost impact characteristics
WCu50	50%	50%	Both tungsten and copper raw material costs have a relatively obvious impact
WCu70	70%	30%	The impact of tungsten raw material price changes is usually greater
WCu80	80%	20%	Relatively sensitive to tungsten powder procurement prices
WCu90	90%	10%	Tungsten raw material cost usually occupies a more important position

Under otherwise identical conditions, higher tungsten content usually increases material cost, but it does not mean that the finished product price will necessarily increase proportionally

with tungsten content. Reasons include that different grades may differ in powder metallurgy process, densification difficulty, yield, and subsequent processing costs.



To estimate raw material cost, the following expression convenient for procurement calculation can be used: theoretical raw material cost = product material mass × (tungsten mass fraction × tungsten powder unit price + copper mass fraction × copper raw material unit price). Actual procurement should also include manufacturing loss, infiltration loss, blank machining allowance, and material utilization rate. For complex parts, the blank weight may be significantly higher than the finished product weight, so directly calculating raw material cost by finished product weight easily underestimates cost.

II. How do product dimensions affect procurement cost?

Product dimensions not only determine how much material is needed but also affect blank manufacturing method, processing equipment selection, clamping method, and material loss.

Dimensional and structural feature	Main impact on cost
Increased product volume and blank weight	Increased material usage, and manufacturing and handling costs may rise
Thin-wall, slender, or small-size structures	Increased clamping difficulty, prone to deformation, chipping, or processing damage
Deep holes, narrow grooves, & complex cavities	Increased processing time, may require special tools or multiple clampings
Large flat surfaces or long parts	Flatness, parallelism, and processing deformation control may be more difficult
Large difference between blank &finished	More material removed, lower material utilization rate, higher cost
Non-standard dimensions or special blanks	May require custom blanks, increased material preparation time, or additional minimum order costs

For example, if two tungsten-copper parts have the same finished weight, and one is a simple block while the other has deep holes, thin walls, and complex grooves, the latter usually requires more processing hours and inspection processes, and the quotation may also be higher. During procurement, finished product dimensions and blank requirements should be provided at the same time. If the supplier is allowed to design the blank, it can be required to optimize the blank dimensions while meeting performance and processing requirements to reduce unnecessary material loss.

III. How does machining accuracy affect procurement cost?

Higher machining accuracy usually requires stricter equipment control, tool management, measurement methods, and in-process inspection, but cost does not increase linearly as tolerances tighten. When tolerances approach the limits of equipment capability, material stability, or measurement capability, costs may rise significantly.

Processing requirement	Impact on cost
General dimensional tolerance	Conventional machining & conventional measurement methods can be used
Strict dimensional tolerance	May increase finish machining, fine grinding, repeated measurement, and inter-process inspection
High flatness and parallelism requirements	Need to control clamping deformation, residual stress, & processing sequence
High surface quality requirements	May increase fine grinding, polishing, deburring, and surface inspection
Strict hole position & position tolerance requirements	May require high-precision positioning, dedicated fixtures, or coordinate measuring machines
High density, low porosity, microstructural uniformity requirements	Require strengthened material process control and increased corresponding inspection and verification

For tungsten-copper alloy, the tungsten phase has high hardness and the material microstructure is heterogeneous, so processing also needs to control tungsten phase chipping, copper phase smearing, local cracks, and processing stress. Therefore, precision requirements not only affect machining costs but may also affect manufacturing yield.

Procurement drawings should set strict tolerances only for functionally critical dimensions as far as possible, and use reasonable tolerances for non-critical dimensions. This can ensure product assembly and performance while avoiding unnecessary costs caused by excessive finish machining.

IV. How do the three factors jointly affect quotations?

The following cost structure can be used for preliminary judgment: finished product procurement cost ≈ material cost + manufacturing cost + machining cost + inspection cost + packaging and transportation cost. Among these, tungsten content mainly affects material cost and part of manufacturing cost; product dimensions affect material usage, blank cost, and processing time; machining accuracy affects finish machining hours, equipment occupation, inspection investment, and nonconforming risk. Procurement cost judgment example (the following table is a qualitative comparison and does not represent actual market quotations):

Scheme	Product conditions	Main cost characteristics
Scheme A	WCu70, standard-size blank, general tolerance	Material and processing costs are relatively easy to control
Scheme B	WCu80, same finished dimensions, strict tolerance	W raw material cost and finish machining and inspection costs may be higher
Scheme C	WCu80, complex thin-wall structure, strict geometric tolerance	Material cost, processing hours, yield control, and inspection may all increase

The actual price difference between schemes still depends on raw material procurement prices, process routes, product quantity, and the supplier's manufacturing capability, and a fixed increase cannot be directly inferred from the above conditions alone.

V. How to reduce procurement cost without sacrificing quality?

It is recommended to optimize from three directions: material selection, structural design, and tolerance allocation. First, select an appropriate tungsten-copper ratio according to actual requirements for electrical conductivity, thermal conductivity, arc erosion resistance, or thermal expansion matching, and do not blindly increase tungsten content when there is no actual performance need. Second, minimize unnecessary deep holes, narrow grooves, thin walls, and excessive machining allowances, and negotiate reasonable blank dimensions with the supplier. Finally, concentrate strict tolerances on assembly surfaces, contact surfaces, sealing surfaces, and key functional dimensions, while clarifying inspection methods and acceptance standards. For batch orders, unit costs can also be reduced by unifying specifications, optimizing production scheduling, reducing changeovers, and establishing stable supplier quality agreements. When inquiring, suppliers should be required to separately explain material, processing, and inspection costs, and unify delivery status, inspection requirements, and quotation validity period for effective comparison. If purchasing custom tungsten-copper alloy products, relevant material and processing information from CTIA GROUP can be consulted, and costs can be evaluated in combination with actual drawings and technical requirements.

Tungsten content determines the material cost basis, product dimensions determine material usage and processing workload, and machining accuracy determines manufacturing difficulty and quality control investment; through reasonable material selection, optimized structure, and function-based tolerance allocation, it is usually more conducive to controlling total procurement cost than simply 压低 the supplier's unit price.

Q71 Why are the prices of tungsten-copper alloy blanks and precision-machined finished products different?

The prices of tungsten-copper alloy blanks and precision-machined finished products are different, and the core reason is that their delivery states are different. Blanks mainly reflect material cost and basic manufacturing cost, while precision-machined finished products also include costs for dimensional machining, tool wear, process control, surface treatment, quality inspection, and processing loss. Therefore, even if the material grade and finished product net weight are the same, the procurement price of precision-machined finished products is usually higher.

I. Cost composition of blanks and precision-machined finished products

Cost item	W-Cu alloy blank	Precision-machined finished product
Tungsten-copper raw materials	One of the main costs	Also required
Powder metallurgy manufacturing	Usually required	Usually required
Blank forming and densification	Required	Required; part of the cost has been included in the blank cost
Turning, milling, grinding	Usually relatively little	May occupy a large proportion
Special tools and tooling	low requirements	complex structures or high-precision products
Precision dimensional inspection	Usually relatively simple	May require multi-process measurement, coordinate measuring machines, etc.
Surface treatment	Depends on requirements	May add fine grinding, polishing, deburring, and other processes
Processing loss	Usually relatively low	Affected by machining allowance, structural complexity, and yield
Quality traceability special inspection	According to contract requirements	Usually requires more complete inspection records

It should be distinguished that a blank is not necessarily unqualified low-quality material. Tungsten-copper blanks with high density, low porosity, or strict composition requirements may also require complex manufacturing processes and strict quality control.

II. Why does precision machining significantly increase price?

First, material utilization rate affects actual cost. Tungsten-copper alloy blanks usually need to reserve machining allowance. If the part has many deep holes, narrow grooves, complex surfaces, or thin-wall structures, the proportion of material removed may be relatively high. Some chips can be recycled, but the recycling value does not equal a full return of the original blank cost.

Second, tungsten-copper alloy has relatively high hardness and heterogeneous microstructure characteristics. The tungsten phase has high hardness, while the copper phase is relatively soft, and processing may cause tungsten phase chipping, copper phase smearing, burrs, and local cracks, so tools, cutting parameters, and processing sequence need to be selected according to the material grade.

Third, the stricter the tolerances, the higher the manufacturing and inspection costs are usually. For example, general dimensional tolerances can use conventional machining, while high flatness, high parallelism, precision hole positions, and low surface roughness requirements may require additional fine grinding, dedicated fixtures, repeated measurement, and process adjustment.

Fourth, finished product delivery responsibility is greater. Blank suppliers mainly guarantee the agreed material and blank quality; finished product suppliers are also responsible for drawing dimensions, processing defects, surface quality, and agreed functional performance. If the procurement agreement requires complete material certificates, factory inspection reports, and special inspection records, quality management costs will also increase.

III. Use a simple example to understand the price difference

Assume a batch of WCu80 (tungsten-copper 80, i.e., tungsten mass fraction of approximately 80% and copper mass fraction of approximately 20%) parts is purchased, with a blank weight of 1.5 kg per piece and a final finished product weight of 1.0 kg per piece. In this example, 0.5 kg of material per piece needs to be removed during processing. The blank cost is calculated by blank weight, while the finished product cost should include processing, inspection, and other delivery costs in addition to the blank cost. It can be estimated as follows: precision finished product cost ≈ blank procurement cost + machining cost + inspection cost + surface treatment cost + packaging and transportation cost. This does not mean that every 0.5 kg of material removed per piece will form an equal loss, because chips may have recycling value; however, cutting hours, tool consumption, and processing equipment occupation usually cannot be offset by recycling chips.

IV. Under what circumstances is it more cost-effective to purchase blanks?

If an enterprise has stable machining capability, mature processes, and complete dimensional inspection equipment, purchasing blanks and processing them in-house may be more economical, especially for products with simple structures, large batches, or frequent design modifications. If the part has a complex structure, strict tolerances, high surface quality requirements, or the buyer lacks equipment and experience suitable for processing tungsten-copper alloy, directly purchasing precision-machined finished products is often more convenient and makes quality responsibility clearer.

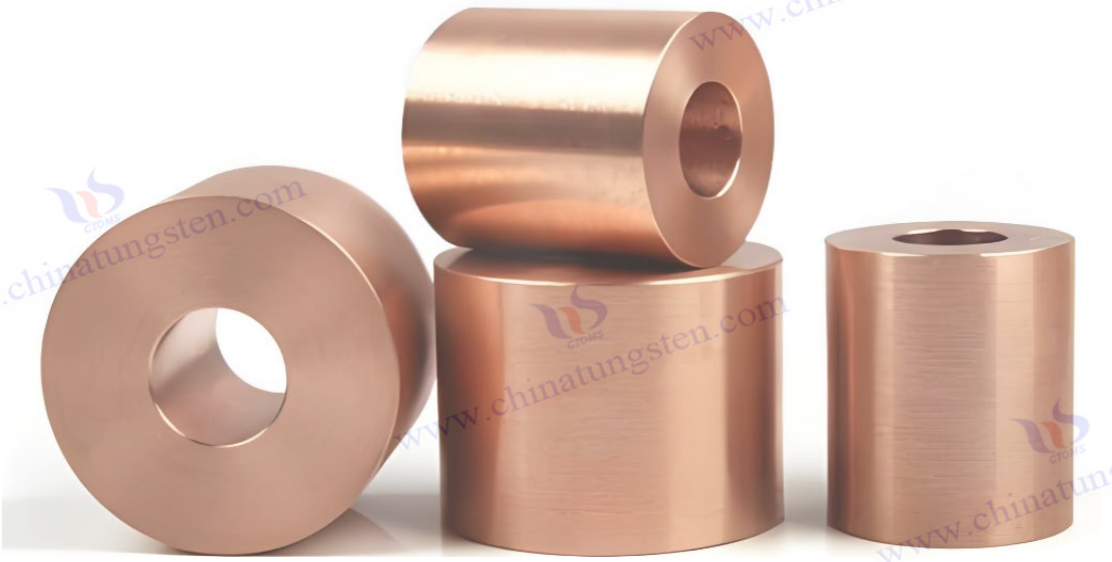
Procurement condition	More suitable approach
Has mature in-house processing capability	Prioritize comparing the total cost of blank procurement plus in-house processing
Simple product structure, stable batch	Can focus on evaluating the economy of in-house processing
Many deep holes, thin walls, or complex cavities	Compare finished product quotations from professional suppliers
Strict dimensional and geometric tolerances	Focus on evaluating precision machining capability and inspection system
Requires complete quality documents & batch traceability	Clarify documents and inspection scope in the quotation

V. How to compare the two quotations during procurement?

Do not directly compare the price per kilogram of blanks with the price per piece of precision finished products; instead, unify the material grade, product quantity, blank state, processing drawings, dimensional tolerances, performance requirements, and inspection scope.

It is recommended to separately calculate blank cost, in-house processing hours, tools and tooling, material utilization rate, inspection costs, rework risk, and transportation costs. Only by incorporating these items into the same cost basis can it be determined which procurement method is more economical. For custom tungsten-copper products, relevant material and processing information from CTIA GROUP can also be consulted, and the quotation boundary between blanks and finished products can be confirmed according to actual drawings.

It can be seen that blank prices mainly reflect material and basic manufacturing costs, while precision-machined finished product prices reflect the comprehensive cost of materials, processing difficulty, precision requirements, quality inspection, and delivery responsibility. During procurement, the total cost of the final qualified product should be compared, rather than only looking at the material unit price.





Q72 How to compare the quotations and performance data of tungsten-copper alloy provided by different suppliers?

When comparing the quotations and performance data of tungsten-copper alloy provided by different suppliers, it is not enough to look only at the price per kilogram or a single performance indicator; instead, material performance, actual procurement cost, and batch stability should be comprehensively compared on the premise that the material grade, testing conditions, product state, dimensional accuracy, quality assurance, and delivery scope are consistent. Especially for tungsten-copper alloy, even if suppliers mark the same tungsten-copper ratio, the actual density, internal microstructure, electrical and thermal conductivity, and processing quality may differ.

I. First unify the basis for quotation comparison

It is recommended to first convert the quotations of each supplier into the same comparison basis, focusing on checking the following contents.

Comparison item	Content to be confirmed	Impact on quotation
Material grade	WCu50, WCu70, WCu80, WCu90, etc.	Higher W usually means higher material cost
Product form	blank, semi-finished, precision-machined finished	Different scope of processing, inspection, quality responsibility
Product dimensions	Length, width, thickness, dia., & structure	Determine material usage and processing difficulty
Dimensional accuracy	Dimensional tolerance, flatness, parallelism, position tolerance, etc.	Higher precision requirements usually mean higher processing and inspection costs
Delivery quantity	Unit price, batch price, minimum order quantity	Affect production efficiency and unit manufacturing cost
Inspection scope	Composition, density, hardness, electrical conductivity, thermal conductivity, nondestructive testing, etc.	More inspection items usually mean higher costs and a larger quality assurance scope
Delivery conditions	Packaging, transportation, delivery cycle, taxes, and after-sales	Affect the actual landed cost

In particular, it should be confirmed whether the quotation includes finish machining, inspection reports, material certificates, surface treatment, and transportation costs. If one supplier quotes a blank and another quotes a precision-machined and inspected finished product, the two cannot be directly compared.

II. Performance data should be checked item by item

Technical data from different suppliers must be compared under the same material grade, similar dimensions, and consistent testing conditions. It is recommended to establish the following performance comparison table.

Performance indicator	Comparison focus	Procurement judgment method
Tungsten content, copper content	Mass fraction, testing method, composition tolerance	Confirm whether it meets the grade agreed in the contract
Density	Measured value, theoretical density basis, testing method	Judge material density and assist in evaluating porosity risk
Electrical conductivity	Value, unit, test temperature, test method	Check whether it meets the requirements for electrodes, electrical contacts, etc.
Thermal conductivity	Value, unit, test method and temperature	Judge whether heat dissipation performance meets design requirements
Hardness	Hardness scale, test load, specimen state	Make horizontal comparison only when test conditions are consistent
Bending strength or compressive strength	Specimen dimensions, sampling direction, test method	Evaluate load-bearing capacity and service reliability
Metallographic structure	Tungsten particle distribution, copper phase continuity, abnormal structure	Judge microstructural uniformity and manufacturing quality
Porosity and internal defects	Testing method, detection capability, acceptance limit	Evaluate the impact of internal defects on strength and thermal and electrical conductivity
Dimensions and geometric tolerances	Measured values, measuring equipment, sampling quantity	Judge whether the finished product can be directly assembled and used

Among these, density, electrical conductivity, and thermal conductivity are especially prone to inconsistent data bases. For example, electrical conductivity may be expressed as a percentage of the International Annealed Copper Standard, i.e., %IACS (International Annealed Copper Standard), or may use other units such as resistivity. Units must be unified before comparison, and the specimen temperature, state, and test method must be confirmed. In addition, the electrical conductivity and thermal conductivity of tungsten-copper alloy are not determined only by tungsten content but are also related to porosity, copper phase continuity, microstructural uniformity, and manufacturing process. Therefore, it cannot simply be assumed that the performance is necessarily the same when the tungsten content is the same.

III. Use measured data to judge whether performance is credible

Data provided by suppliers can be divided into three categories: typical values in product technical specifications, guaranteed values specified in contracts, and measured values of

specific delivery batches. The three have different probative force. Typical values in technical specifications are mainly used for preliminary material selection and cannot directly replace batch acceptance; contract guaranteed values are used to clarify the supplier's delivery responsibility; batch measured values should be traceable to the actual delivered products. During review, it is recommended to focus on checking the following contents:

Whether the testing method, unit, testing conditions, and acceptance standards are indicated.
Whether the inspection report corresponds to the actual delivery batch, and whether the sample number can be associated with the product batch.
Whether measured values of key indicators are provided, rather than all using typical values or the word "qualified."
Whether the inspection results meet the upper and lower limits specified in the contract, rather than merely being close to common industry levels.
Whether necessary re-inspection, third-party testing, or dispute handling mechanisms can be provided.

For high-requirement applications, key indicators, sampling ratios, re-inspection methods, and nonconforming handling methods can be agreed in the procurement contract. If a supplier only provides product brochures or performance tables without indicating testing conditions, they should be regarded as preliminary technical information rather than complete quality proof.

IV. Do not look only at unit price; calculate actual procurement cost

For blanks and precision-machined finished products, it is recommended to calculate the landed cost and the final qualified product cost separately. Total landed cost = product quotation + processing fee + inspection fee + packaging and transportation fee + taxes and other explicit fees. If there are significant differences in the yield or batch qualification rate among different suppliers, the loss caused by nonconforming products should also be evaluated. For products of the same specification and same acceptance requirements, the following method can be used for comparison: unit qualified product cost = total batch procurement and related costs ÷ final accepted qualified quantity.

For example, the following figures are only used to illustrate the calculation method and are not actual market quotations.

Item	Supplier A	Supplier B
Batch quotation	10,000 yuan	9,200 yuan
Additional costs such as inspection and transportation	500 yuan	800 yuan
Total batch cost	10,500 yuan	10,000 yuan
Final qualified quantity	100 pieces	90 pieces
Unit qualified product cost	105 yuan/piece	Approximately 111.11 yuan/piece

Although Supplier B's initial quotation is lower, its unit qualified product cost is actually higher due to the smaller final qualified quantity. During actual procurement, evaluation should also be combined with rework cost, delivery delay, production line stoppage risk, and after-sales handling cost.

V. Establish a comprehensive supplier scoring table

For projects requiring long-term procurement or batch supply, a 100-point system can be used for preliminary screening. The following is an adjustable weight example.

Evaluation dimension	Suggested weight	Main evaluation content
Material performance	30 points	Composition, density, electrical conductivity, thermal conductivity, and mechanical properties
Quality stability	25 points	Batch consistency, defect rate, inspection records, and traceability capability
Comprehensive cost	20 points	Unit qualified product cost, processing and inspection costs
Processing & delivery capability	15 points	Dimensional accuracy, complex structure processing capability, delivery performance rate
Technical service & after-sales	10 points	Technical response, re-inspection mechanism, exception handling, and quality compensation

Necessary elimination conditions should be set before scoring, such as key performance not meeting standards, batches not traceable, internal cracks exceeding acceptance limits, or dimensions unable to meet assembly requirements. Products that do not meet mandatory technical requirements should not be accepted just because of low price, fast delivery, or high total score.

If purchasing electrodes, electrical contacts, heat dissipation components, or high-precision counterweight parts, the weights should be adjusted according to the actual application. For example, for electrodes, the weight of electrical conductivity, arc erosion resistance, and dimensional stability can be increased; for heat dissipation components, the weight of thermal conductivity, density, and thermal cycle reliability can be increased.

VI. Several key judgments in procurement decisions

In actual comparison, the most vigilance should be paid to the following situations: the quotation is significantly lower than other suppliers but does not explain the material state or processing scope; none of the data in the performance table has a testing method; the inspection reports of different batches are completely identical but cannot prove the correspondence; only average performance is promised, without clarifying the acceptance upper and lower limits of key indicators; and there are no clear handling clauses for internal defects, dimensional out-of-tolerance, and batch nonconformity.

For tungsten-copper alloy products with high technical requirements, small-batch samples of the same grade and specification can be purchased from candidate suppliers first, verified according to a unified inspection plan, and then subsequent orders can be decided based on actual inspection results, processing performance, and batch consistency. For long-term projects, first article confirmation, batch sampling inspection, and regular supplier re-evaluation mechanisms should also be retained.

For supplier technical review and precision machining capability evaluation, relevant product and technical information from CTIA GROUP can also be consulted, but the final procurement

basis should still be the contract requirements of the specific product, traceable measured data, and acceptance results.

In short, the reasonable sequence for comparing tungsten-copper alloy suppliers is: first confirm that the grade, specification, and delivery scope are consistent, then verify key performance and inspection data, then calculate the comprehensive cost per qualified unit, and finally evaluate batch stability, delivery capability, and after-sales responsibility. Only when compared under the same acceptance standards does the price level truly have reference value.



Q73 How to judge the production capacity and quality management level of a tungsten-copper alloy supplier?

To judge the production capacity and quality management level of a tungsten-copper alloy supplier, it is not enough to look only at plant size, number of equipment, or corporate promotional materials; focus should be on verifying whether the supplier has stable powder metallurgy manufacturing capability, key process control capability, precision machining capability, inspection and verification capability, and batch traceability capability. For tungsten-copper electrodes, electrical contacts, heat dissipation components, and high-precision counterweight parts, it should also be judged whether the supplier's technical capability matches the product requirements in combination with the specific application. The following are some basic judgment factors summarized by CTIA GROUP based on its 30 years of design and processing experience.

I. Judge actual manufacturing capability from the production process

Tungsten-copper alloy is usually manufactured by the powder metallurgy route, and typical processes include raw material inspection, powder batching and mixing, pressing and forming, sintering or tungsten skeleton preparation, copper infiltration, subsequent heat treatment, and mechanical processing. The process routes of different suppliers may differ, and their actual product processes should prevail.

Inspection item	Key verification content	Manifestation of strong capability
Raw material control	Purity, particle size, batch, and supplier management of tungsten powder and copper powder	Raw materials have inspection records, and batch sources are traceable
Powder preparation and mixing	Batching accuracy, mixing uniformity, equipment cleanliness, and contamination prevention measures	Key parameters are recorded, and batching and mixing processes are controlled
Pressing &forming	Pressing equipment, mold condition, forming density, and green body defect control	Stable process parameters and green body inspection records
Sintering & copper infiltration	Temperature, time, atmosphere, infiltration conditions, and cooling process	Key process parameters are traceable, and abnormalities have handling records
Precision machining	CNC turning, milling, grinding, hole processing, dedicated tooling	Can meet the dimensions and geometric tolerances in actual drawings
Post-treatment & cleaning	Deburring, cleaning, surface treatment, anti-oxidation packaging	Standardized processes, with surface contamination & processing damage controllable

During inspection, it is not enough to confirm whether the equipment exists; it is also necessary to check whether the equipment is suitable for the target product. For example, the fact that a supplier has a CNC machining center does not necessarily mean it can stably process high-tungsten-content tungsten-copper alloy. High hardness, brittleness, material non-uniformity, and tool wear may all affect processing quality. For parts requiring complex inner holes, thin-wall structures, micro grooves, or high flatness, the supplier should be required to provide processing cases of similar materials, similar structures, and similar tolerance levels, and the actual measurement results should be checked.

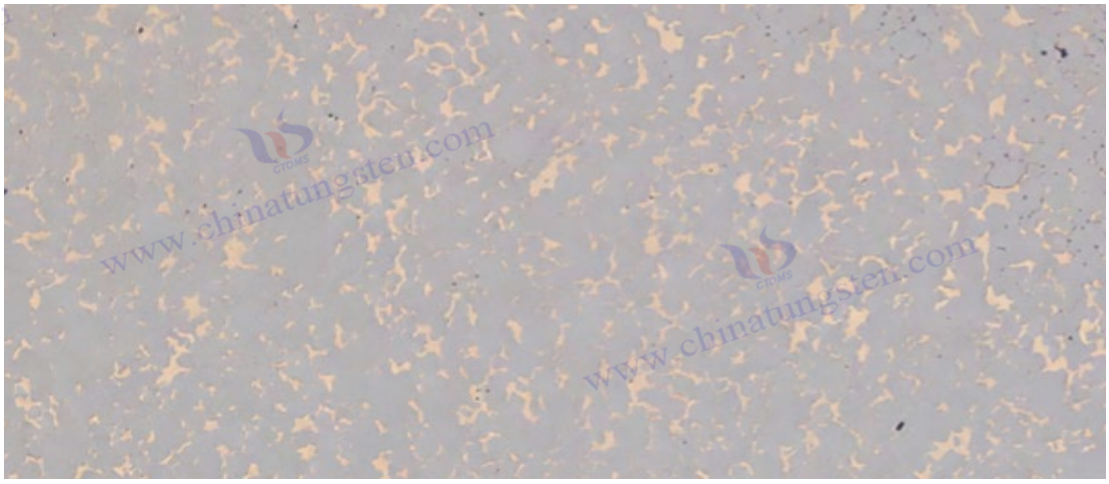
II. Verify quality control capability through testing equipment and inspection records

The quality management level of a supplier should be reflected in the ability to discover problems, accurately measure problems, and associate inspection results with specific batches, rather than simply listing a list of testing equipment.

Inspection item	Verifiable equipment or method	Main purpose
Chemical composition	X-ray fluorescence spectrometry, inductively coupled plasma optical emission spectrometry	Verify tungsten and copper content and related impurities
Density	Archimedes method or applicable volume measurement method	Evaluate density
Electrical conductivity	Eddy current method or four-terminal resistance method, etc.	Verify electrical performance
Thermal conductivity	Laser flash method to measure thermal diffusivity, combined with relevant parameters for calculation	Verify heat conduction performance
Hardness	Applicable hardness testing equipment	Check material state and performance consistency
Metallographic structure	Metallographic microscope and appropriate specimen preparation equipment	Observe tungsten particle distribution, copper phase continuity, and microstructural defects
Internal defects	Industrial computed tomography (industrial CT), ultrasonic testing	Check internal cracks, porosity, and abnormal areas
Dimensions &geometric tolerances	Coordinate measuring machine, image measuring instrument, micrometer, roughness meter, etc.	Verify dimensional accuracy and assembly requirements

The testing means should match the material characteristics and product structure. For example, the detection capability of industrial CT for high-tungsten-content, thick-wall, or complex geometric structures needs to be verified through actual samples, and it cannot be judged solely by the equipment name that it can detect all internal defects.

During on-site audits, it is recommended to randomly select a batch of completed products, trace from the physical object to the inspection report, raw material batch number, and key process records, and then reverse trace from a certain raw material record to the final product. Completing two-way traceability is more convincing than simply showing management documents.



III. Check whether the quality management system is truly operating

A supplier may hold a quality management system certification, but the certification itself cannot prove that every batch of tungsten-copper alloy meets the requirements. Focus should be on checking whether the system is implemented in daily production.

Management link	Records to be checked	Main judgment criteria
Supplier and raw material management	List of qualified suppliers, raw material acceptance records	Raw material sources are clear, and abnormal raw materials will not be put into use without approval
Process control	Process cards, equipment parameters, operation records	Key parameters are specified and recorded, and changes are controlled
Inspection management	Inspection specifications, raw data, equipment calibration records	Inspection methods are clear, and data are authentic and reviewable
Nonconforming product management	Isolation records, review records, rework or scrap records	Nonconforming products will not flow into the delivery link without authorization
Correction and prevention	Cause analysis, corrective actions, effectiveness verification	Not only repair a single product but also reduce the recurrence rate of problems
Document and batch traceability	Batch coding, material certificates, factory inspection reports	Documents correspond to physical objects, and records are complete and queryable
Change management	Records of changes in raw materials, processes, equipment, and outsourcing	Major changes have been evaluated and necessary re-verification has been carried out

If a supplier claims to implement international standards or quality management system standards, the complete number of the standard, scope of application, certificate validity, and actual production sites covered should be verified. For products with special applications, it should also be confirmed whether the supplier has corresponding experience in implementing industry standards; general quality management certification cannot be directly equated with product performance qualification.

IV. Judge batch stability through actual quality data

A single sample being qualified only shows that the sample meets the corresponding requirements and cannot prove that the supplier can supply stably over the long term. It is recommended to require the supplier to provide key performance data of several recent batches, covering at least composition, density, electrical conductivity or thermal conductivity, dimensional accuracy, and major defects. Focus on observing three types of indicators.

First, batch qualification rate. The statistical period, inspection quantity, qualification judgment standard, and statistical method of reworked products should be clarified to avoid showing only batches with better performance.

Second, performance fluctuation. For key indicators such as density, electrical conductivity, and dimensions, not only the average value but also the maximum value, minimum value, and batch-to-batch difference should be checked. If the data have long been concentrated near the acceptance boundary, even if temporarily qualified, there may be a high delivery risk.

Third, abnormal closed-loop capability. Require the supplier to show real nonconforming cases

and check whether cause analysis, corrective actions, effectiveness verification, and subsequent batch tracking have been completed. Being able to explain how the problem occurred and how to prevent recurrence is usually more valuable than simply claiming zero defects.

For products with strict dimensional requirements and large batches, the supplier can be further required to provide process capability analysis. Common indicators include the process capability index (Cp, Process Capability Index) and process performance index (Pp, Process Performance Index), but these indices are meaningful only when the data collection method, process stability, and distribution assumptions are applicable, and the quality level cannot be judged in isolation based on a single value.

V. Evaluate precision machining, production capacity, and delivery assurance capability

Production capacity includes not only whether it can manufacture but also whether it can continuously manufacture qualified products within the specified time. It is recommended to focus on checking the following: the actual load of existing equipment, whether there are single-point bottlenecks in key processes, whether molds and tooling have backups, emergency arrangements after key equipment shutdown, the quality control method of outsourced processes, and whether raw material inventory and production plans can support the order delivery date. For tungsten-copper precision machined parts, it should be further confirmed whether the supplier has stable tool management, processing parameter optimization, inter-process dimensional inspection, and processing deformation control capabilities. If the product requires deep holes, thin walls, complex profiles, or high flatness, it is best to require sample trial production and confirm using measurement methods consistent with formal acceptance. The supplier's theoretical annual capacity or equipment nameplate capacity can only be used as a reference. More valuable evidence is the actual monthly output of similar products, continuous batch delivery records, on-time delivery rate, and batch quality data.

VI. It is recommended to use a combination of on-site audit and sample verification

For important suppliers, evaluation can be carried out according to the following process:

Document pre-review: check corporate qualifications, production processes, equipment lists, testing capabilities, quality systems, and typical product records.

On-site audit: observe raw material storage, production environment, key processes, inspection areas, nonconforming product isolation, and record management.

Sample verification: clarify drawings, technical agreements, and acceptance standards, and require the supplier to submit samples and corresponding complete quality documents.

Small-batch trial production: verify batch consistency, dimensional stability, delivery cycle, and exception handling capability.

Batch admission: only after technical indicators, quality traceability, and delivery performance meet requirements should the procurement scale be gradually expanded.

In the sample verification stage, especially, it is necessary to prevent suppliers from providing specially selected high-quality samples but being unable to guarantee subsequent batch quality. Samples should be taken from normal production batches as far as possible, and sampling rules,

re-inspection methods, and nonconforming handling mechanisms should be clarified in the procurement contract.

VII. Supplier evaluation table that can be used directly

The following is a 100-point scoring scheme suitable for preliminary screening of tungsten-copper alloy suppliers, which can be adjusted according to product application.

Evaluation dimension	Suggested score	Core judgment basis
Raw materials & manufacturing process	20 points	Raw material inspection, powder metallurgy process, key parameter control
Testing capability & data credibility	20 points	Testing equipment, method applicability, calibration, and raw data
Quality management and traceability system	20 points	Batch traceability, nonconforming product control, corrective actions
Product performance and batch stability	20 points	Sample testing, multi-batch data, fluctuation of key indicators
Precision machining and delivery capability	15 points	Dimensional accuracy, actual production capacity, on-time delivery performance
Technical service and after-sales support	5 points	Technical response, re-inspection arrangements, quality responsibility agreement
Total	100 points	Score based on evidence, not promotional materials in place of actual records

It is recommended to use 80 points or above as a reference threshold for priority entry into trial production verification, 60 to 79 points as supplementary audit objects, and below 60 points as temporarily deferred admission. These scores are suggested values for internal procurement management and are not uniform industry standards. If key performance is unqualified, quality records are materially distorted, batches cannot be traced, or the supplier refuses necessary sample verification, even if the total score is high, direct admission is not appropriate.

For long-term procurement projects, suppliers can also be divided into three states: qualified, key monitoring, and suspended supply, and adjusted regularly based on batch qualification rate, repeated defect rate, on-time delivery rate, and abnormal closure cycle.

Ultimately, the most valuable evidence for judging whether a tungsten-copper alloy supplier is reliable is not the equipment list or the production capacity figures in promotional materials, but whether it can trace from raw materials, key processes, and actual inspection data all the way to the final delivered product, and whether it can prove the stability of its production and quality management with continuous batch results.

Q74 What key technical indicators need to be confirmed when purchasing tungsten-copper alloy?

When purchasing tungsten-copper alloy, the key is to clarify material composition, density, electrical conductivity, thermal conductivity, mechanical properties, internal defects, dimensional tolerances, and inspection requirements according to the product application, and to write these indicators into the procurement technical agreement. It is not enough to specify only grade names such as WCu70 (70% tungsten-copper alloy, 70% Tungsten-Copper Alloy) or WCu80 (80% tungsten-copper alloy, 80% Tungsten-Copper Alloy), because products with the same nominal composition may still exhibit significant differences due to different manufacturing processes, microstructural uniformity, and density.

I. Core technical indicators that must be confirmed during procurement

Technical indicator	Content to be confirmed	Procurement control focus
Tungsten and copper content	Mass fraction of each element and allowable deviation	Clarify the composition range and avoid acceptance based only on grade
Density	Minimum allowable value or specified range, testing method	Evaluate material density and assist in judging porosity risk
Electrical conductivity	Minimum value, unit, test temperature, and method	Key control for conductive applications such as electrodes and electrical contacts
Thermal conductivity	Minimum value, unit, test method, and temperature	Key control for heat dissipation components
Hardness	Hardness scale, target range, test conditions	Confirm wear resistance and processing adaptability
Bending or compressive performance	Indicator range, specimen state, and test method	Key control for load-bearing, clamping, or stressed parts
Internal defects	Cracks, porosity, inclusions, and allowable limits	Formulate acceptance requirements according to part thickness, structure, and failure risk
Metallographic structure	Tungsten particle distribution, copper phase continuity, and microstructural uniformity	Requirements can be added for high-performance electrodes and thermal management components
Dimensions and geometric tolerances	Length, width, thickness, hole diameter, flatness, parallelism, position tolerance	Precision-machined finished products must be specified item by item according to drawings
Surface quality	Scratches, chipping, burrs, copper seepage, oxidation, and contamination	Clarify acceptable defects and repair rules
Batch consistency	Batch number, measured data, sampling ratio	Ensure different batches meet the same acceptance standards

Not every product must inspect all of the above indicators. During procurement, priority should be given to controlling indicators that directly affect performance and safety, and then inspection items should be added according to product value, structural complexity, and failure consequences.

II. Material composition and density: confirm whether the material meets requirements

Tungsten-copper alloy grades are usually expressed by the mass fractions of tungsten and

copper. For example, WCu50 means a nominal tungsten content of 50% and copper content of 50%; WCu70 means a nominal tungsten content of 70% and copper content of 30%. The specific allowable deviation should be specified by the applicable standard or a bilateral technical agreement, and the nominal ratio cannot be directly regarded as the actual test result.

Density is an important auxiliary indicator but cannot be used alone to determine whether the material is qualified. It is recommended to check the measured density, the calculation basis of the theoretical pore-free density, and the measurement method used at the same time. Porosity can be approximately estimated as: porosity (%) ≈ [1 – measured density ÷ theoretical pore-free density] × 100%. The accuracy of this method depends on whether the theoretical density calculation is applicable, and it cannot completely replace metallographic or nondestructive testing.

Composition testing can use applicable methods such as XRF (X-ray Fluorescence, X-ray fluorescence spectrometry) or ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry, inductively coupled plasma optical emission spectrometry). For critical products, the composition testing method, sampling location, and re-inspection rules should be specified in the procurement documents.

III. Electrical conductivity, thermal conductivity, and mechanical properties: set thresholds according to actual application

Tungsten-copper alloy for different applications has different performance priorities. Electrical conductivity can be expressed in %IACS (International Annealed Copper Standard, International Annealed Copper Standard) or by indicators such as resistivity. During procurement, units, temperature, and testing methods must be unified, and values under different testing bases cannot be directly compared. Thermal conductivity should also specify the testing method and temperature conditions. If a supplier only provides typical values without measured data for the corresponding batch, it is recommended to use them for preliminary material selection rather than directly as the basis for delivery acceptance.

Application scenario	Indicators to be confirmed first	Suggested additional verification items
EDM electrode	Electrical conductivity, density, hardness, dimensional accuracy	Electrode wear, processing efficiency, surface quality
Electrical contact	Electrical conductivity, density, arc erosion resistance	Contact resistance, arc resistance, and service life
Electronic packaging & heat dissipation components	Thermal conductivity, thermal expansion performance, dimensional stability	Thermal cycle reliability, interfacial bonding performance
High-temperature stressed parts	High-temperature strength, thermal stability, internal defects	Thermal cycling and actual working condition verification
Counterweight parts	Density, dimensions, mass, and center of gravity requirements	Mass tolerance, dynamic balance, or assembly verification

IV. Internal defects and processing quality: do not only inspect appearance

Tungsten-copper alloy may have problems such as internal porosity, cracks, microstructural non-uniformity, and abnormal copper phase distribution. For thick-wall parts, high-value parts, and high-reliability applications, the testing methods and acceptance limits for internal defects should be specified according to product structure and failure risk.

Common methods include metallographic inspection, applicable ultrasonic testing, industrial CT (Industrial Computed Tomography, industrial computed tomography), etc. The detection capabilities of different methods are not the same, especially for high-tungsten-content or thick-wall parts; the applicability of the testing method to the target defect should be verified first, and it cannot be vaguely required that there be no internal defects at all without specifying detection capability and judgment standards. Precision-machined finished products should also specify dimensional and geometric tolerances, surface roughness, hole chamfers, burrs, and chipping requirements. For blank procurement, machining allowance, allowable defect depth, and whether the final dimensions can be guaranteed after defect removal should also be confirmed.

V. Inspection reports and quality certification documents

In addition to technical indicators, the procurement contract should also specify the quality documents that the supplier needs to provide with the goods. At least include material certificates, factory inspection reports, batch numbers, and corresponding raw material and manufacturing records. For key performance, specific measured values, units, testing methods, sampling quantity, and acceptance conclusions should also be required, rather than only marking "qualified." If ASTM (American Society for Testing and Materials, American Society for Testing and Materials) or other standards are used, the complete standard number, version, and scope of application should be stated. For example, ASTM B702 is for copper-tungsten electrical contact materials and cannot be used for all tungsten-copper products without applicability confirmation. For electronic packaging components, heat dissipation components, and counterweight parts, corresponding technical requirements should be formulated according to the actual product.

VI. Confirmation list that can be directly used in procurement technical agreements

Before formally placing an order, it is recommended to confirm at least the following matters:

Material grade and tungsten and copper content range

Density requirements and testing method

Acceptance values of electrical conductivity, thermal conductivity, or other core performance

Hardness, strength, and necessary thermal performance requirements

Acceptance rules for internal cracks, porosity, and surface defects

Finished product dimensions, geometric tolerances, surface roughness, and machining allowance

Inspection items, sampling ratio, re-inspection method, and nonconforming handling method

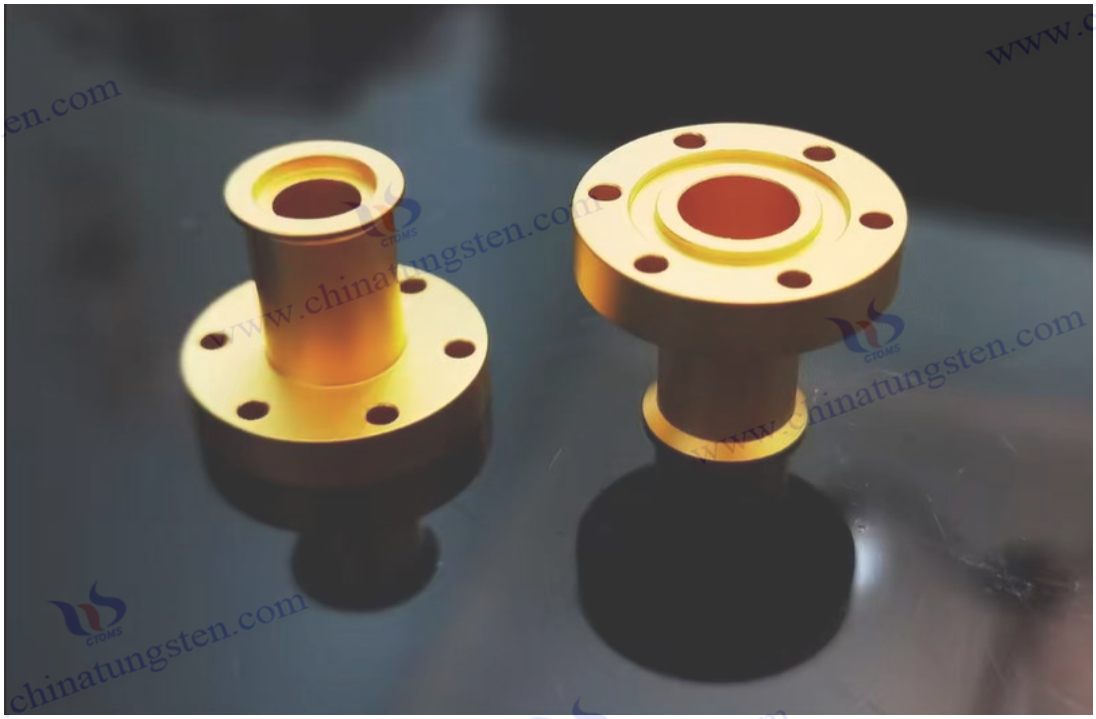
Batch traceability, material certificates, and factory inspection reports

Packaging, delivery date, quality objection period, and after-sales responsibility

For high-requirement tungsten-copper alloy products, relevant product and technical information from CTIA GROUP can also be referred to for preliminary supplier screening, but

final acceptance should be based on procurement drawings, bilaterally confirmed technical agreements, and batch measured data.

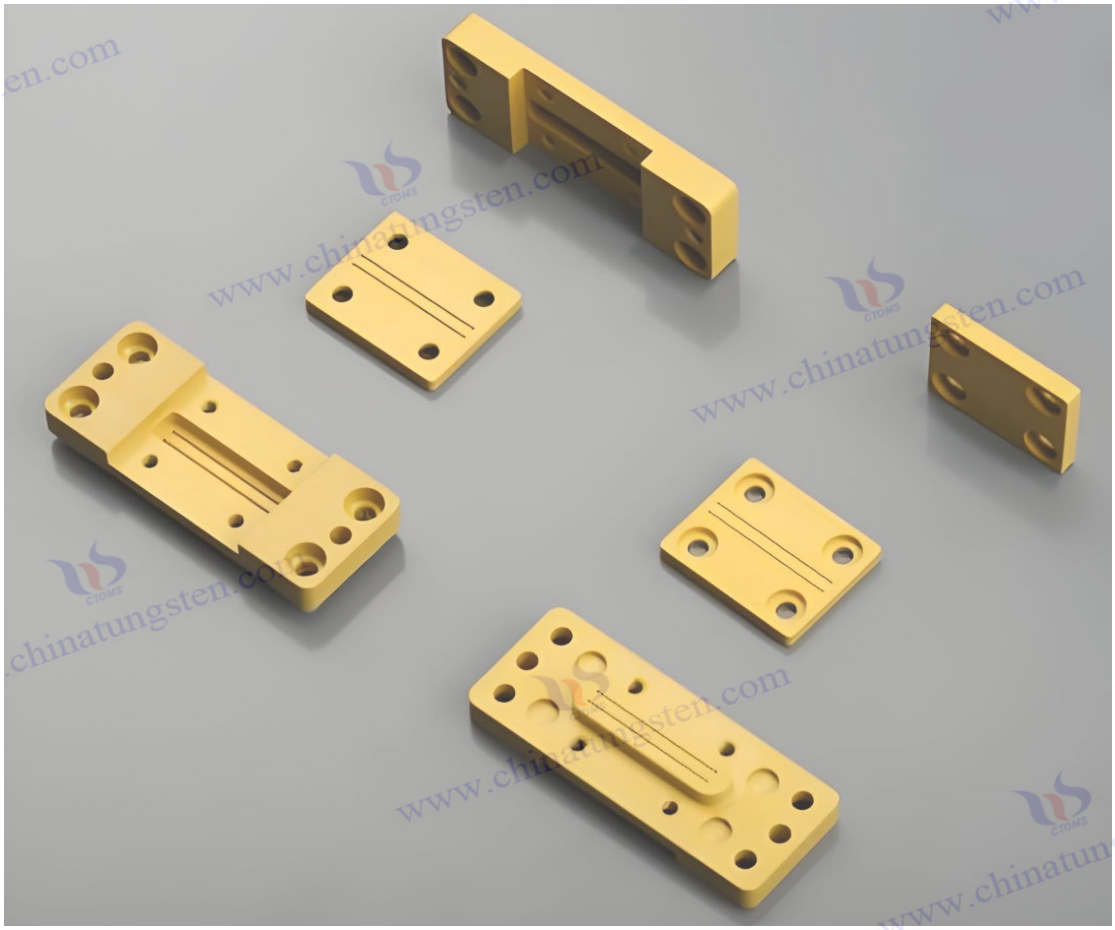
In actual procurement, the most effective approach is to first determine the product application and key failure risks, and then translate the corresponding performance into clear acceptance indicators. Rather than requiring suppliers to provide as many inspection items as possible, it is better to clearly specify the three to five indicators that most affect the use effect first, and at the same time agree on testing methods, batch traceability, and nonconforming handling mechanisms.





Q75 How should sample testing, trial production verification, and batch acceptance of tungsten-copper alloy be arranged?

For sample testing, trial production verification, and batch acceptance of tungsten-copper alloy, it is recommended to adopt a phased release approach: first verify whether the material meets the technical requirements, then confirm the processing technology and actual service performance, and finally control stability through batch sampling and quality traceability. The purposes of the three stages are different; a qualified sample test report cannot replace trial production verification, nor can subsequent batch acceptance be canceled just because the first batch is qualified.



I. Establish a three-stage verification process

First stage: sample testing

Goal: confirm that the material and sample meet the basic technical requirements.

Check composition, density, electrical conductivity or thermal conductivity, hardness, metallographic structure, appearance, and key dimensions. Add internal defect testing according to product risk, form a sample test report, and decide whether to proceed to trial production.

Second stage: trial production verification

Goal: confirm that manufacturing, processing, assembly, and service performance can be reproducibly achieved. Use the material, process, equipment, and inspection methods

intended for mass production to produce small-batch trial production parts, verify processing stability, dimensional consistency, yield, and necessary working condition performance, and complete the trial production review.

Third stage: batch acceptance

Goal: confirm that each delivery batch meets the contract requirements.

Inspect material performance, dimensions, surface quality, and quality documents according to the agreed sampling plan. When key indicators are unqualified, isolate, re-inspect, rework, or return according to the contract; unqualified key indicators cannot be offset by the qualification of other items.

II. First stage: how to arrange sample testing

First determine the representativeness of the sample

Samples should come from the supplier's normal production process, and it is not appropriate to accept only specially selected display samples. The material grade, nominal composition, manufacturing batch, product state, processing state, and sampling location should be recorded. If multiple suppliers are evaluated at the same time, drawings, specifications, inspection methods, and sample states should be unified as much as possible. The number of samples should not be generalized. A small number of samples can be taken for preliminary material screening, but if microstructural uniformity, batch differences, or dimensional consistency of complex products need to be evaluated, the number of samples should be increased, and different locations or different production batches should be covered as much as possible.

Set test items according to product application

Inspection category	Suggested items	Main purpose
Composition & material identity	Tungsten and copper content and necessary impurity testing	Confirm grade and material consistency
Basic physical properties	Density, electrical conductivity, or thermal conductivity	Verify core performance
Mechanical properties	Hardness, with bending or compressive performance added when necessary	Judge whether the material is suitable for actual working conditions
Microstructure & defects	Metallography, porosity, and applicable internal defect testing	Identify microstructural non-uniformity, cracks, and abnormal porosity
Appearance & dimensions	Key dimensions, geometric tolerances, surface roughness, and appearance	Confirm the basic conditions for processing and assembly
Service performance	Applicable items such as electrode wear, contact performance, thermal cycling	Verify whether actual functions meet requirements

Among these, electrical conductivity and thermal conductivity must specify units, temperature, and testing methods. If %IACS (International Annealed Copper Standard, International Annealed Copper Standard) is used to express electrical conductivity, the testing basis should be unified. Qualified material composition and density do not automatically mean qualified electrical conductivity, thermal conductivity, or actual service performance.

Form a sample release conclusion

After sample testing is completed, a traceable test record should be formed, including at least

sample number, batch, test items, test methods, measured values, acceptance limits, and judgment results. Only when key indicators meet requirements, data are credible, and defect risk is acceptable should the next stage be entered. If nonconformity occurs, material problems, manufacturing problems, processing problems, and testing method problems should be distinguished first. Retesting or re-sampling can be done when necessary, but nonconforming data cannot be concealed by repeated testing and retaining only qualified results.

III. Second stage: how to arrange trial production verification

The focus of trial production is not to repeat material performance testing once, but to verify whether the supplier can continuously manufacture products that meet service requirements.

Use conditions close to mass production

Trial production should use, as far as possible, the raw material specifications, manufacturing processes, processing equipment, fixtures, inspection equipment, and operating procedures planned for mass production. If special equipment, additional manual screening, or special processes are used in the trial production stage, and mass production cannot maintain the same conditions, the trial production results cannot fully represent subsequent delivery capability. The trial production quantity should be determined according to product complexity, production cycle, and quality risk. Simple, low-risk parts can use smaller batches; complex precision parts, critical electrodes, or high-reliability thermal management components should consider multiple production batches or different processing batches to observe stability.

Verify processing, assembly, and service performance

In the trial production stage, it is recommended to focus on checking the following aspects:

Processing stability: whether problems such as tool wear, chipping, cracks, copper phase smearing, or surface damage occur, and whether process parameters can be executed stably.

Dimensional consistency: whether key dimensions and geometric tolerances continuously meet requirements, and whether systematic deviation or processing deformation exists.

Yield and rework rate: count the first-pass qualified quantity, rework quantity, and scrap quantity, and record the main causes of defects.

Assembly adaptability: verify fitting dimensions, positioning accuracy, connection method, and actual assembly effect.

Working condition performance: carry out electrical performance, thermal performance, wear resistance, thermal cycling, or other necessary tests according to the application.

Completeness of quality documents: confirm that material certificates, process records, inspection reports, and product batches can correspond.

For parts with many key dimensions, the supplier can be required to submit statistical data on key dimensions, and its batch manufacturing capability can be evaluated according to data distribution and process stability. If the process capability index (Cp, Process Capability Index) or process performance index (Ppk, Process Performance Index) is used, the data conditions, statistical methods, and contractually agreed judgment thresholds should be clarified first, and a conclusion cannot be made based on a single index alone.

Release conditions for trial production review

After trial production is completed, it is recommended that the procurement, technical, quality, and actual user departments jointly review. Release conditions should at least include: key technical indicators qualified, dimensions and assembly verification passed, major defects closed, batch traceability complete, mass production process determined, and nonconforming handling process clarified. If the material grade, powder source, sintering or infiltration process, key processing parameters are changed during trial production, or important equipment is replaced, the impact of the change on material performance and product reliability should be evaluated. Some or all verification should be repeated when necessary.

IV. Third stage: how to execute batch acceptance

Batch acceptance should specify in advance in the procurement contract or technical agreement the acceptance items, sampling quantity, judgment standards, and re-inspection procedures, rather than deciding temporarily after the goods arrive at the factory.

Acceptance item	Suggested control method	Description
Batch and documents	Check material certificates, inspection reports, and batch numbers for each batch	Documents must correspond to the physical objects
Appearance and key dimensions	Inspect according to drawings and sampling plan	Inspection ratio can be increased for key fitting dimensions
Composition and density	Conduct batch sampling inspection according to contract	Important materials may require measured results for each batch
Electrical conductivity, thermal conductivity, and hardness	Determine sampling frequency according to application and quality risk	Clarify limits and test conditions for core performance
Internal defects	Inspect according to product risk and agreed methods	Inspection coverage can be increased for high-risk parts
Special performance	Execute according to specified batches, specimen quantity, and cycle	Not all destructive tests need to be performed on every product
Packaging and marking	Check protection, quantity, batch, and product marking	Prevent transportation damage and batch mixing

The sampling plan should consider batch size, defect severity, supplier historical performance, and inspection cost. For key safety or functional indicators, if the contract requires inspection of every piece, general sampling cannot be used instead; if sampling is used, the sampling method, acceptance quality limit, and handling method for nonconforming batches should be clarified.

Handling principles for batch nonconformity: when key indicators are found to be unqualified, the batch should be isolated first, use or transfer to the next process without evaluation should be suspended, and it should be confirmed whether the problem may affect other products in the same batch. Then, re-inspection, expanded sampling, full inspection, rework, return, or concession acceptance approval should be executed according to the contract. Concession acceptance should be approved by authorized technical and quality personnel of the buyer, and it should be confirmed that the deviation will not affect product safety and function. Suppliers cannot replace nonconforming handling with reissued reports or verbal promises

alone.

V. Suggested quality control frequency

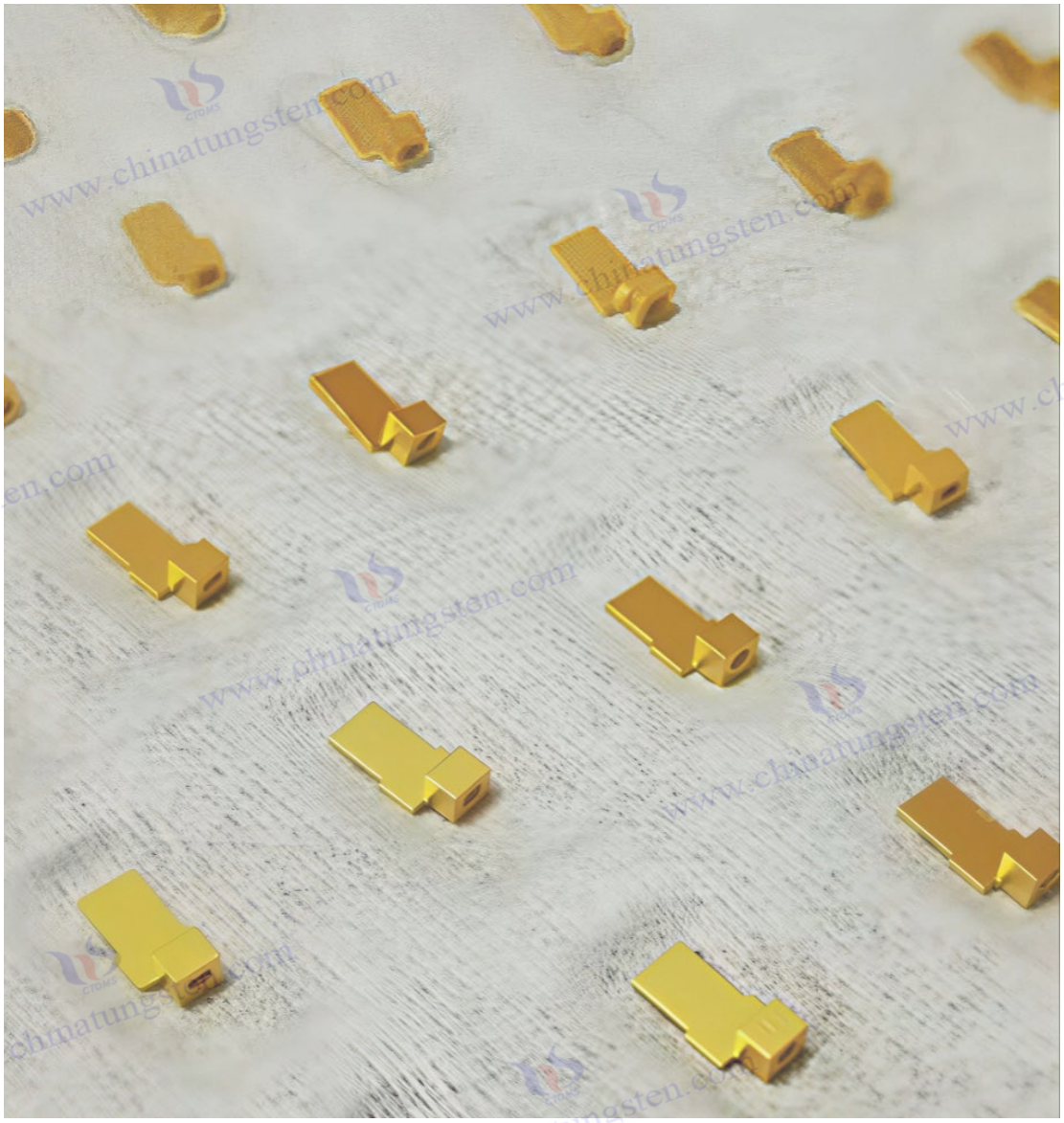
The following is a suggested scheme that can be used to establish an initial procurement system. The specific frequency should be adjusted according to product risk, batch size, and supplier historical performance, and is not a uniform mandatory industry requirement.

Control stage	Suggested frequency	Key records
Initial supplier introduction	Complete at least one full sample verification for each supplier	Sample report, process capability, and review conclusion
New product or major process change	Re-verify the relevant items	Change content, risk assessment, and verification results
Initial batch supply	Strengthen sampling inspection for the first several batches	Batch performance, dimensions, defects, and yield
Stable mass production	Execute according to the per-batch sampling plan specified in the contract	Batch reports and traceability records
After quality abnormalities occur	Increase inspection for the relevant batches, and restore strengthened inspection when necessary	Cause analysis, corrective actions, and effectiveness verification
Regular supplier re-evaluation	Execute according to internal cycles such as quarterly, semi-annual, or annual	Qualification rate, delivery date, repeated defect rate, and traceability completeness rate

VI. What should be specified in the procurement technical agreement

To avoid the situation of qualified samples but batch disputes, it is recommended to specify the following information in the contract annex or technical agreement: material grade and composition range, density and core performance limits, dimensions and geometric tolerances, surface and internal defect standards, testing methods and units, sample and trial production release conditions, batch sampling rules, quality certification document requirements, batch traceability methods, re-inspection procedures, quality objection period, and responsibility for handling nonconforming products. If purchasing EDM electrodes, actual application indicators such as electrode wear, processing efficiency, and surface quality should be included in verification; if purchasing electronic packaging or heat dissipation components, thermal conductivity, thermal expansion matching, and thermal cycle reliability should be mainly considered. When involving tungsten-copper shielding parts or counterweight parts, relevant product technical information from CTIA GROUP can also be referred to for understanding product types, but acceptance should still be based on bilaterally confirmed drawings, technical agreements, and measured data.

It is recommended to form the entire process into a release record table, recording stage by stage whether samples are qualified, whether trial production problems are closed, whether mass production conditions are locked, and whether batch acceptance is passed. This can prevent unverified products from directly entering batch procurement, and can also quickly locate the batch, process, and responsibility link when problems such as low electrical conductivity, internal cracks, or dimensional out-of-tolerance occur later.



Q76 How to reduce quality, delivery, and supply risks in tungsten-copper alloy procurement?

Reducing quality, delivery, and supply risks in tungsten-copper alloy procurement requires establishing a complete control mechanism from six aspects: supplier admission, technical agreements, sample verification, production process monitoring, batch acceptance, and supply assurance. Tungsten-copper alloy is a powder metallurgy material, and product performance depends not only on the tungsten-copper ratio but is also affected by powder quality, forming and sintering processes, copper infiltration effect, internal microstructure, and subsequent processing conditions. Therefore, procurement management cannot focus only on unit price and contractual delivery dates; it should also ensure that suppliers can continuously and stably deliver products that meet technical requirements. At the same time, equipment information, technical indicators, process parameters, inspection reports, and other technical documents involved in the procurement process should also comply with China's applicable dual-use item export control regulations and suppliers' internal confidentiality systems. The buyer's request for information does not mean that the supplier can disclose all equipment, technology, and

document information without restriction; the scope of disclosure should be determined according to the specific project, nature of the information, recipient, and end use.

I. Control quality risk: clarify technical requirements from the source

Quality risks usually come from problems such as material composition deviation, insufficient density, substandard electrical or thermal conductivity, internal cracks, out-of-tolerance dimensions, and poor batch consistency. Before procurement, a clear technical agreement should be formulated according to the product application, avoiding procurement based only on grades such as WCu50, WCu70, or WCu80. It is recommended to focus on controlling the following:

Risk item	Main control measure	Acceptance basis
Composition deviation	Clarify tungsten and copper content and allowable deviation, and require batch inspection data	Composition inspection report, material certificate
Density and porosity	Specify density requirements, and add metallographic or internal defect inspection when necessary	Measured density value, defect inspection results
Substandard electrical and thermal conductivity	Clarify performance limits, units, temperature, and test methods	Batch performance inspection report
Internal cracks or microstructural non-uniformity	Formulate inspection plans according to product structure and risk	Metallographic and applicable nondestructive testing reports
Unstable dimensions and processing quality	Clarify dimensional tolerances, geometric tolerances, surface roughness, and defect limits	Dimensional inspection report, drawings, and technical agreement
Batch performance fluctuations	Establish batch numbering, key parameter records, and anomaly traceability mechanism	Production records, batch inspection data

For critical products, the guaranteed material performance values should be distinguished from typical reference values. Product catalog data provided by suppliers can only be used for preliminary material selection and cannot directly replace the measured data of the delivery batch. When critical performance is involved, the sampling quantity, retest method, and nonconforming product disposal procedure should be agreed in advance. In addition, technical indicators and the scope of information disclosure should be managed separately. The buyer can prioritize requesting composition, density, electrical conductivity, thermal conductivity, dimensions, and batch inspection results directly related to product acceptance, but should not, without confirming compliance and confidentiality boundaries, require suppliers to unconditionally disclose all manufacturing process parameters, internal equipment structures, proprietary technical documents, or other restricted information.

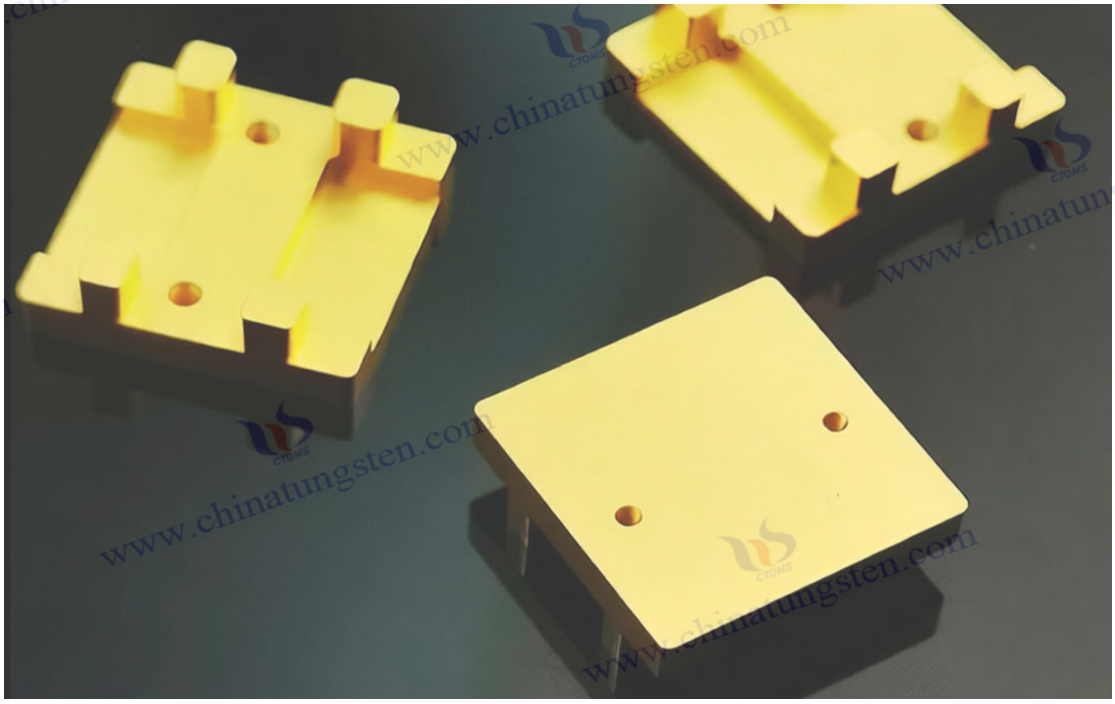
II. Control supplier risk: establish admission and tiered management mechanisms

Supplier qualifications, equipment lists, and quality management system certificates can only serve as preliminary screening bases; what really matters is their actual manufacturing capability, inspection capability, and continuous supply performance. Before procurement, raw material inspection, powder metallurgy process control, copper infiltration process, precision machining capability, testing equipment, and batch traceability system should be checked. For high-requirement products, whether the supplier can provide actual production cases of similar

grades, similar structures, and similar tolerance levels should also be checked. It is recommended to divide suppliers into three tiers: core suppliers undertake the main procurement share, qualified alternative suppliers have verified alternative supply capability, and suppliers to be verified can only gradually enter the procurement system through samples or small-batch trial production. For long-term cooperative suppliers, their quality qualification rate, on-time delivery rate, repeated defect rate, and anomaly handling efficiency should be periodically re-evaluated.

According to CTIA GROUP's successful experience in designing and producing tungsten-copper alloy over the past thirty years, the key to reducing procurement risk is not only to select suppliers whose material indicators appear excellent, but to confirm whether they can integrate material ratio, powder metallurgy process, precision machining, and quality inspection into a stable, repeatable, and traceable production system. For tungsten-copper alloy products, sustained and stable manufacturing capability and a complete quality control chain often determine the reliability of long-term procurement more than single sample performance or mere low price.

Supplier audits should also include compliance assessment. Especially when Chinese suppliers are involved, it should be verified whether the disclosure and delivery of relevant equipment, technical indicators, technical data, and documents are subject to dual-use item control, export control, or internal confidentiality requirements. When necessary, the supplier's compliance, legal, or confidentiality management personnel should confirm whether the information can be provided, to what extent it can be provided, and whether methods such as desensitization, summarization, on-site verification, or restricted access are required. It cannot be assumed that all technical information may be freely disclosed or transmitted across borders merely because the procurement contract stipulates a document delivery obligation.



III. Control delivery risk: match the procurement plan with actual production capacity

The delivery time of tungsten-copper alloy may be affected by multiple stages such as raw material procurement, powder metallurgy manufacturing, copper infiltration, heat treatment, precision machining, special inspection, and rework. Especially for complex structures, high-precision parts, and small-batch customized products, production plans cannot be arranged solely based on the delivery dates orally promised by suppliers. The following measures are recommended:

Delivery risk	Control method
Raw material supply delay	Verify the procurement cycle of key raw materials, and clarify safety stock and material preparation responsibilities
Manufacturing process queue	Require suppliers to provide staged production plans and key process milestones
Precision machining overtime	Confirm drawings, tooling, cutting tools, and processing capability in advance, and identify capacity bottlenecks
Inspection or retest delay	Determine inspection items, laboratory arrangements, and report cycles in advance
Delay caused by rework	Set intermediate inspection points to detect dimensional, crack, and performance anomalies as early as possible
Logistics or delivery anomalies	Clarify packaging, transportation methods, shipping milestones, and delay notification mechanisms

For critical orders, suppliers should be required to provide an executable delivery plan, at least listing milestones such as raw material arrival, manufacturing completion, processing completion, final inspection, and shipment. For continuous production or critical equipment maintenance projects, reasonable safety stock can be set according to actual consumption, replenishment cycle, and consequences of shortage. Safety stock should not be increased blindly. Too low inventory increases the risk of production stoppage, while too high inventory ties up capital and may cause losses due to design changes or long-term storage. A more reasonable approach is to adjust dynamically according to demand fluctuations, supply cycles, and supplier performance.

If the procurement involves controlled equipment, technical data, or other restricted items, the necessary compliance review, license application, or internal approval time should also be included in the project plan to avoid affecting the overall delivery time because data transmission, technical exchange, or delivery approval has not been completed.

IV. Control supply interruption risk: avoid excessive dependence on a single source for critical products

For tungsten-copper alloy products with large usage, long delivery cycles, difficult substitution, or serious consequences of supply stoppage, it is recommended to establish a verified second supply source. A second supplier cannot be deemed qualified based only on quotation and material grade; independent sample testing, trial production verification, and necessary assembly or performance confirmation should be completed. At the same time, the following risks should be assessed: whether key raw materials depend on a single channel, whether

important manufacturing processes are mastered by only one supplier, whether there are alternatives after core equipment downtime, whether there are uncontrollable links in outsourced processing, and whether early warning can be given when the supplier undergoes business or capacity changes.

For high-precision or special tungsten-copper parts, even if two suppliers use the same nominal grade, they may not be directly interchangeable due to differences in material microstructure, machining allowance, and process route. Therefore, when establishing a second source, consistency confirmation of drawings, technical agreements, and acceptance standards should be completed simultaneously, and re-verification should be carried out when necessary.

However, supply chain diversification also needs to comply with applicable control requirements. For projects involving dual-use items, restricted technologies, or internal confidential information, complete drawings, process parameters, equipment data, or technical documents cannot be directly transferred to other suppliers without review in order to establish alternative supply sources. The necessary information permitted to be shared should be determined first, and then supplier introduction should be completed through controlled documents, tiered authorization, and compliance review.

V. Connect sample verification, trial production, and batch acceptance into a closed loop

To reduce quality and delivery risks, inspection should not be limited to incoming goods; control points should be moved forward to the supplier's production process. It is recommended to release gradually in three stages: sample testing, small-batch trial production, and batch supply. The sample stage confirms material performance and basic dimensions; the trial production stage confirms process stability, processing yield, assembly effect, and necessary working condition performance; the batch stage performs inspection according to the sampling plan and acceptance standards specified in the contract. In the early stage of batch procurement, the inspection frequency of key indicators can be appropriately increased. After continuous batches show stable performance, the sampling level can be adjusted according to risk assessment; once problems such as substandard electrical conductivity, internal cracks, out-of-tolerance dimensions, or repeated delivery delays occur, enhanced inspection should be restored, and suppliers should be required to submit cause analysis, corrective measures, and effectiveness verification records. For important products, it is recommended to include the following indicators in supplier performance assessment:

Performance indicator	Management purpose
Batch qualification rate	Evaluate product quality stability
First-pass inspection qualification rate	Reflect manufacturing and process control level
On-time delivery rate	Evaluate production planning and delivery management capability
Repeated defect rate	Determine whether corrective measures are effective
Anomaly closure cycle	Evaluate problem response and resolution efficiency
Traceability completeness rate	Ensure quality problems can be traced to specific batches and processes

These indicators should adopt unified statistical calibers, and the assessment cycle should be clarified to avoid comparison distortion caused by different calculation methods among different suppliers. Documents required for sample, trial production, and batch acceptance should also be managed hierarchically. The buyer should distinguish between quality certification documents that must be delivered, information that can be confirmed through summaries or verification, and technical data that may involve dual-use item control or internal confidentiality requirements. For the latter two categories, compliance confirmation should be completed first, and then the form of provision, receiving personnel, storage method, and scope of use should be determined to ensure that quality verification is sufficient without exceeding the legal disclosure boundary.

VI. Clarify responsibility boundaries through contracts and technical agreements

Even if a supplier has strong manufacturing capability, if the contract does not specify technical requirements and anomaly handling mechanisms, the buyer may still face quality disputes, delivery delays, and additional costs. The procurement contract or technical agreement is recommended to specify the material grade and composition range, key performance acceptance values, dimensional tolerances, test methods, sampling ratios, batch traceability requirements, delivery milestones, quality objection period, retest mechanism, and nonconforming product handling method. For custom-machined parts, the drawing version, machining allowance, surface treatment, packaging requirements, and design change process should also be specified. In terms of delivery management, delay warning, remedial plans, partial delivery, and liability for breach of contract can be agreed; in terms of quality management, responsibility for rework, replacement, return, retest costs, and quality losses can be agreed. Relevant clauses should match the applicable law, actual transaction conditions, and responsibilities of both parties, avoiding provisions that only stipulate penalties but lack executable quality determination methods.

For equipment lists, technical indicators, manufacturing processes, inspection documents, and other technical data, the disclosure boundary, use authority, confidentiality responsibility, and cross-border transmission restrictions should be further clarified in the contract. For projects involving Chinese suppliers, the responsible parties should verify whether they fall within the scope of China's applicable dual-use item control, whether they involve controlled acts such as export, re-export, technology transfer, or providing data overseas, and confirm whether licenses or other approvals are required. At the same time, suppliers' internal confidentiality requirements and third-party rights should be respected.

If certain information cannot be fully disclosed, approved alternative verification methods can be used without violating control regulations and confidentiality obligations, such as providing reviewed inspection summaries, on-site verification by authorized personnel, entrusting qualified third-party testing, or completing review through restricted access permissions. Whether the alternative method is sufficient should be confirmed jointly according to product risk and contract requirements; it is not acceptable to directly cancel all necessary quality verification on the grounds of confidentiality, nor to require unrestricted disclosure of controlled technology on the grounds of quality review.

VII. Establish a procurement risk grading mechanism

Different tungsten-copper products should not use exactly the same control intensity. Procurement can be divided into three levels according to product criticality, supply cycle, substitution difficulty, and consequences of quality failure.

Risk level	Typical situation	Recommended management method
High risk	Critical electrical contacts, high-requirement electrodes, important thermal management components, major impact after supply stoppage	Supplier on-site audit, complete sample verification, small-batch trial production, enhanced batch inspection, and alternative sources
Medium risk	Conventional machined parts with clear performance requirements, stable batch procurement parts	First article confirmation, batch inspection, regular supplier re-evaluation
Low risk	Standard parts or blanks for non-critical uses, mature specifications, easy substitution	Basic document review, reasonable sampling inspection, and routine delivery management

The risk level should be dynamically adjusted according to the actual application. When major changes occur in product structure, key performance, supplier process, or raw material source, the risk needs to be re-evaluated, and past qualification conclusions cannot be continued. In addition to quality, delivery, and supply risks, compliance and information disclosure risk assessments should also be set up independently. For any equipment, technical indicators, and document disclosure involving Chinese suppliers, it should be confirmed whether the relevant project is subject to dual-use item control and internal confidentiality requirements, and then the depth of technical exchange, information transmission method, and supplier collaboration scope should be decided. For projects with doubts, compliance or legal personnel should review first to avoid illegal disclosure, inability to deliver data, or forced project interruption during contract performance.

To reduce tungsten-copper alloy procurement risk, supplier capability audits, technical agreements, staged verification, batch acceptance, delivery tracking, alternative supply sources, contract responsibilities, and compliance review should be combined. The goal of procurement management is not simply to find the supplier with the lowest price, but to continuously obtain tungsten-copper alloy products with qualified performance, stable quality, on-time delivery, and traceability at a reasonable cost.

For procurement projects involving Chinese suppliers, it is also necessary to simultaneously determine whether the disclosure of equipment, technical indicators, and documents is subject to dual-use item control and internal confidentiality requirements. Only by incorporating product quality control, supply chain assurance, and compliance management into the same process can comprehensive risks such as quality disputes, delivery delays, supply interruptions, and illegal disclosure of technical information be reduced while ensuring procurement efficiency.



XI. Tungsten-Copper Alloy Industry and Future Development

Q77 What are the main application fields and demand drivers of global tungsten-copper alloy?
Tungsten-copper alloy (W-Cu Alloy) is a composite material composed of tungsten (W, Tungsten) and copper (Cu, Copper). It usually utilizes the high melting point, high hardness, and low thermal expansion characteristics of tungsten, as well as the high electrical conductivity and high thermal conductivity of copper, to achieve performance combinations that are difficult for a single metal to balance. Its main applications are concentrated in fields such as EDM electrodes, electrical contacts and electrical switches, electronic packaging and thermal management, aerospace and defense industry, special resistance welding electrodes, high-temperature and arc-resistant components, and high-density counterweights and special engineering parts.

Global demand for tungsten-copper alloy is not driven by a single industry, but jointly promoted by power infrastructure upgrading, heat dissipation demand for advanced electronic equipment, precision manufacturing, automotive electrification, aerospace investment, and the development of special industrial equipment. Different fields have greatly different requirements for materials: electrical contacts value electrical conductivity, arc erosion resistance, and contact reliability; electronic packaging focuses more on thermal conductivity, thermal expansion matching, and dimensional stability; EDM electrodes focus on processing efficiency, electrode wear, material uniformity, and precision machining capability.

A distinction should also be made between end demand for tungsten-copper alloy and upstream demand for tungsten resources. Changes in tungsten prices will affect the material cost and procurement strategy of tungsten-copper alloy, but this does not mean that all growth

in tungsten consumption will translate proportionally into tungsten-copper alloy demand. Market size also depends on product grade, application substitution relationships, unit product usage, manufacturing process, and terminal industry investment rhythm.

I. Main application fields of global tungsten-copper alloy

Power systems and high- and medium-voltage electrical switches

Core applications: electrical contacts, arc-extinguishing contacts, and vacuum switch contacts

Tungsten-copper alloy can balance relatively good electrical conductivity, arc erosion resistance, and high-temperature dimensional stability, and is suitable for some medium- and high-voltage switchgear, vacuum circuit breakers, and other high-current switch components. The tungsten phase helps improve the contact's erosion resistance under arc action, while the copper phase provides electrical and thermal conduction channels. Main demand drivers include global grid expansion, substation renewal, industrial distribution equipment upgrading, renewable energy grid connection, and higher requirements for power supply reliability from data centers and large industrial facilities.

As wind, solar, and energy storage systems connect to the grid, power systems require more complete switching, protection, and distribution equipment. However, this does not mean that all switch contacts will use tungsten-copper alloy. Actual material selection also depends on switch structure, breaking current, working voltage, vacuum or gas medium, and the comprehensive performance of alternative materials such as silver-based contacts and copper-chromium contacts.

Electronic packaging and high-power thermal management

Important growth direction: heat dissipation base plates, chip carriers, and heat spreader components.

Tungsten-copper alloy can be used for heat dissipation base plates, carriers, and heat spreader components in some power electronic devices, radio frequency (RF, Radio Frequency) devices, microwave components, lasers, and optoelectronic packaging. Its advantage is that it can provide a relatively low coefficient of thermal expansion under a certain thermal conductivity, reducing thermal expansion mismatch between the material and ceramics, semiconductor chips, or other packaging materials. The demand drivers in this field mainly come from increasing power density of semiconductor devices, miniaturization of power modules, upgrading of RF and microwave equipment, increasing output power of lasers, and requirements for thermal cycle life of high-reliability electronic systems. Especially in high-power packaging, thermal management is not only about conducting heat away but also about controlling stress and interfacial fatigue caused by temperature changes. The specific advantages of tungsten-copper alloy depend on whether the tungsten-copper ratio, microstructural uniformity, thermal conductivity, and coefficient of thermal expansion match the target packaging structure. However, tungsten-copper is not the first choice for all heat dissipation scenarios. For cost-sensitive products or products with different quality requirements, pure copper, molybdenum-copper alloy, aluminum-silicon-carbide materials, and other composite materials may also be more suitable. Therefore, growth in this field is more reflected in opportunities for high-performance, customized thermal management materials

rather than comprehensive replacement of traditional copper materials.

EDM electrodes and precision mold manufacturing

Mature application: EDM electrodes

Tungsten-copper alloy is often used for precision electrodes in electrical discharge machining (EDM, Electrical Discharge Machining), especially suitable for scenarios requiring relatively high wear resistance, dimensional stability, and complex profile processing capability. Its performance helps control electrode wear and improve the processing performance of precision molds, complex cavities, and some difficult-to-machine materials. Main demand comes from automotive molds, precision injection molds, aerospace part molds, medical device molds, and other complex metal part manufacturing. Demand in this field is related to manufacturing capital expenditure, mold replacement cycles, penetration of precision processing equipment, and the application scale of difficult-to-machine materials. As mold structures become more complex, requirements for electrode shape accuracy, surface quality, material uniformity, and processing stability will also increase. However, the EDM electrode market is not composed only of tungsten-copper alloy. Graphite electrodes, pure copper electrodes, and other electrode materials are still widely used. Tungsten-copper is more advantageous in applications where wear resistance, detail accuracy, material strength, or specific discharge conditions are relatively demanding.

Resistance welding and industrial connection equipment

Typical applications: welding electrodes, contact tips, and heat-resistant conductive components

In some resistance welding applications, tungsten-copper alloy can be used for welding electrodes, contact tips, and parts bearing relatively high electrothermal loads. Its heat resistance, wear resistance, and electrical conductivity help extend service life under specific working conditions and maintain electrode geometry.

Demand is mainly driven by automotive body manufacturing, battery case and structural part connection, home appliance production, metal processing, and automated welding lines. As industrial automation increases, users increasingly value electrode life, maintenance cycles, welding consistency, and manufacturing cost per qualified product. For high-cycle production lines, frequent electrode wear or replacement brings downtime costs, so durability and stability may be more important than unit purchase price. Specific material selection should still be determined according to welding current, pressure, workpiece material, contact area, and cooling conditions. Under some working conditions, copper alloys such as copper-chromium-zirconium may be more cost-effective; tungsten-copper is usually used at specific stations where its performance combination better meets the requirements.

Aerospace, defense, and special high-temperature engineering

Specialized applications: high thermal load, arc-resistant, and special engineering components

Tungsten-copper alloy can be used for some aerospace electronic equipment, electrical connection components, high thermal load conductive components, and special engineering devices. Its value lies in combining high-temperature resistance, electrical and thermal

conductivity, and dimensional stability, rather than simply pursuing the highest temperature resistance or highest strength. Demand drivers include aerospace equipment renewal, development of high-reliability electrical systems, defense industry investment, and demand for special components under high temperature, high current, and complex environments. This field usually has high technical thresholds, long verification cycles, and strict quality traceability requirements. Even if market usage is not as large as general industrial materials, higher requirements may be placed on material consistency, custom processing, and batch certification. A distinction should also be made between tungsten-copper alloy and other tungsten-based materials such as pure tungsten and tungsten heavy alloy. Some aerospace or defense applications use other material systems and cannot be directly classified into the tungsten-copper alloy market merely because the application involves tungsten.

High-density counterweights and precision functional parts

Specific applications: counterweights, balance parts, and high-density structural parts

Tungsten-copper alloy has relatively high density and can be used for some counterweights or special functional parts that need to arrange a certain mass in a limited space. However, compared with tungsten-based high-density alloys, its density is usually lower, and the copper phase ratio significantly affects density, so not all high-density counterweight scenarios prioritize tungsten-copper. This type of demand mainly comes from precision equipment, instruments, some aerospace structures, dynamic balancing components, and special industrial devices. During procurement, more attention is usually paid to density, mass tolerance, center of gravity position, machined dimensions, and long-term stability.

Other specialized industrial uses

In addition to the above fields, tungsten-copper alloy can also be used for some special electrodes, conductive wear-resistant components, and high heat flux engineering components. Some applications are small in scale but may have high technical added value. It should be noted that material selection for plasma-facing components, medical device components, or radiation-related components is highly dependent on specific design, and not all related applications should be regarded as conventional demand for tungsten-copper alloy.

II. Main drivers of global tungsten-copper alloy demand

Power infrastructure upgrading

Grid expansion, substation renewal, industrial distribution system upgrading, and renewable energy grid connection drive demand for switchgear, contacts, and arc-resistant components. Its characteristic is that the demand base is relatively mature, and some products have continuous procurement brought by maintenance replacement and equipment renewal.

Development of semiconductors and high-power electronic equipment

Power devices, RF modules, lasers, and high-reliability electronic packaging continue to raise requirements for heat dissipation and thermal expansion matching. Opportunities for tungsten-copper alloy are mainly concentrated in market segments with high requirements for material performance combinations, rather than all electronic heat dissipation materials.

Precision manufacturing and complex mold demand

Automotive parts, precision injection molds, aerospace machined parts, and high-hardness

material manufacturing drive demand for EDM and special electrodes. Electrode life, processing efficiency, and dimensional consistency are the main procurement drivers.

Automotive electrification and automated production

Electric vehicles, power electronics, automated welding, and precision part production will drive demand for some electrodes, contacts, and heat dissipation components. However, the specific amount of tungsten-copper used depends on component design and the competitiveness of alternative materials, and cannot be simply inferred from new energy vehicle production.

Aerospace and defense equipment investment

High-reliability electrical components, special electrodes, and special thermal management components have higher requirements for performance stability and material traceability. Such demand is usually driven by specific equipment projects and certification cycles, and market size and delivery rhythm may fluctuate significantly.

Progress in material design and manufacturing processes

Improvements in powder particle size control, tungsten skeleton uniformity, copper infiltration integrity, precision machining, and inspection capabilities enable suppliers to provide products with more stable performance, more complex dimensions, and stronger pertinence. This not only improves the use effect of some applications but also helps expand high value-added markets.

III. Comparison of demand characteristics in different application fields

Application field	Main demand source	Procurement focus	Demand characteristics
Electrical switch contacts	Grid construction, equipment renewal, industrial distribution	Electrical conductivity, arc erosion resistance, contact reliability	Mature application with renewal and maintenance demand
Electronic packaging thermal management	Power electronics, RF, laser, optoelectronic devices	Thermal conductivity, thermal expansion matching, dimensional stability	Higher requirements for material performance and customization capability
EDM electrodes	Precision molds, complex part processing	Electrode wear, processing efficiency, dimensional accuracy	Related to manufacturing capital expenditure and mold demand
Resistance welding	Automotive, home appliances, industrial automation	Electrode life, wear resistance, electrical and thermal conductivity	Related to production line output and maintenance cycles
Aerospace and defense	Special equipment and high-reliability systems	Batch consistency, traceability, working condition verification	Project-driven, long certification cycle
High-density counterweights	Precision equipment and special structural parts	Density, mass tolerance, dimensions and balance	Relatively segmented scale, emphasis on custom processing

IV. Demand differences in global regional markets

Global demand distribution is closely related to power equipment manufacturing, electronic industry clusters, precision processing industry, aerospace manufacturing capability, and supply chain layout. Because different research institutions may have different statistical boundaries for tungsten-copper alloy—some count material blanks, while others include machined parts or electronic packaging substrates—regional market shares should not be directly compared horizontally without a unified caliber.

Asia-Pacific region

China, Japan, South Korea, and other Asian manufacturing economies have foundations in electronic manufacturing, power equipment, the automotive industry, and precision processing. Regional demand comes from traditional electrical contacts, electrodes, and welding components as well as electronic packaging and high-performance heat dissipation materials. Industrial chain completeness, supplier manufacturing capability, and delivery efficiency are important competitive factors.

North America region

Demand is related to grid upgrading, advanced electronic equipment, aerospace, defense industry, and high-end manufacturing. High-reliability products usually place more emphasis on material certification, quality traceability, supply continuity, and localized services.

Europe region

Electrical equipment, industrial automation, automotive manufacturing, aerospace, and precision engineering are important sources of demand. Supplier competitiveness depends not only on material prices but is also affected by product consistency, processing quality, energy efficiency requirements, and supply chain compliance capability.

India and other emerging manufacturing markets

Power infrastructure expansion, industrial equipment investment, automotive manufacturing, and electronic assembly development provide potential increments for electrical components, welding electrodes, and industrial processing materials. The speed of demand release still depends on local manufacturing capability, investment cycles, and supply chain support.

From the perspective of the industrial chain, China is both an important producer of tungsten resources and tungsten powder and an important participant in the tungsten-copper alloy manufacturing and processing supply chain. For overseas buyers, material supply stability, price fluctuations, delivery times, technical document management, and cross-border compliance requirements will all affect procurement decisions.

V. Restrictive factors affecting future demand growth

Tungsten-copper alloy has multiple performance advantages, but its demand does not only increase; it is mainly constrained by the following factors.

First, raw material cost. Tungsten powder prices, copper prices, energy costs, and processing fees jointly affect product quotations. Rising tungsten prices may push up procurement costs, and may also prompt some users to optimize the tungsten-copper ratio, reduce machining allowance, or evaluate alternative materials.

Second, competition from substitute materials. Pure copper, copper-chromium-zirconium, molybdenum-copper, aluminum-silicon-carbide, and other metal matrix composites may have advantages in cost, density, thermal conductivity, or processing in different applications. Tungsten-copper is more likely to obtain continuous orders only when its comprehensive

performance better meets requirements.

Third, manufacturing process and quality consistency. Powder metallurgy, copper infiltration, precision machining, and inspection all require corresponding technical capabilities. Porosity, microstructural non-uniformity, cracks, and processing defects will reduce yield, increase costs, and affect customer certification.

Fourth, terminal industry investment cycles. The investment rhythms of power equipment, automotive manufacturing, mold industry, and aerospace projects differ, which may lead to different growth or adjustment cycles in various market segments.

Fifth, supply chain and compliance requirements. Raw material supply, cross-border trade policies, technical document management, and applicable export control regulations may all affect delivery cycles and market access. For specific projects, compliance review and supplier qualification certification may become important constraints on procurement.

VI. How to determine which fields deserve more attention

If analyzed from the perspective of market development and product layout, tungsten-copper alloy demand can be divided into mature basic markets and specialized growth markets. Mature basic markets mainly include electrical contacts, EDM electrodes, and resistance welding components. These fields have formed a relatively stable application base, and procurement usually focuses more on comprehensive cost, life, dimensional consistency, and delivery stability. Suppliers that can establish advantages in standard grades, stable quality, and precision machining are more likely to form continuous orders.

Specialized growth markets mainly include high-power electronic packaging, RF and microwave components, laser thermal management, and some aerospace special components. These fields place more emphasis on thermal expansion matching, thermal conductivity, microstructural uniformity, complex structure processing, and strict quality traceability. They may provide higher technical added value, but development cycles, verification costs, and customer entry thresholds are also often higher.

For suppliers, three directions can be tracked: first, continuous replacement demand in the power equipment and industrial manufacturing fields; second, customized thermal management demand brought by high-power electronic equipment; third, demand for high-performance electrodes and complex machined parts from precision manufacturing. During evaluation, terminal industry growth, material usage per piece, product substitution risk, customer certification cycle, and the supplier's own manufacturing capability should be examined simultaneously, rather than judging market size only based on the macroeconomic growth rate of a certain industry.

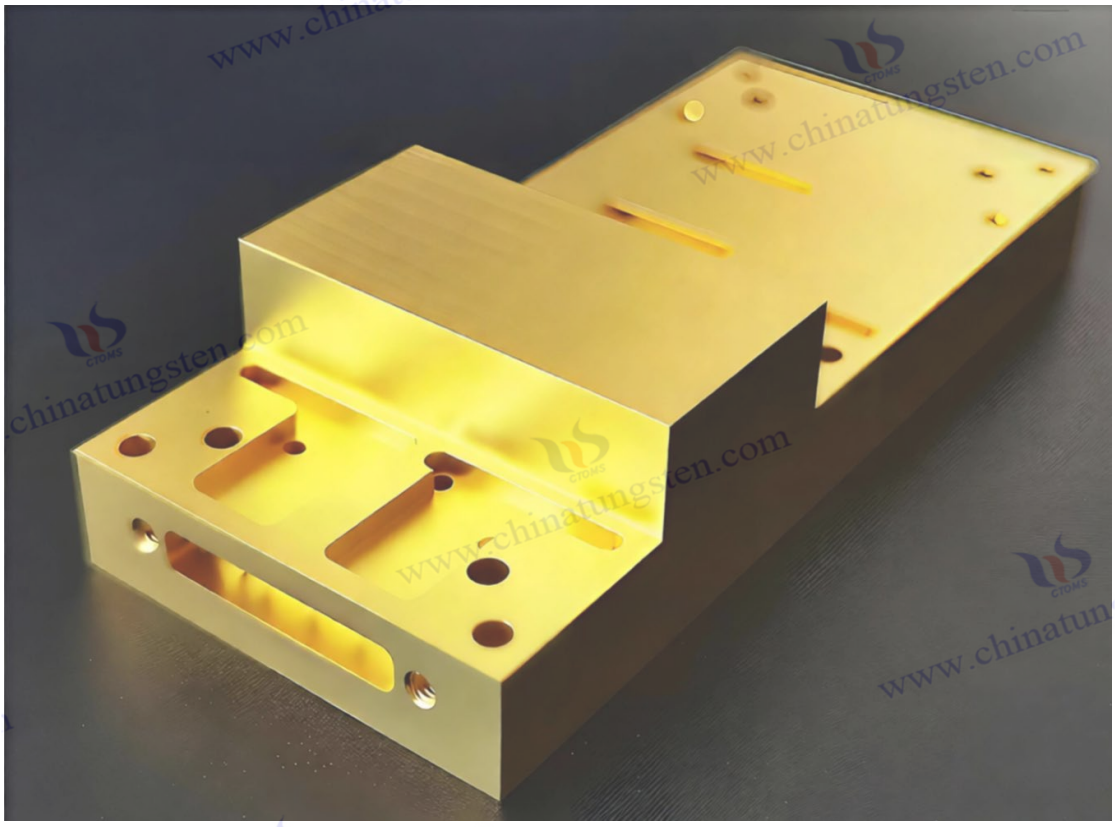
VII. Conclusion

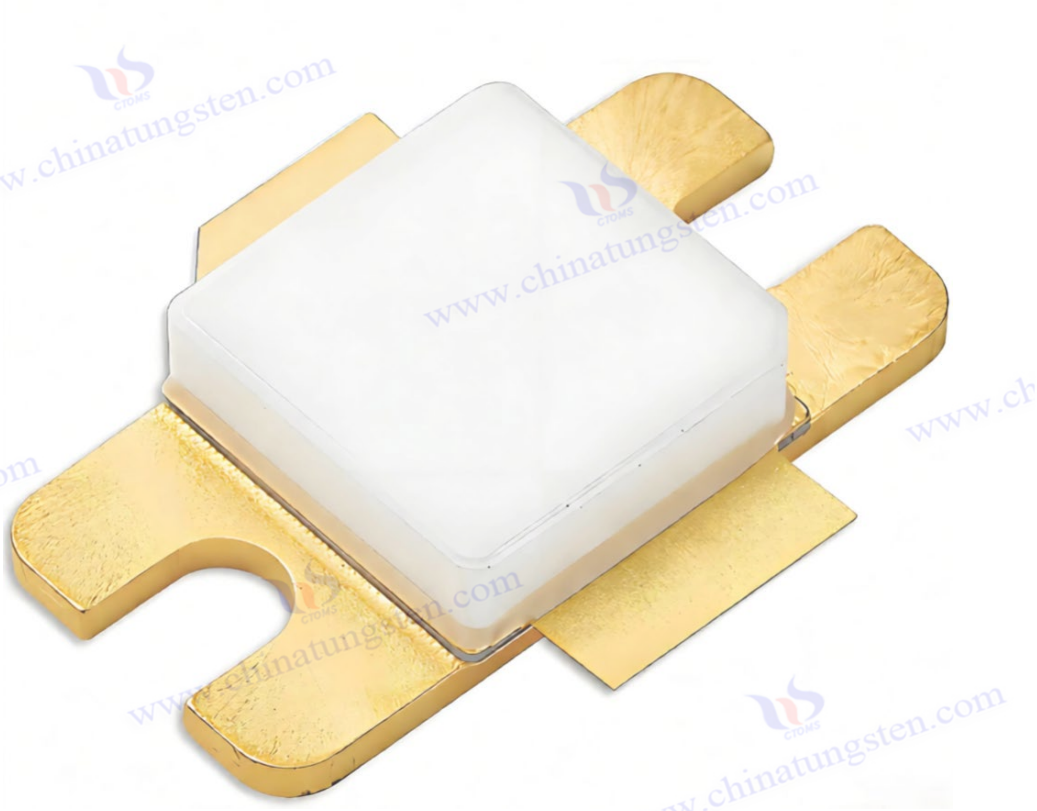
The main application base of the global tungsten-copper alloy market remains traditional industrial fields such as electrical contacts, EDM electrodes, and resistance welding; electronic

packaging and high-power thermal management are specialized directions worthy of key attention, while aerospace, defense, and high-density special parts constitute market segments with smaller scale but higher technical requirements.

Future demand will be jointly affected by power infrastructure upgrading, power electronics development, precision manufacturing, automotive electrification, aerospace investment, and material process progress. However, actual growth still depends on the performance advantages of tungsten-copper alloy relative to substitute materials, manufacturing costs, and customer certification results.

For enterprises formulating market strategies, it is recommended not to judge only which industry is growing fastest, but to further confirm whether the target application truly requires the performance combination of tungsten-copper alloy, whether customers are willing to pay for reliability and customization, and whether the enterprise has the corresponding material design, manufacturing, inspection, and batch delivery capabilities.





Q78 What are the advantages of China's tungsten-copper alloy industry chain?

The competitiveness of China's tungsten-copper alloy industry chain mainly comes from tungsten resources and the foundation of smelting and processing, powder metallurgy manufacturing capability, a supporting industrial system, large-scale production conditions, and synergy with downstream application markets. Unlike an industrial model that relies solely on raw material exports, China has an industrial foundation covering everything from tungsten raw materials, tungsten powder and copper powder preparation, to tungsten-copper composite material processing, precision part manufacturing, and terminal application support. However, tungsten-copper alloy is not a product that can develop advantages simply by having tungsten resources. It requires balancing material density, tungsten-copper interface bonding, electrical and thermal conductivity, dimensional accuracy, and batch stability. Therefore, China's industrial advantages are reflected not only in resources and manufacturing costs but also in whether enterprises can transform raw material advantages into stable, verifiable product performance.

I. Strong foundation in tungsten resources and raw material supply

China has a relatively complete industrial foundation in tungsten mining, beneficiation, smelting, tungsten powder preparation, and deep processing of tungsten. The tungsten content in tungsten-copper alloy is usually relatively high, and indicators such as the particle size distribution, purity, morphology, and oxygen content of tungsten powder directly affect the sintering behavior, density, and final performance of the material. The relatively complete domestic tungsten raw material supply system provides tungsten-copper alloy enterprises with

a variety of raw material options and is also conducive to material design for different tungsten contents, different powder particle sizes, and different performance targets. Compared with production systems that rely entirely on imported tungsten powder, domestic procurement channels and processing support can reduce some logistics, delivery, and communication costs. However, resource advantages do not mean that raw material costs are always the lowest. Prices at different stages such as tungsten concentrate, ammonium paratungstate, tungsten oxide, and tungsten powder are affected by factors such as market supply and demand, environmental protection requirements, energy costs, and export policies, and enterprises still need to control raw material procurement risks.

II. Relatively mature powder metallurgy and material preparation processes

Tungsten-copper alloy is a typical composite material system in which tungsten and copper do not form a continuous solid solution. Because tungsten has a high melting point and copper has a low melting point, the melting points and wetting behavior of the two differ significantly, and conventional melting methods are difficult to use to directly obtain products with uniform microstructure and stable performance. Therefore, industrial manufacturing usually relies on powder metallurgy and related composite processes. Relevant Chinese enterprises already have an industrialization foundation for a variety of tungsten-copper alloy manufacturing routes, such as copper infiltration after tungsten skeleton sintering, mixed powder pressing and sintering, and other densification and post-treatment processes developed for specific products. Different routes are suitable for different tungsten contents, size specifications, structural complexity, and performance requirements.

The advantages brought by this process foundation mainly include: the ability to adjust the tungsten-copper ratio according to application requirements and control material density, electrical conductivity, and thermal conductivity; the ability to improve porosity, microstructural uniformity, and dimensional stability through process parameter optimization; and the ability to provide material solutions of different specifications for electrical contacts, EDM electrodes, welding electrodes, and thermal management parts. What truly distinguishes enterprises is often not whether they own a certain piece of equipment, but whether links such as powder control, pressing and forming, sintering temperature and atmosphere, copper infiltration, heat treatment, and precision machining can form a stable process window.

III. Relatively complete upstream and downstream industrial support and high synergy efficiency

China's advantage lies not only in tungsten raw material supply but also in relatively good supporting conditions in links such as tungsten smelting, metal powder processing, copper material supply, powder metallurgy equipment manufacturing, heat treatment, precision machining, and industrial inspection. Tungsten-copper alloy production requires simultaneous management of tungsten powder, copper powder, molds, sintering equipment, infiltration equipment, and subsequent processing. Complete industrial support helps enterprises establish shorter collaboration chains among raw material procurement, process adjustment, equipment maintenance, and outsourced processing, reducing the connection costs between different suppliers. This advantage is particularly important for customized products. For

example, electrical contacts, EDM electrodes, and electronic packaging heat sinks differ greatly in dimensions, tungsten content, electrical performance, and surface requirements. Domestic enterprises can provide services at different levels from blanks and semi-finished products to finished parts through the synergy of material preparation and precision machining.

IV. Competitive large-scale manufacturing and cost control

China has a large industrial manufacturing system and strong supporting capabilities in powder processing, machining, mold manufacturing, and general industrial equipment. For tungsten-copper alloy products with mature technical requirements and relatively standardized specifications, large-scale production helps amortize equipment depreciation, mold development, quality inspection, and production management costs. Specifically, batch production can improve the utilization rate of pressing, sintering, copper infiltration, and precision machining equipment; a stable supplier system helps reduce procurement and logistics costs; and mature machining support can shorten the manufacturing cycle from blank to finished product. However, low cost is not a common advantage of all products. High purity, high density, low porosity, strict dimensional tolerances, and high-reliability applications often require stricter process control and higher inspection investment. For markets such as aerospace, advanced electronic packaging, and high-reliability electrical equipment, buyers usually pay more attention to the total lifecycle cost, performance consistency, and verification records of products rather than just the unit quotation.

V. Broad downstream industrial market, conducive to product iteration

China has a relatively complete industrial system for power equipment, electronics manufacturing, automobile manufacturing, precision molds, and industrial automation, providing a diversified application market for tungsten-copper alloy.

Downstream field	Typical use	Main requirements for materials
Power equipment	Medium- and high-voltage switch contacts, vacuum switch-related parts	Arc erosion resistance, electrical conductivity, contact stability
Precision machining	EDM electrodes (Electrical Discharge Machining)	Wear resistance, dimensional accuracy, processing stability
Resistance welding	Welding electrodes, conductive wear-resistant parts	Electrical conductivity, hardness, softening resistance
Electronic packaging	Heat sinks, heat spreaders, packaging substrates	Thermal conductivity, thermal expansion matching, dimensional stability
Aerospace & special equipment	High-density functional parts, specific thermal management and electrical parts	Density, reliability, environmental adaptability

The large number of domestic downstream customers helps manufacturers obtain application feedback, adjust material ratios, optimize processing techniques, and develop specialized products for specific working conditions. However, a large domestic market scale does not mean that all segmented fields already have equal competitiveness; some high-end applications still need to enter the supply chain through long-term verification, customer certification, and reliability testing.

VI. Relatively flexible product customization and rapid delivery capability

Tungsten-copper alloy usually requires adjusting the tungsten-copper ratio, material density, electrical conductivity, thermal conductivity, and coefficient of thermal expansion according to the use environment. Another advantage of China's supply chain is that many manufacturing enterprises can undertake small-batch trial production, non-standard size processing, and multi-specification orders. For example, although all are tungsten-copper alloy, electrical contacts pay more attention to arc erosion resistance and electrical contact stability during breaking, EDM electrodes pay more attention to processing loss and dimensional retention, and electronic packaging materials pay more attention to thermal conductivity and thermal expansion matching. Therefore, enterprises that can combine material design, process verification, and precision machining are more likely to form differentiated competitiveness.

Taking CTIA GROUP as an example, its website https://www.ctia.com.cn provides information on tungsten-copper alloy and related tungsten products and can serve as an industry channel for understanding product types and application directions. During specific procurement, supplier capability should still be evaluated in combination with actual product specifications, inspection reports, sample test results, and delivery records.

VII. Development space for recycling and circular supply chains

Tungsten is an important strategic metal, and raw material prices and supply conditions affect the production cost of tungsten-copper alloy. Tungsten scrap recycling, sorting of offcuts, and reuse of tungsten-containing scrap can help enterprises improve resource utilization efficiency and, to a certain extent, reduce dependence on primary raw materials. However, tungsten-copper alloy scrap cannot be directly reused in new material production without distinction. The copper content, tungsten content, degree of oxidation, oil contamination, and other impurities in scrap may all affect subsequent powder making, sintering, and material performance. If used for high-reliability products, a clear scrap classification, composition testing, recycling process, and quality traceability system need to be established. Therefore, the competitiveness of recycling is not only about whether recycling channels are sufficient but also depends on whether stable recycled raw material quality can be achieved while controlling impurities and batch differences.

VIII. Industrial advantages still face several practical constraints

China's tungsten-copper alloy industry chain has a strong comprehensive manufacturing foundation, but it should not be assumed that tungsten resource advantages are directly equivalent to technological leadership in all high-end tungsten-copper alloy products. Among different enterprises, there may still be obvious differences in powder quality, sintering densification, copper infiltration uniformity, precision machining, testing capability, and customer certification.

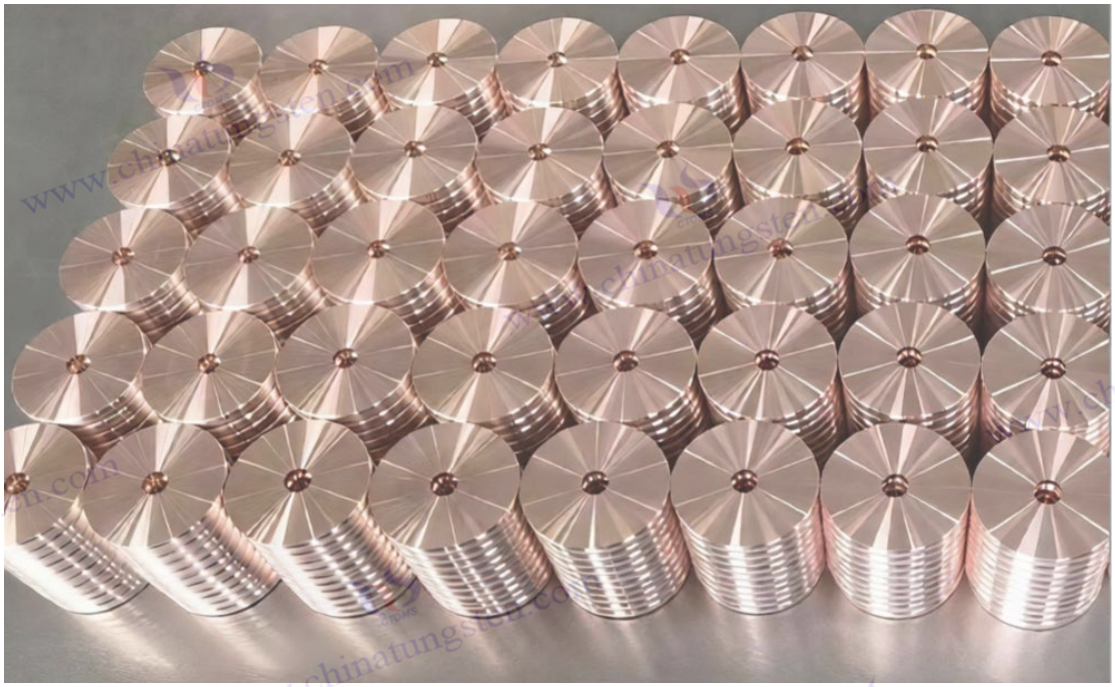
Main constraints include: first, fluctuations in tungsten raw material prices and resource management policies will affect procurement costs and supply arrangements; second, the control of high density, low porosity, and microstructural uniformity of tungsten-copper materials has a certain technical threshold; third, high-end applications usually require stricter

batch consistency, reliability verification, and quality traceability; fourth, some products face competition from materials such as molybdenum-copper and copper-chromium-zirconium and must prove their value through comprehensive performance and cost of use.

The main advantages of China's tungsten-copper alloy industry chain can be summarized as a strong resource foundation, rich experience in powder metallurgy manufacturing, relatively complete upstream and downstream support, good conditions for large-scale production, a broad downstream industrial market, and a relatively flexible customization and delivery system.

From the perspective of industrial competition, standardized electrical contacts, EDM electrodes, and conventional industrial parts are more likely to reflect scale and cost advantages; high-power electronic packaging, high-reliability electrical components, and other precision functional parts rely more on material design, process stability, testing capability, and customer certification.

For buyers, to judge whether a Chinese tungsten-copper alloy enterprise truly has competitiveness, it is recommended to focus on checking the tungsten-copper ratio and material grade, density and porosity, electrical conductivity and thermal conductivity, dimensional tolerances, batch inspection reports, raw material traceability system, sample verification results, and on-time delivery records. Enterprises that can effectively connect raw material supply, process control, and terminal quality requirements are more likely to transform the advantages of China's complete industry chain into long-term, stable product competitiveness.



Q80 How do changes in tungsten powder and copper raw material prices affect the cost of tungsten-copper alloy?

Tungsten powder and copper raw material prices are the core factors affecting the manufacturing cost of tungsten-copper alloy, but their degrees of influence are not the same. Because tungsten-copper alloy usually contains a relatively high proportion of tungsten, and the unit mass price of tungsten raw materials is usually much higher than that of copper, in most common grades the impact of tungsten powder price changes on raw material cost is more significant; although the unit price of copper is lower, in grades with higher copper content it may also have a relatively obvious impact on cost. In addition, raw material prices are not directly transmitted to the final selling price in a fixed proportion. Actual cost also depends on the tungsten-copper ratio, powder utilization rate, sintering or infiltration process, processing loss, energy and labor costs, inventory valuation method, and the price adjustment mechanism between suppliers and customers.

I. Which costs are affected by tungsten powder and copper prices respectively?

The production cost of tungsten-copper alloy can be simplified as: unit product cost = tungsten raw material cost + copper raw material cost + manufacturing and processing cost + quality inspection cost + management and delivery cost. Among these, tungsten raw material cost and copper raw material cost are mainly determined by material usage, procurement unit price, and actual utilization rate.

Cost factor	Impact of tungsten powder price increase	Impact of copper raw material price increase
Raw material cost	Usually greater impact, especially for high-tungsten-content grades	More obvious impact when copper content is higher
Product manufacturing cost	May increase indirectly through powder loss, rework, and inventory costs	May increase indirectly through copper used for infiltration, processing loss, and inventory costs
Procurement capital occupation	High-value tungsten raw material inventory increases capital occupation	Depends on copper usage, inventory scale, and price increase
Finished product quotation	May push quotations upward, but affected by inventory and contract mechanisms	May push quotation adjustments; transmission range depends on grade and cost structure
Supply risk	Affected by tungsten raw material supply, market supply and demand, and procurement cycle	Affected by copper market supply and demand, processing fees, and procurement methods

For products using the process of copper infiltration after tungsten skeleton sintering, the tungsten powder cost mainly comes from the tungsten skeleton material, and the copper cost mainly comes from the infiltrated copper and corresponding losses. For other preparation routes, the specific input methods of the two raw materials may differ, and the actual process and bill of materials should be used as the basis.

II. The tungsten-copper ratio determines the sensitivity to raw material price increases

The raw material cost of tungsten-copper alloy is closely related to the mass proportions of tungsten and copper. Assuming the product is composed of two main metals, tungsten and copper, with tungsten mass proportion W% and copper mass proportion Cu%, and W% + Cu% = 100%, the theoretical raw material cost can be expressed as: Theoretical raw material cost per kilogram = tungsten mass proportion × tungsten powder unit price + copper mass proportion × copper raw material unit price.

For example, comparing a tungsten-copper alloy with 70% tungsten and 30% copper and a tungsten-copper alloy with 90% tungsten and 10% copper, it can be seen that high-tungsten-content grades are more sensitive to tungsten powder prices.

Tungsten-copper alloy grade	Increase in theoretical raw material cost when tungsten powder price rises 10%	Increase in theoretical raw material cost when copper price rises 10%
W70Cu30	Depends on the actual proportion of tungsten in raw material cost	Depends on the actual proportion of copper in raw material cost
W80Cu20	Usually higher than low-tungsten-content grades	Usually lower than low-tungsten-content grades
W90Cu10	Usually higher	Usually lower

The specific increase in the above table cannot be directly determined by mass proportion because the unit procurement prices of tungsten powder and copper are different. A more accurate method is to calculate their cost contributions based on the actual procurement unit prices of the two raw materials.

III. Calculating the impact of raw material price changes with numbers

Assume that the theoretical ratio of a tungsten-copper alloy product is W80Cu20, i.e., tungsten

accounts for 80% and copper for 20%. For ease of demonstration, assume the tungsten powder procurement price is 1,000 yuan/kg and the copper raw material procurement price is 80 yuan/kg. The hypothetical prices are used here only for calculation and do not represent current market quotations. Theoretical raw material cost per kilogram = 80% × 1,000 + 20% × 80 = 816 yuan. Among these, the tungsten raw material cost is 800 yuan and the copper raw material cost is 16 yuan. Therefore, tungsten raw materials account for approximately 98.0% of the theoretical raw material cost, and copper raw materials approximately 2.0%. Under otherwise unchanged conditions:

Price change scenario	Theoretical raw material cost per kilogram	Change relative to original cost
Base scenario	816 yuan	—
Tungsten powder price rises 10%	896 yuan	Increase of approximately 9.80%
Copper price rises 10%	817.6 yuan	Increase of approximately 0.20%
Tungsten powder and copper prices both rise 10%	897.6 yuan	Increase of approximately 10.00%
Tungsten powder price falls 10%	736 yuan	Decrease of approximately 9.80%

This example shows that under the assumed W80Cu20 ratio and price conditions, tungsten powder price changes clearly dominate the theoretical raw material cost. However, actual production also needs to consider raw material input, loss rate, infiltration efficiency, recovery utilization rate, and yield, so the change range of the final unit product cost may differ.

IV. How are raw material price changes transmitted to finished product quotations?

Raw material price increases do not necessarily immediately cause finished product quotations to rise by the same proportion, mainly depending on the following links.

First, the inventory cycle causes a lag in price transmission. If an enterprise uses tungsten powder purchased earlier at a low price, short-term production costs may be lower than the current market replacement cost; cost pressure will only gradually appear after the low-price inventory is consumed. Conversely, if an enterprise holds high-priced inventory, book costs may remain high even if market raw material prices have already fallen.

Second, procurement contracts determine the speed of cost adjustment. Enterprises that purchase at monthly spot prices usually respond faster to market fluctuations; enterprises using quarterly pricing, annual framework agreements, or long-term contracts may have relatively lagged cost adjustments. If finished product sales contracts use fixed prices, profit margins during raw material price increases may be squeezed.

Third, manufacturing costs and yield will amplify or buffer raw material fluctuations. The pressing, sintering, copper infiltration, heat treatment, and precision machining processes of tungsten-copper alloy may all generate losses. If raw material prices rise while product yield declines, the unit qualified product cost will increase in an superimposed manner; if the process is stable and the loss rate is low, enterprises are more able to buffer part of the raw material price changes.

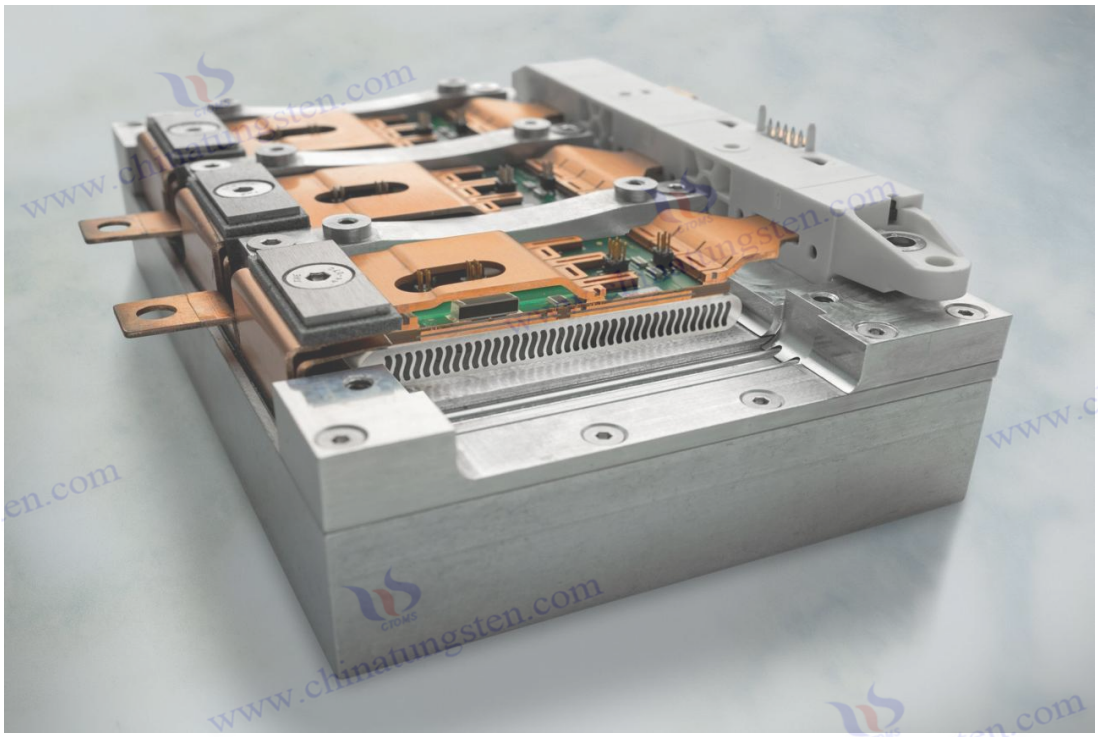
Fourth, market competition limits the extent of cost pass-through. When downstream customers have strong bargaining power, there are many similar suppliers, or terminal demand is weak, suppliers may not be able to pass all cost increases on to customers and can only absorb part of the pressure by compressing profits, optimizing procurement, or improving production efficiency.

V. How can purchasing enterprises respond to tungsten powder and copper price fluctuations?

For tungsten-copper alloy buyers, a more effective approach is not simply predicting price rises and falls but incorporating raw material price risk into procurement mechanisms and supplier management. On the one hand, suppliers should be required to provide information such as the main raw material cost composition, the tungsten-copper ratio corresponding to the grade, material utilization rate, and yield, so as to judge whether quotation changes have a reasonable basis. On the other hand, procurement can be arranged in batches according to actual demand to avoid concentrated establishment of excessive inventory at high prices, while reasonable safety stock can be used to cope with delivery cycles and supply risks. For long-term procurement projects, a raw material price linkage mechanism can also be agreed with suppliers. For example, the benchmark prices of tungsten powder and copper raw materials, adjustment cycle, price change trigger conditions, and quotation validity period can be written into the contract to avoid disputes over price adjustments during market fluctuations. If the procurement volume is large, it is recommended to evaluate at least two categories of indicators: one is material performance and quality stability, including density, electrical conductivity, thermal conductivity, dimensional tolerances, and batch consistency; the other is commercial indicators, including raw material price linkage method, delivery time, inventory policy, quotation validity period, and supply guarantee capability under abnormal conditions.

Tungsten powder prices are usually the main driver of raw material cost changes in tungsten-copper alloy, especially for high-tungsten-content grades such as W80Cu20 and W90Cu10; the impact of copper prices varies with copper content, procurement price, and actual process usage. Whether raw material prices can ultimately be transmitted to finished product quotations also depends on inventory, yield, processing costs, contract mechanisms, and market competition.

In actual evaluation, it is recommended to establish a cost model based on the tungsten-copper ratio of the specific grade, real procurement unit prices, and production loss data, and then separately calculate the unit product cost when tungsten powder rises or falls by 5%, 10%, and 20% and when copper prices change by the same magnitude, so as to formulate quotation adjustment rules and procurement plans.



Q81 What are the main technical barriers and quality barriers in the tungsten-copper alloy industry?

The core barriers in the tungsten-copper alloy (W-Cu Alloy) industry are not just raw material procurement and equipment investment, but whether products that meet target performance, dimensional requirements, and service life requirements can be manufactured stably over the long term. Because tungsten and copper differ greatly in melting point, density, wetting characteristics, and thermophysical properties, the material preparation process involves multiple interrelated links such as powder control, forming, sintering, copper infiltration, precision machining, and quality inspection. Technical barriers mainly determine whether an enterprise can manufacture high-performance products, while quality barriers determine whether an enterprise can continuously and stably deliver qualified products. For applications such as high-reliability electrical equipment, precision machining electrodes, and electronic packaging, the two often together constitute the threshold for market entry.

I. Main technical barriers

Powder raw materials and microstructure control

The purity, particle size distribution, particle morphology, oxygen content, and batch consistency of tungsten powder and copper powder affect mixing uniformity, pressing performance, sintering behavior, and final microstructure. If the tungsten powder particle size is too coarse or the distribution is unreasonable, the uniformity and densification of the tungsten skeleton may be affected; the surface state and oxidation degree of copper powder may affect wetting, interfacial bonding, and electrical conductivity. Even if the chemical composition of raw materials meets the requirements, differences in powder morphology and particle size distribution may still cause product performance to change. Therefore, enterprises

need to establish raw material acceptance, powder batch management, mixing parameter control, and process verification mechanisms, rather than relying only on the composition certificates provided by suppliers.

Sintering and copper infiltration process

This is one of the most important process barriers in tungsten-copper alloy manufacturing. In the process of copper infiltration after tungsten skeleton sintering, a tungsten skeleton with appropriate pore structure and strength must first be formed, and then copper must fully enter the connected pores. If the porosity of the tungsten skeleton is too low, copper may be difficult to fully infiltrate; if the pore structure is unreasonable, the skeleton strength is insufficient, or the infiltration conditions are improperly controlled, problems such as residual porosity, uneven copper distribution, local copper deficiency, or abnormal dimensional changes may occur. Key control factors include sintering temperature and time, protective atmosphere, tungsten skeleton density, pore connectivity, copper wetting and infiltration conditions, and microstructural and dimensional changes during cooling. The process windows required for different tungsten-copper ratios and product geometries are not exactly the same. Being able to stably replicate these parameters across different batches and specifications requires long-term process accumulation.

High-density and low-defect manufacturing capability

The density, electrical conductivity, thermal conductivity, mechanical properties, and arc erosion resistance of tungsten-copper alloy are closely related to internal pores, microstructural uniformity, and interface state. Pores may reduce the effective conductive cross-sectional area and increase local resistance and heat concentration; internal defects may also become damage initiation points under thermal cycling, arc impact, or mechanical load. For products with large dimensions, complex shapes, or obvious local thickness changes, consistency control of internal microstructure is usually more difficult. Enterprises with higher technical levels not only need to achieve target density but also need to control local defects, copper distribution, and performance differences at different locations, and verify them through appropriate testing methods.

Tungsten-copper ratio and performance matching

The tungsten content of tungsten-copper alloy directly affects material density, thermal expansion, electrical conductivity, thermal conductivity, and arc erosion resistance, but these properties are not independent of each other. Generally, increasing tungsten content helps increase material density and reduce the coefficient of thermal expansion, but may also reduce electrical conductivity and thermal conductivity; increasing copper content may improve electrical and thermal conductivity but will change performance under high temperature, softening resistance, and arc action. Actual results also depend on material density, microstructure, and preparation process. Therefore, enterprises need to carry out material design according to terminal working conditions, rather than simply believing that the higher the tungsten content, the better the comprehensive performance of the material.

Precision machining and dimensional stability

Tungsten-copper alloy usually has relatively high hardness, density, and wear resistance, and some products also need to be machined into complex contours, small holes, thin-walled structures, or high-precision contact surfaces. This places high requirements on tool selection, processing parameters, clamping methods, surface quality, and dimensional inspection. In addition, non-uniform internal microstructure, residual stress, and processing heat may cause local chipping, surface defects, dimensional deviation, or subsequent deformation. For electrical contacts, precision electrodes, and electronic packaging heat sinks, dimensional accuracy not only affects assembly but may also affect electrical contact, machining accuracy, and heat conduction paths.

Process development capability for specific applications

Different applications have quite different requirements for tungsten-copper alloy. Electrical contacts focus on breaking capacity, arc erosion resistance, and contact stability; EDM electrodes focus on electrode loss, processing efficiency, and surface quality; electronic packaging materials pay more attention to thermal conductivity, coefficient of thermal expansion, and matching with adjacent materials. Enterprises that can carry out material design, process development, sample testing, and failure analysis for specific use environments are more likely to enter high value-added markets. This type of capability usually requires the accumulation of material engineering experience, equipment conditions, testing capability, and downstream customer collaboration and is difficult to quickly replicate by simply purchasing equipment.

II. Main quality barriers

Technical barriers focus on whether it can be manufactured, while quality barriers focus on whether it can be continuously manufactured and the product proven qualified. The two are interrelated, but quality barriers emphasize systematic control, data traceability, and delivery consistency.

Quality control link	Main quality risk	Key control content
Raw material acceptance	Fluctuation in powder composition, particle size, or oxygen content	Composition testing, particle size analysis, batch traceability
Forming and sintering	Uneven density, insufficient skeleton strength	Forming parameters, sintering curve, process records
Copper infiltration	Residual porosity, uneven copper distribution	Infiltration process verification, density and microstructure inspection
Finished product inspection	Performance or dimensions not meeting requirements	Density, electrical conductivity, dimensions, and appearance inspection
Batch management	Performance differences between batches of the same grade	Batch numbering, process records, trend analysis
Customer verification	Laboratory indicators qualified but actual working condition failure	Application testing, life evaluation, failure analysis
Delivery management	Mixed materials, wrong grade, packaging damage, or missing traceability	Identification management, shipping inspection, document review

Testing methods and measurement capability

Quality management cannot rely on a single indicator alone. Qualified density does not mean that the internal microstructure is necessarily uniform, and qualified electrical conductivity does not mean that the arc erosion life necessarily meets requirements. Different testing methods reflect different aspects of material performance and need to be used in combination according to product application. Common items include chemical composition, density, electrical conductivity, thermal conductivity, coefficient of thermal expansion, dimensional tolerance, surface quality, and metallographic microstructure inspection. For products with high requirements for internal defects, applicable nondestructive testing methods may also be required.

Enterprises need to clarify testing methods, equipment calibration status, sampling locations, sample preparation methods, and judgment standards; otherwise, data from different batches or different suppliers may not be directly comparable.

Batch consistency and process traceability

For high-reliability applications, customers require not only that a certain sample is qualified but also that consecutive batches meet the same specifications and performance requirements. Enterprises need to be able to trace raw material batches, mixing records, forming parameters, sintering and infiltration conditions, processing records, inspection results, and shipping batches. Only when a product abnormality occurs can it be determined whether the problem originates from raw material changes, equipment status, process drift, or the inspection link, and targeted corrective measures can be taken. The actual value of a quality system lies not only in whether certification has been obtained but also in whether real records can prove that the production process is controlled.

Customer certification and application verification

Products related to high-reliability electrical equipment, electronic packaging, and aerospace often need to go through sample testing, installation or working condition verification, and supplier audits. Some applications also require thermal cycling, electrical performance, mechanical strength, or life testing.

Certification barriers have obvious application differences: the verification cycle for conventional industrial electrodes may be relatively short, while entering the supply chain of high-reliability equipment may require a longer verification cycle and stricter document requirements. Once a supplier has completed verification and continues to maintain stable delivery, customers usually need to bear testing, verification, and quality risks again when changing suppliers, so mature suppliers may gain strong customer stickiness.

Quality cost and nonconforming product control

Tungsten-copper alloy raw materials have relatively high value, and scrapping, rework, and performance nonconformity during production may cause relatively large economic losses. If internal porosity or poor infiltration is not discovered until the precision machining or final inspection stage, the material, processing, and inspection costs invested earlier may not be

recoverable. Therefore, advanced quality control usually moves the focus forward, carrying out process monitoring at key nodes such as raw material acceptance, tungsten skeleton forming, sintering, and copper infiltration, rather than concentrating all quality judgment at the final inspection stage.

III. Differences between technical barriers and quality barriers

Comparison dimension	Technical barriers	Quality barriers
Core issue	Whether target material performance can be achieved	Whether requirements can be continuously met and proven
Main reliance	Material design, process development, equipment, and engineering experience	Quality system, process control, testing, and traceability
Accumulation method	Process trials, parameter optimization, failure analysis	Batch data, standardized management, continuous improvement
Competitive manifestation	High performance, complex specifications, special application development	Stable delivery, low defect rate, reliability, and traceability
Value to customers	Meeting special working condition requirements	Reducing procurement, assembly, and use risks

For mature products, the gap between enterprises may be more reflected in cost, yield, and quality consistency; for high-performance, complex-structure, or high-reliability products, material design, process capability, testing capability, and customer verification together constitute a higher entry threshold.

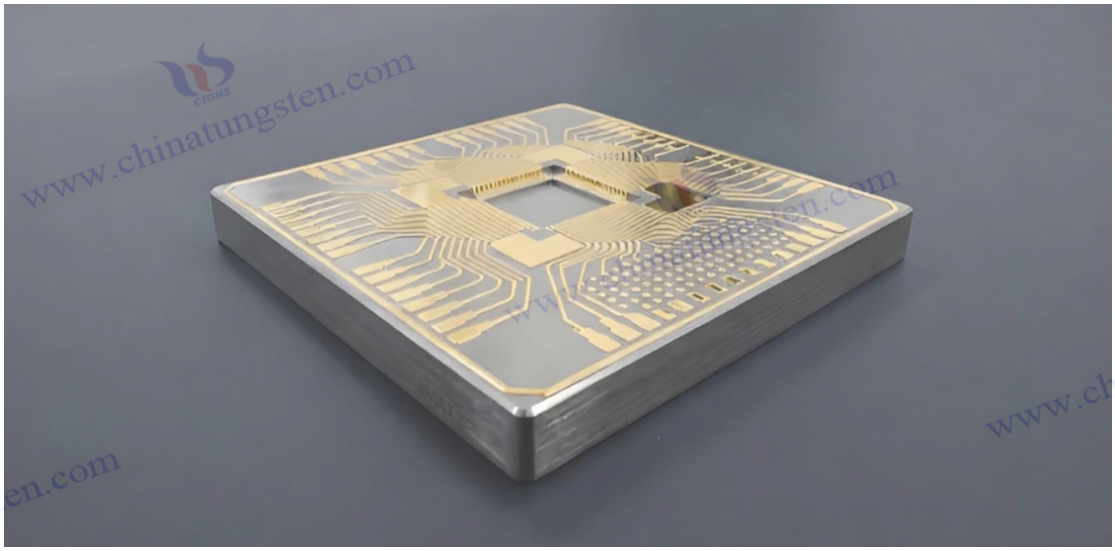
IV. How can enterprises build competitive barriers?

To form sustainable competitiveness, tungsten-copper alloy enterprises should combine technical research and development with quality management. First, establish a raw material specification and supplier evaluation system to reduce powder batch differences; second, carry out process verification for key processes such as forming, sintering, infiltration, and processing to determine parameter ranges and abnormal handling methods; third, establish a testing system covering raw materials, processes, and finished products, and identify performance drift through batch data analysis; finally, establish sample verification, customer feedback, and failure analysis mechanisms for target applications. Buyers should focus on checking whether suppliers have stable process records, complete inspection reports, batch traceability capability, and relevant application experience. For critical parts, it is recommended to first verify material performance through sample testing or small-batch trial production, and then gradually expand the procurement scale.

The technical barriers in the tungsten-copper alloy industry are mainly concentrated in powder quality control, sintering and copper infiltration, high-density manufacturing, material performance matching, precision machining, and application development; quality barriers are mainly concentrated in testing capability, batch consistency, process traceability, customer certification, and nonconforming product control.

Truly competitive enterprises are not just able to manufacture a batch of products with qualified performance, but are able to stably meet customer requirements across different batches, different specifications, and continuous production conditions, and prove their quality level with reliable inspection data and process records.





Q82 What development opportunities does tungsten-copper alloy have in the fields of power equipment, semiconductors, and high-power electronics?

The development opportunities of tungsten-copper alloy (W-Cu Alloy) mainly come from power system upgrades, power semiconductor performance improvements, and the increasing requirements of high-power electronic equipment for heat dissipation and thermal expansion matching. The opportunities in the three fields are not the same: power equipment is mainly about mature application upgrades and reliability improvements, the semiconductor field pays more attention to precision packaging materials, and the high-power electronics field is expected to increase product added value through high-performance thermal management components and customized parts. Tungsten-copper alloy combines the low thermal expansion, high-temperature stability, and arc erosion resistance of tungsten with the electrical and thermal conductivity of copper, and is suitable for components that simultaneously withstand electrical, thermal, and mechanical loads. However, it is not the best material for all applications, and specific opportunities still depend on working temperature, heat flux density, dimensions, cost, and competition from other materials. Its traditional uses and electronic packaging development direction are also supported by relevant material research and industry information.

I. Power equipment: mature demand upgrades and high-reliability components

Power equipment is a relatively mature application field for tungsten-copper alloy. Its development opportunities are mainly reflected in grid expansion and renovation, improvement of switchgear reliability, and upgrading of contact materials under high-current and frequent operation conditions.

Segmented direction	Typical use of tungsten-copper alloy	Main development opportunity
Medium- and high-voltage switchgear	Arc contacts, switch contacts, and conductive parts	Improve arc erosion resistance and extend service life
Vacuum switchgear	Specific contact and electrode materials	Optimize breaking performance, contact stability, and material consistency
High-current electrical systems	Specific high-temperature, high-current contact parts	Improve thermal stability and long-term operational reliability
Power equipment maintenance and replacement	Contact replacement parts, customized materials and machined parts	Form continuous orders based on equipment maintenance, renovation, and spare parts demand

The core opportunity in this field is not simply expanding output but improving the performance stability of materials under actual breaking conditions. Arcs cause local high temperatures, material erosion, and changes in contact surfaces, so customers not only pay attention to the tungsten-copper ratio but also value arc erosion rate, contact resistance, anti-welding ability, thermal shock performance, and service life.

For suppliers, directions worth investing in include optimizing the tungsten skeleton and copper phase distribution, improving batch consistency, improving contact surface processing quality, and cooperating with downstream equipment manufacturers in breaking tests and life verification. It should be distinguished that not all contacts in power equipment use tungsten-copper alloy. Contact material selection is also affected by switch structure, arc-extinguishing medium, rated current, breaking capacity, and specific technical standards, and tungsten-copper alloy is more suitable for applications where its performance advantages match actual working conditions.

II. Semiconductor field: precision packaging and thermal expansion matching

Opportunities in the semiconductor field are mainly concentrated in power device packaging, RF device packaging, laser packaging, and thermal management structural parts of high-reliability electronic components. Semiconductor chips generate heat during operation. If the packaging material cannot conduct heat away in time, or if the thermal expansion difference between the packaging material and the chip or ceramic substrate is too large, repeated heating and cooling may generate thermal stress, leading to solder layer fatigue, interfacial delamination, or other reliability problems. Tungsten-copper alloy can balance thermal conductivity and coefficient of thermal expansion to a certain extent by adjusting the tungsten-copper ratio. Main opportunities include: power semiconductor packaging bases, heat sinks, and heat dissipation substrates, especially structures with higher requirements for thermal expansion matching and thermal cycle reliability. RF and microwave device packaging, such as high-frequency power amplifiers and related communication electronic components. Laser diode and optoelectronic device packaging, requiring materials to balance heat dissipation, dimensional stability, and precision machining. Precision support parts, packaging covers, and other thermal management components in high-reliability electronic packaging. An important change in this field is that customer procurement demand is shifting from simple material grades to more specific performance combinations, including thermal conductivity, coefficient

of thermal expansion, flatness, surface roughness, coating quality, and stability after thermal cycling. Related research on tungsten-copper alloy also lists electronic packaging, heat sinks, and thermal expansion matching as important application directions.

For manufacturing enterprises, a more valuable upgrade path is to gradually expand from supplying tungsten-copper alloy blanks to precision machining, surface treatment, coating, dimensional inspection, and packaging component supporting. If customers can directly purchase verified finished components, they can reduce their own processing and supplier coordination work, and suppliers have more opportunities to obtain higher added value through technical services and precision manufacturing. But entering the semiconductor supply chain is not easy. Products usually require strict control of internal defects, thermophysical property parameters, flatness, and batch differences, and may also require a long customer verification process. Therefore, investment in technical research and development and quality systems is usually more important than for ordinary industrial parts.

III. High-power electronics: wide-bandgap semiconductors and high heat flux density equipment

High-power electronics overlaps with semiconductor packaging, but its requirements emphasize maintaining stable equipment operation under higher power density, larger current, or complex thermal cycling conditions. One important direction is wide-bandgap semiconductors, especially silicon carbide (SiC) and gallium nitride (GaN) devices. These materials can be used for high-efficiency power conversion, high-frequency switching, and high-power-density systems, but device performance improvements also place higher requirements on packaging heat dissipation, parasitic parameter control, and reliability.

Power conversion and power control

Electric vehicle drive inverters, industrial motor drives, power modules, and some new energy converter equipment need to effectively control chip temperature rise and thermal stress. Tungsten-copper alloy is suitable for some packaging bases or heat spreader components with higher thermal expansion matching requirements, but not all power modules will use it.

RF and microwave high-power devices

Communication base stations, radar, satellite communications, and high-frequency power amplifiers have higher requirements for thermal management and packaging dimensional stability. Tungsten-copper alloy can be used for some RF packaging, heat sinks, and precision mounting structures.

High-power lasers and optoelectronic equipment

Laser diode arrays, optical communication devices, and other high-power optoelectronic modules need timely heat conduction and control of structural offset caused by temperature changes. Precision tungsten-copper heat sinks and mounting bases have certain application potential.

High-power power supplies and data center equipment

High-power power supplies, server power supplies, and some data center power conversion equipment place higher requirements on thermal management. The opportunities for tungsten-copper alloy are mainly concentrated in local components with special thermal expansion matching or high-reliability requirements, rather than replacing the entire heat dissipation system.

The common opportunity in these directions is to combine material design with specific packaging structures. Compared with only selling tungsten-copper plates or rods with fixed ratios, suppliers that can control thermal expansion, thermal conductivity, dimensional accuracy, and surface state according to customer requirements are more likely to enter high-value applications. Industry information also lists power devices, RF and microwave, laser, and optoelectronic packaging as important development directions for tungsten-copper thermal management materials.

IV. How should the opportunities in the three major fields be ranked?

Field	Market maturity	Main competitive factors	Development strategy more suitable for enterprises
Power equipment	Relatively mature	Arc resistance, life, batch stability, customer certification	Focus on stable supply, process improvement, and supporting
Semiconductor packaging	Relatively high technical threshold	Thermophysical property matching, precision machining, surface, reliability verification	Develop customized materials and precision packaging components
High-power electronics	Large application differences, some with high growth potential	Thermal management, thermal cycle reliability, application adaptability	Specific devices and packaging scenarios, joint development with customers

If an enterprise already has stable tungsten-copper alloy production capability, the power equipment field is usually more suitable for expanding business through existing product improvement and customer supporting; if the enterprise has high-precision machining, surface treatment, and testing capabilities, semiconductor packaging and RF electronics are more worth attention; if the enterprise has material research and joint development capabilities, it can make medium- and long-term 布局 around silicon carbide and gallium nitride power devices, high-power lasers, and high-frequency communication modules.

V. What thresholds must be crossed to enter high value-added markets?

The first is the repeatability of material performance.

Enterprises need to stably control the tungsten-copper ratio, density, porosity, thermal conductivity, and coefficient of thermal expansion, not just provide a sample that passes one test.

The second is precision manufacturing capability.

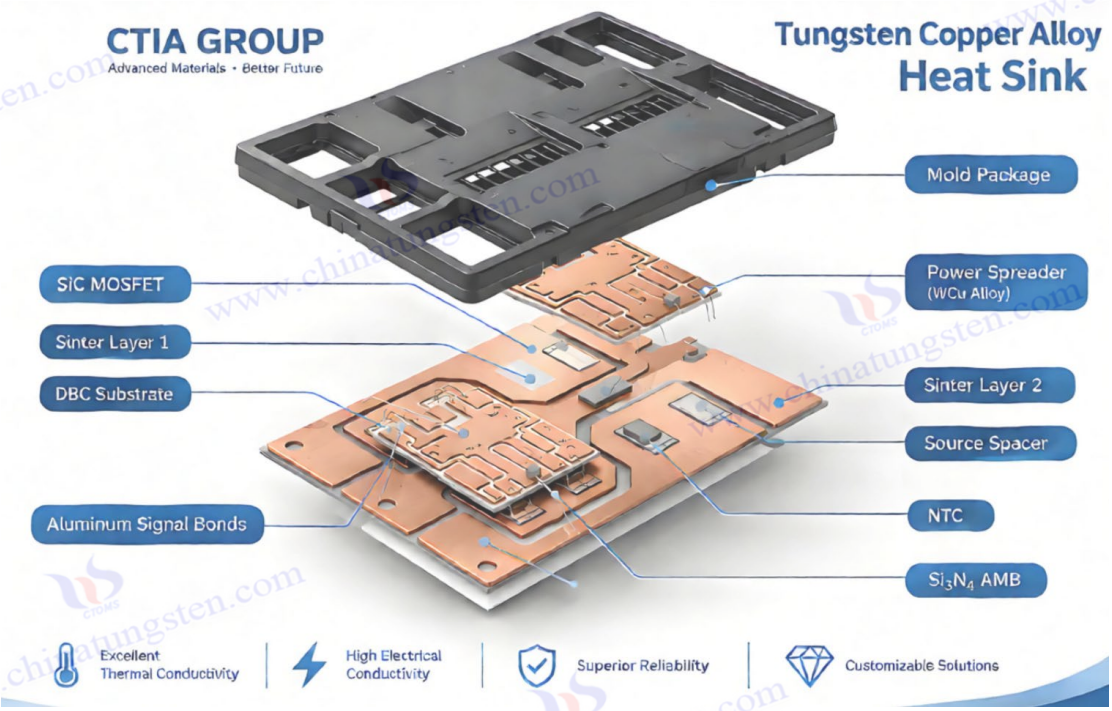
Semiconductor and high-power electronic components often have stricter requirements for flatness, thickness, dimensional tolerances, and surface quality, and some products also involve coating, soldering, or other surface treatment processes.

The third is application verification capability.

Qualified laboratory material parameters do not necessarily mean that the component is reliable under actual working conditions. Thermal cycling, electrical load, interfacial bonding, and long-term operational stability may all affect the customer's final choice.

The fourth is material substitution competition.

Molybdenum-copper (Mo-Cu), aluminum silicon carbide (AlSiC), copper-diamond composites, and advanced ceramics can also be used for different types of thermal management structures. The advantages of tungsten-copper alloy need to be proven through actual thermophysical properties, reliability, processing cost, and service life, rather than being determined solely by material name or a single parameter.





Judgment on the Development of Tungsten-Copper Alloy

Tungsten-copper alloy has development opportunities in power equipment, semiconductors, and high-power electronics, but the nature of the opportunities differs: power equipment focuses on mature product upgrades and reliability improvement, semiconductors focus on precision packaging and thermal expansion matching, and high-power electronics focus on thermal management needs brought by power density improvement. The industrial upgrade direction more worth attention is to gradually shift from selling general materials to providing application-designed material grades, precision machined parts, and verified functional components. For manufacturing enterprises, what truly determines whether they can enter high value-added markets is not whether a downstream industry is popular, but whether they can stably meet the customer's thermal, electrical, mechanical, and dimensional requirements for specific working conditions and establish reliable supply capability through long-term verification. Future applications of CTIA GROUP tungsten-copper alloy in power equipment, semiconductors, and high-power electronics.

Tungsten-copper alloy (W-Cu Alloy) combines the high melting point, low coefficient of thermal expansion, and arc erosion resistance of tungsten with the good electrical and thermal conductivity of copper, and has application value in power switch contacts, precision electrodes, electronic packaging, and high thermal load components. Its development opportunities mainly come from power infrastructure upgrades, power semiconductor development, and higher requirements of electronic equipment for heat dissipation efficiency, structural stability, and operational reliability. The growth logic of these three markets is not exactly the same: the power equipment market values long-term operational reliability and breaking performance, semiconductor packaging values thermal expansion matching and

precision manufacturing, and the high-power electronics field pays more attention to heat dissipation, thermal cycle reliability, and component integration under high heat flux density. For tungsten-copper alloy manufacturing enterprises, the direction worth developing is not only expanding material output but extending from supplying standardized blanks to customized materials, precision machined parts, and verified functional components.

I. Power equipment: grid upgrades and high-reliability switch components

Power equipment is a relatively mature field for tungsten-copper alloy applications. With grid expansion, switchgear renewal, industrial electrification, and the development of high-reliability power supply demand, contact materials with advantages in arc erosion resistance, electrical conductivity, and thermal stability still have continuous technical improvement and supporting opportunities.

Segmented application	Application direction of W-Cu alloy	Main development opportunity
Medium- & high-voltage switchgear	Arc contacts, specific switch contacts, and conductive parts	Improve arc erosion resistance and reduce contact loss
Vacuum switchgear	Specific contact and electrode parts	Improve breaking performance, contact stability, and batch consistency
Industrial high-current equipment	Specific high-current, high thermal load contact parts	Improve thermal stability and service life
Power equipment maintenance and renovation	Contact replacement parts, non-standard machined parts	Provide customized specifications, spare parts, and continuous supply services

Contact material performance optimization

Switch contacts may withstand strong arcs, local high temperatures, and thermal shock when breaking current. If the material is prone to melting, evaporation, or severe erosion, it may cause changes in contact surface morphology, increased contact resistance, and even affect the service life of switchgear. Tungsten-copper alloy can improve the comprehensive performance of the material by adjusting the tungsten-copper ratio, optimizing the tungsten skeleton structure, and improving the uniformity of copper phase distribution. However, the higher the tungsten content, the better is not necessarily true; actual material selection also needs to balance electrical conductivity, heat conduction, anti-welding ability, and breaking performance, and verify through tests on specific switchgear.

Developing from material supply to contact component supporting

Power equipment customers purchase not only metal materials but also stable dimensions, reliable connection interfaces, traceable quality records, and predictable supply cycles. Therefore, tungsten-copper alloy enterprises can extend their business to precision machining, contact surface processing, connection structure manufacturing, and finished product inspection. For enterprises with mature production capability, this upgrade helps reduce simple material price competition and increase the depth of customer collaboration. Especially in the fields of equipment maintenance, replacement parts, and non-standard contacts, suppliers that can quickly respond to drawings, batch, and delivery requirements have certain advantages.



Related development direction of CTIA GROUP

CTIA GROUP has thirty years of experience in tungsten-copper alloy design and production, and its related business direction can be combined with the material selection, product customization, and process improvement needs of the power equipment field. For arc contacts and specific switch components, long-term accumulated experience in material ratio, forming and sintering, copper infiltration, and subsequent processing helps carry out product design and process optimization for different working conditions. Related product and enterprise information can be found on the CTIA GROUP official website: https://www.ctia.com.cn. Whether a specific product is suitable for a certain type of switchgear should still be based on the inspection data of the corresponding specification, equipment requirements, and actual breaking verification results.

II. Semiconductor field: thermal management and precision packaging materials

Opportunities in the semiconductor field are mainly concentrated in power device packaging, RF and microwave devices, laser packaging, and high-reliability electronic components. As chip power density increases, packaging materials not only need to conduct heat away in time but also need to maintain appropriate thermal expansion matching with chips, ceramic substrates, and other structural materials.

Power semiconductor packaging

Power semiconductors are used for electrical energy conversion, power control, and current regulation. Chips generate heat during operation; if the packaging material has insufficient heat dissipation capability, the chip temperature may rise; if the thermal expansion difference between adjacent materials is too large, repeated heating and cooling may also cause solder layer fatigue, interfacial delamination, or structural damage. Tungsten-copper alloy can be used for packaging bases, heat sinks, heat spreader components, and other structural parts of some power devices. By adjusting the tungsten-copper ratio, a trade-off can be made among thermal conductivity, coefficient of thermal expansion, stiffness, and processing performance.

Potential applications include industrial frequency converters, power conversion modules, some new energy vehicle power electronic components, and high-reliability power supply equipment. It should be emphasized that tungsten-copper alloy is not a universal packaging material for all power modules; whether it is used depends on chip structure, packaging form, thermal resistance requirements, cost, and reliability standards.

RF and microwave device packaging

RF and microwave devices are widely used in communications, radar, satellite communications, and high-frequency power amplification equipment. These devices may simultaneously face relatively high local thermal loads, strict dimensional requirements, and complex electromagnetic environments. Tungsten-copper alloy can be used for some RF packaging bases, flanges, heat sinks, and precision support structures. Its opportunities come not only from material thermal conductivity but also from the ability to reduce thermal stress in packaging structures by adjusting the coefficient of thermal expansion.

Laser and optoelectronic packaging

High-power laser diodes, optoelectronic devices, and some optical communication components have relatively high requirements for heat conduction, mounting surface accuracy, and long-term dimensional stability. Tungsten-copper alloy can be used for specific heat sinks, mounting bases, and packaging structural parts.

In this field, the competitiveness of enterprises depends on whether they can combine material performance with part geometry, chip mounting method, and cooling structure. Providing material grades alone is usually not enough to meet all requirements of high-end customers.

Key thresholds of the semiconductor packaging market

Technical indicator	Impact on product performance
Thermal conductivity	Affects the ability to conduct heat from the chip to the external heat dissipation structure
Coefficient of thermal expansion	Affects thermal stress among the chip, substrate, and packaging structure
Material density and porosity	Reflects the densification level and may affect thermal, electrical, and mechanical performance
Flatness and dimensional tolerance	Affects chip mounting, soldering, and interface contact quality
Surface quality and coating	Affects soldering, connection, and long-term interface reliability
Batch consistency	Affects mass production yield, product reliability, and customer certification

Therefore, the semiconductor field is more suitable for enterprises with material design, precision machining, surface treatment, and reliability testing capabilities. Developing from standardized plates, discs, or blanks to customized heat sinks, packaging bases, and precision components is an important path to increase product added value.

III. High-power electronics: new demand brought by power density improvement

The high-power electronics field overlaps with semiconductor packaging, but its requirements pay more attention to the stable operation of devices under high current, high frequency, high thermal load, and repeated thermal cycling conditions. Wide-bandgap semiconductors, especially silicon carbide (SiC) and gallium nitride (GaN) devices, can be used for high-efficiency

power conversion, high-frequency switching, and high-power-density systems. With the application development of these devices, packaging structures place higher requirements on heat dissipation capability, thermal expansion matching, and reliability.

Power conversion and power control

New energy vehicle drive inverters, industrial motor drives, industrial power supplies, and some new energy converter equipment need to control chip temperature rise and packaging thermal stress. Tungsten-copper alloy has opportunities to be used in specific packaging bases, heat spreader components, and precision mounting structures, but the solution needs to be determined after comparison with other thermal management materials.

RF and microwave high-power devices

Local thermal management components in communication base stations, radar, satellite communications, and high-frequency power amplifiers need to balance heat conduction, dimensional stability, and packaging reliability. Tungsten-copper alloy can be used for specific packaging heat sinks, flanges, and support structures.

High-power lasers and optoelectronic equipment

Laser diode arrays and other high-power optoelectronic modules need rapid heat conduction and control of structural offset caused by temperature changes. Precision tungsten-copper heat sinks, mounting bases, and packaging parts have certain development potential.

High-power power supplies and data center equipment

The requirements for local thermal management in high-power power supplies and data center power conversion equipment continue to increase. Tungsten-copper alloy is more suitable for components with special thermal expansion matching, structural stability, or reliability requirements, rather than directly replacing the entire liquid-cooled or air-cooled heat dissipation system.

Where are the opportunities in the high-power electronics field?

First, joint design of materials and devices. Enterprises can adjust the tungsten-copper ratio and part structure according to the thermal expansion characteristics of chips, ceramic substrates, and cooling structures to reduce stress concentration that may occur during thermal cycling. Second, precision structural part manufacturing. Through precision machining, surface treatment, and dimensional inspection, material performance is transformed into products that can be directly used in packaging components. Third, reliability verification. Carry out thermal cycling, interfacial bonding, and heat conduction performance verification for high-power devices to help customers judge whether materials meet requirements under actual working conditions. The core of these opportunities is not to promote tungsten-copper alloy as generally superior to other materials, but to identify applications where the combined advantages of low thermal expansion, relatively high thermal conductivity, and dimensional stability can truly create value.

IV. Comparison of market opportunities in the three fields

Comparison dimension	Power equipment	Semiconductor packaging	High-power electronics
Main source of demand	Grid upgrades, equipment renewal, reliability improvement	Chip packaging, thermal expansion matching, precision manufacturing	Increased power density, heat dissipation and thermal cycle reliability
Market maturity	Relatively mature	Relatively high technical threshold, large differences among segmented markets	Development speed of segmented applications varies
Core competitive factors	Arc resistance, life, stable supply	Thermophysical properties, precision machining, customer verification	Thermal management, structural integration, reliability
Main business opportunities	Contact material upgrades, replacement parts	Packaging bases, heat sinks, precision substrates	Power modules, RF devices, laser-related components
Main risks	Customer certification and differences in equipment working conditions	Long verification cycle, strict performance requirements	Material substitution, changes in heat dissipation solutions

From the perspective of enterprise operation, the power equipment field is suitable for accumulating business through mature processes and stable supply; semiconductor packaging is more suitable for enterprises with precision machining, testing, and joint customer development capabilities; the high-power electronics field requires product development in combination with specific devices and thermal management structures, and the market scale should not be judged solely by industry popularity.

V. How can the experience of CTIA GROUP be integrated into these development opportunities?

CTIA GROUP has thirty years of experience in tungsten-copper alloy design and production. Combined with the material characteristics of tungsten-copper alloy and the above application requirements, the value of this long-term accumulation is mainly reflected in material ratio design, powder metallurgy process optimization, tungsten skeleton sintering and copper infiltration control, and manufacturing and processing adaptation of products of different specifications. For power equipment applications, relevant experience can be used to carry out material and process selection around contact arc erosion resistance, electrical conductivity, dimensional stability, and batch consistency. For semiconductor and high-power electronics applications, suitable tungsten-copper ratios and precision manufacturing solutions can be studied according to target coefficient of thermal expansion, thermal conductivity, product dimensions, and processing requirements. This type of experience is especially suitable for the process from sample trial production to batch delivery: first determine technical indicators according to the customer's working conditions and drawings, then verify material performance through sample testing and application testing, and then solidify the verified process conditions into batch production specifications. Enterprise website: CTIA GROUP.

Actual projects still need to be judged based on the performance data and verification results of specific products. Thirty years of design and production experience can serve as a reference for supplier technical accumulation, but it cannot replace an independent evaluation of a specific grade, a specific batch of products, and their application adaptability.

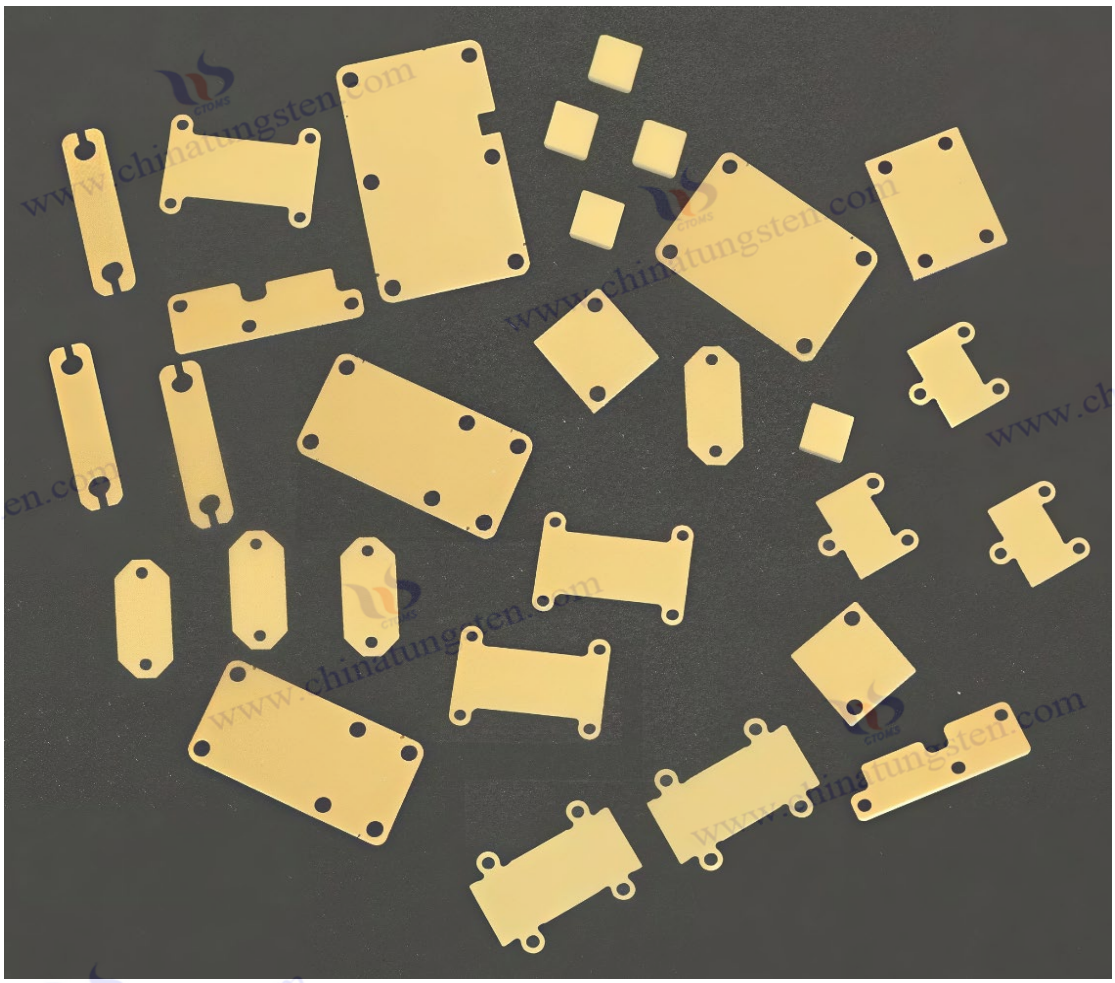
VI. Technical directions worth focusing on in the future

Development direction	Technical focus	Potential commercial value
W skeleton & Cu infiltration	Control pore structure, copper distribution, and density	Reduce defect & improve batch stability
Customization of thermophysical properties	Match thermal conductivity and coefficient of thermal expansion according to device requirements	Enter precision packaging and thermal management segmented markets
Precision machining and surface engineering	Flatness, dimensional tolerance, surface roughness	Upgrade from material supply to finished
Reliability and failure analysis	Thermal cycling, contact performance, interface stability, and life verification	Enhance customer trust and supply chain stickiness
Process digitization and quality traceability	Process parameter records, batch correlation, and quality trend analysis	Reduce batch fluctuations and quality risks
Joint development for specific devices	Collaborative design and verification with equipment manufacturers and packaging manufacturers	Form differentiated products and long-term cooperation

In addition, tungsten-copper alloy is not the optimal solution for all thermal management applications. Molybdenum-copper (Mo-Cu), aluminum silicon carbide (AlSiC), copper-diamond composites, and other advanced packaging materials may all compete under specific thermal conductivity, coefficient of thermal expansion, weight, or cost requirements. Therefore, enterprises should concentrate resources on segmented scenarios where tungsten-copper alloy has comprehensive advantages, rather than pursuing coverage of all electronic heat dissipation applications.

Tungsten-copper alloy has development opportunities in power equipment, semiconductors, and high-power electronics, but different market strategies need to be adopted. Power equipment focuses on contact performance, reliability, and stable supply; the semiconductor field focuses on thermal expansion matching, precision packaging, and batch consistency; the high-power electronics field focuses on thermal management and structural reliability requirements brought by device power density improvement.

For enterprises such as CTIA GROUP, which has thirty years of experience in tungsten-copper alloy design and production, a more valuable development direction is to extend existing material and process experience to customized grades, precision machined parts, and application verification services. Whether material performance, manufacturing process, and actual customer working conditions can be effectively combined, and whether product value can be proven with stable inspection data and delivery records, will determine whether enterprises can establish long-term competitiveness in these high value-added markets.



Q83 How will the substitution relationship between tungsten-copper alloy and other composite materials develop?

The substitution relationship between tungsten-copper alloy (W-Cu Alloy) and molybdenum-copper alloy (Mo-Cu Alloy), copper-chromium-zirconium alloy (CuCrZr), aluminum silicon carbide composite (AlSiC), copper-diamond composite, and other advanced thermal management materials will gradually shift from single material performance comparison to comprehensive competition oriented toward specific application scenarios. In the future, it will not be that one material completely replaces another, but that different materials redraw their applicable ranges based on electrical conductivity, thermal conductivity, coefficient of thermal expansion, arc erosion resistance, density, mechanical strength, processing cost, and service environment. The competitive advantages of tungsten-copper alloy are mainly concentrated in scenarios that need to balance electrical conductivity, thermal conductivity, low thermal expansion, and high-temperature resistance, especially specific electrical contacts, EDM electrodes, and some electronic packaging components. However, in applications pursuing higher thermal conductivity, lower weight, lower cost, or higher mechanical strength, other materials may be more advantageous.

I. Main substitution relationships between different materials

Comparison material	Main characteristics relative to tungsten-copper alloy	Applications more likely to form substitution	Scenarios where tungsten-copper alloy has advantages
Mo-Cu alloy	Adjustable coefficient of thermal expansion, suitable for some electronic packaging and heat sinks	Electronic packaging, semiconductor bases, thermal management structural parts	Components requiring higher density, specific electrical performance, or arc resistance
CuCrZr alloy	Relatively high electrical and thermal conductivity, certain strength and softening resistance	Resistance welding electrodes, conductive parts, cooling electrodes	Specific contacts or electrodes with obvious high-temperature arc erosion and requiring higher burn resistance
AlSiC	Lower density, adjustable coefficient of thermal expansion, suitable for lightweight packaging	Avionics, power module base plates, lightweight electronic packaging	Components with requirements for high density, specific electrical performance, or high-temperature electrical contact
Cu-diamond composite	Potential to achieve very high thermal conductivity; performance depends on interface and preparation process	High heat flux density chips, advanced heat spreader components	Specific parts balancing electrical conductivity, thermal expansion matching, and mature processing technology
Cu & high conductivity Cu	Outstanding electrical and thermal conductivity, mature raw material and processing system	Conventional conductive parts, heat sinks, busbars, and heat spreader components	Specific uses requiring arc erosion resistance, low thermal expansion, or high-temperature dimensional stability

The performance boundaries between these materials are not absolute. For example, copper-diamond composites can achieve relatively high thermal conductivity, but their interface bonding, processing, cost, and batch stability may constitute constraints; both molybdenum-copper and tungsten-copper can adjust thermal expansion performance through composition ratio, and the final choice still depends on target indicators and manufacturing conditions.

II. How will the substitution relationship evolve?

In the future, competition between tungsten-copper alloy and other composite materials will roughly develop in three directions: conventional applications will continue cost substitution, high-performance electronic packaging will expand toward materials with higher thermal conductivity, and traditional electrical contacts will maintain competitiveness through performance optimization and specialization.

Molybdenum-copper alloy: a direct competitor in electronic packaging and lightweight components

Molybdenum-copper alloy and tungsten-copper alloy have relatively similar functional positioning, and both can obtain different coefficients of thermal expansion and thermal conductivity by adjusting the ratio of refractory metal to copper. The density of molybdenum is lower than that of tungsten, so under conditions of meeting similar thermal expansion requirements, molybdenum-copper alloy is usually more conducive to reducing component weight; its processing performance may also be more suitable for some precision structural parts. Therefore, in the fields of semiconductor packaging bases, heat sinks, precision electronic structural parts, and some switch contacts, molybdenum-copper alloy may continue to expand its application. But this substitution is not one-way. Tungsten-copper alloy still has

its own advantages in high density, specific electrical contact, arc erosion resistance, and wear resistance. For tungsten-copper parts that have completed equipment verification, customers will not necessarily switch materials simply because molybdenum-copper is lighter or has lower processing cost. In the future, it is more likely that the two materials will divide work within the same industry according to specific performance requirements, rather than one completely replacing the other.

Copper-chromium-zirconium alloy: cost competition in conventional conductive and welding electrode fields

Copper-chromium-zirconium alloy is a type of copper-based alloy with relatively high electrical and thermal conductivity and balanced strength and softening resistance, suitable for resistance welding electrodes, conductive fixtures, some electrical connectors, and other parts requiring relatively high electrical conductivity. Under working conditions where temperature and arc erosion are relatively mild and the main requirements are electrical conductivity, thermal conductivity, and certain mechanical strength, copper-chromium-zirconium alloy may be more economical than tungsten-copper alloy. Its raw material system and conventional processing technology are also relatively mature. But when electrodes need to withstand strong arc erosion, local extremely high temperatures, or severe burning, the tungsten phase in tungsten-copper alloy can play an important role. Industry information also lists tungsten-copper as one of the materials that can be used when some conventional copper-based electrode materials cannot meet requirements. Therefore, the focus of future competition is to accurately divide working conditions: components that can be satisfied by lower-cost copper-based alloys may gradually shift to copper-chromium-zirconium; components with higher requirements for burn resistance, high-temperature resistance, and dimensional stability may still retain tungsten-copper solutions.

Aluminum silicon carbide composite: substitution opportunities in lightweight electronic packaging

Aluminum silicon carbide composite is composed of an aluminum matrix and a silicon carbide reinforcement phase, with characteristics such as lower density and adjustable coefficient of thermal expansion, and is suitable for some avionics, power module base plates, and lightweight electronic packaging structures. When product requirements for weight, structural stiffness, and thermal expansion matching are higher than requirements for high density and special electrical contact performance, aluminum silicon carbide may be more attractive.

In comparison, tungsten-copper alloy has higher density and is usually not suitable for structural designs whose primary goal is weight reduction. However, in some components requiring higher density, specific electrical performance, arc erosion resistance, or high-temperature stability, aluminum silicon carbide cannot directly provide exactly the same functional combination. The substitution of aluminum silicon carbide for tungsten-copper alloy mainly occurs in some electronic packaging and thermal management structural parts, not in all tungsten-copper application fields.

Copper-diamond composite: potential challenge in high heat flux density scenarios

Copper-diamond composite utilizes the relatively high intrinsic thermal conductivity and low

thermal expansion characteristics of diamond, combined with the thermal conductivity of copper, and has the potential to develop high-performance thermal management materials. With the development of high-power chips, advanced lasers, and high heat flux density electronic equipment, the thermal conductivity requirements of some packaging systems may exceed the applicable range of traditional tungsten-copper or molybdenum-copper materials.

This will provide development space for copper-diamond composites. Related research has demonstrated the technical potential of combining relatively high thermal conductivity with a relatively low coefficient of thermal expansion, but actual performance depends on the interface bonding between diamond and copper, the manufacturing process, and material density. Its commercialization constraints are also relatively obvious, including the cost of diamond raw materials and interface treatment, difficulty of large-scale manufacturing, processing methods, product consistency, and long-term reliability verification. Even if laboratory samples achieve very high thermal conductivity, it does not mean that they can replace tungsten-copper alloy at reasonable cost in all packaging scenarios. A more likely trend is that copper-diamond will first enter segmented markets with extremely high thermal management performance requirements and the ability to bear higher material costs, while tungsten-copper will continue to serve applications with a relatively balanced relationship between performance requirements and manufacturing costs.

III. Competition trends in the next five to ten years

The following are trend judgments based on material performance and manufacturing conditions, not precise predictions of the market share of various materials.

Application field	Possible development trend	Main challenges faced by tungsten-copper alloy
Medium- & high-voltage electrical contacts	Mainly mature material upgrades and reliability improvements	Cost competition from copper-based materials and other contact systems
Resistance welding electrodes	Material selection segmented by current, temperature, and wear degree	Substitution by copper-based alloys such as copper-chromium-zirconium in conventional working conditions
Semiconductor packaging	Parallel competition among tungsten-copper, molybdenum-copper, aluminum silicon carbide, etc.	Requirements for lower weight, higher thermal conductivity, and precision machining
High-power electronics	More emphasis on thermal resistance, thermal expansion matching, and component-level verification	Development of copper-diamond and other advanced thermal management materials
Aerospace & special equipment	Customized material selection according to weight, thermal performance, and environmental conditions	Requirements for lightweight, reliability, and full lifecycle cost

It is necessary to distinguish between material research progress and actual commercial substitution. Even if advanced materials have higher theoretical performance, they still need to solve manufacturing cost, yield, reliability, and customer certification issues. Therefore, in the short term, traditional material systems still have a strong application foundation; in the long

term, more multi-material combinations and structural integration solutions may appear.

IV. How should tungsten-copper alloy enterprises respond to substitution competition?

First, they should shift from simply selling fixed grades to providing material solutions according to application working conditions. Enterprises need to master the density, electrical conductivity, thermal conductivity, coefficient of thermal expansion, and arc resistance performance under different tungsten-copper ratios and be able to explain the applicable working condition boundaries of the materials. Second, they should strengthen precision machining and quality control. As electronic packaging and high-power equipment place higher requirements on dimensions, flatness, internal defects, and batch consistency, the competitive pressure of simply providing alloy blanks may increase. Enterprises that can provide precision machining, surface treatment, inspection reports, and application verification support are more likely to establish differentiated advantages. Third, they should establish a material benchmarking mechanism. For each category of key products, the performance, processing cost, yield, supply stability, and service life of candidate materials such as tungsten-copper, molybdenum-copper, copper-chromium-zirconium, aluminum silicon carbide, and copper-diamond can be regularly compared. This can identify in advance which products are at risk of substitution and which products still have stable technical advantages.

In this process, CTIA GROUP, with thirty years of experience in tungsten-copper alloy design and production, can continuously improve material performance consistency and application adaptability around directions such as tungsten-copper ratio optimization, powder metallurgy process, sintering and copper infiltration control, precision machining, and customized product development. Related product and technical information of the enterprise can be found on the CTIA GROUP official website; specific material competitiveness should still be based on actual product data, customer testing, and working condition verification.

V. How to judge whether a certain product is easily substitutable?

For buyers and manufacturers, the following judgment framework can be used:

If the product mainly requires electrical and thermal conductivity and the working temperature and arc erosion degree are not high, focus should be on evaluating whether copper-based alloys can meet the requirements at lower cost.

If the product requires a lower coefficient of thermal expansion, higher density, and good dimensional stability, focus should be on comparing the performance, weight, processing cost, and assembly conditions of tungsten-copper and molybdenum-copper.

If the primary goal of the product is lightweight while also requiring control of thermal expansion, composite materials such as aluminum silicon carbide can be evaluated.

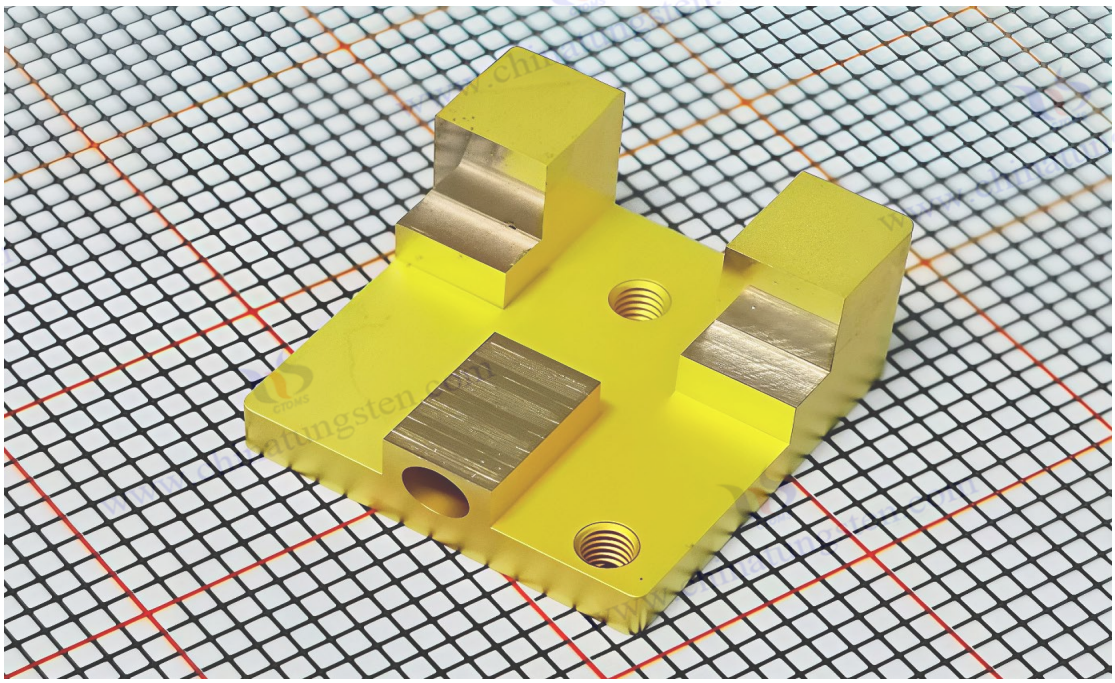
If the product faces extremely high heat flux density and the heat dissipation capability of traditional materials has become a system bottleneck, advanced thermal management materials such as copper-diamond can be studied.

If the product must withstand high temperature, arc erosion, or severe wear, priority should be given to actual working condition tests, and the substitution solution cannot be determined solely based on room-temperature electrical conductivity or thermal conductivity.

For key components already in mass production, material switching should also calculate verification cost, equipment adaptation cost, production yield changes, and long-term maintenance cost. A lower unit quotation for a new material does not necessarily mean that the comprehensive cost of the entire system is lower.

The substitution relationship between tungsten-copper alloy and other composite materials will gradually shift from traditional price competition to comprehensive competition in performance, cost, manufacturing capability, and application verification. Molybdenum-copper may expand its application in some lightweight packaging and precision components, copper-chromium-zirconium may continue to replace some tungsten-copper electrodes under conventional working conditions, aluminum silicon carbide is suitable for some lightweight thermal management structures, and copper-diamond has the potential to challenge high heat flux density applications.

Tungsten-copper alloy still has competitive space in the future. The key is to hold its advantages in specific electrical contacts, arc erosion-resistant components, and functional materials that balance electrical conductivity and low thermal expansion, and to enhance product value through process optimization, precision manufacturing, and reliability verification. For manufacturing enterprises, the most effective strategy is not to try to prevent all material substitution, but to clarify the applicable boundaries of their own materials and establish long-term competitiveness in segmented markets that best reflect comprehensive performance advantages.



Q84 How is tungsten-copper alloy scrap recycled? Can recycled materials be used in high-performance products?

Tungsten-copper alloy scrap has relatively high recycling value, mainly because both tungsten (W) and copper (Cu) are valuable industrial metals, and the tungsten and copper contents in tungsten-copper alloy are usually relatively high. However, whether recycled materials can be reused in high-performance products depends not only on the metal recovery rate but also on whether the scrap source, impurity level, recycling process, and the composition, microstructure, and performance after remanufacturing are stable. From industrial practice, tungsten-copper alloy scrap recycling can be divided into two routes: one is to retain the original alloy system and reuse it through sorting, cleaning, remelting, or re-infiltration; the other is to separate or separately recover tungsten and copper and then prepare new tungsten powder, copper powder, and tungsten-copper alloy. The former process chain may be shorter, but it has higher requirements for scrap cleanliness and composition consistency; the latter has the opportunity to control impurities and raw material quality more effectively but usually involves more processes, energy consumption, and cost.

I. What recycling methods are available for tungsten-copper alloy scrap?

Classification and recycling by scrap state

Scrap from different sources is not suitable for the same recycling process.

Scrap type	Main characteristics	Recommended treatment direction
Processing offcuts, cutting blocks	Composition usually relatively clear, less contamination	Recycle by grade, evaluate re-powdering or metal separation
Turning chips, milling chips, grinding waste	Large specific surface area, may be mixed with cutting fluid, abrasives, and other metals	De-oil, remove impurities, dry, and then evaluate composition
Scrapped electrical contacts and welding electrodes	Arc erosion, oxidation, surface attachments, or local composition changes	Remove attachments, test composition, then choose direct or chemical recycling
Mixed grades or scrap of unknown origin	Large composition fluctuation, may be mixed with impurities such as iron, nickel, and cobalt	Sort and test first; usually more suitable for deep purification
Composite scrap containing other materials	May carry steel, ceramics, insulators, or coatings	Disassemble and separate first, then recover valuable components such as tungsten and copper

Direct recycling: preserve the value of the original material as much as possible

For tungsten-copper alloy processing scrap with clear composition and high cleanliness, sorting, cleaning, crushing, or re-powdering can be considered, followed by composition adjustment, pressing, sintering, and copper infiltration to make new materials. The advantage of this route is the opportunity to reduce the cost of metal separation and re-purification. However, tungsten-copper alloy is a composite material composed of a tungsten skeleton and a copper phase, and it cannot simply be assumed that remelting the scrap will restore the original performance. The sintering, infiltration, thermal cycling, and processing experienced by the scrap may change its pore structure, copper phase distribution, and surface state, so the material microstructure still needs to be restored through appropriate powder treatment and remanufacturing processes. Direct recycling is usually more suitable for production scrap with

a single composition, low contamination, and traceable batches. Research on tungsten material recycling also points out that direct recycling has relatively high requirements for scrap composition consistency, purity, and the ability to be reprocessed into powder.

Chemical recycling: separate tungsten and copper before reuse

If the scrap is mixed, heavily contaminated, or cannot be directly restored to the quality requirements of the target material, hydrometallurgical and other processes can be used to recover tungsten and copper separately. Depending on the specific process, selective dissolution, leaching, electrolysis, precipitation, and subsequent purification may be involved. One approach to recovering tungsten is to first convert it into tungstate or other tungsten-containing intermediates, then further purify and prepare tungsten oxide or tungsten powder; copper can be recovered through appropriate separation and purification processes. For tungsten-copper scrap, studies have used methods such as ammonia leaching and electrowinning to recover tungsten and copper components. The core advantage of this route is the ability to re-establish a basis for raw material purity and composition control. Its disadvantage is a longer process chain, requiring control of chemical consumption, waste liquid treatment, metal recovery rate, and comprehensive cost. The actual choice should be judged in combination with scrap scale, composition, contamination degree, and the target purity of the recycled product.

II. Can recycled materials be used in high-performance tungsten-copper alloy products?

Yes, but the way recycled materials are used must be distinguished. Recycled materials are not naturally equivalent to low-quality raw materials, nor can they be considered suitable for all high-performance products simply because the metal recovery rate is high.

First category: direct reuse of clean production scrap

Offcuts with a clear source, stable composition, and low impurities can be used for remanufacturing of the same or similar grades after verification. If powder quality, sintered microstructure, and performance all meet product requirements, there is an opportunity to use them in products of higher performance grades.

Second category: recycled materials after purification and re-powdering

Separating and purifying tungsten and copper and then re-preparing the alloy can re-establish composition and powder quality control conditions in the process. This route is more promising for products with higher requirements for material consistency, but the final result still depends on impurity control, powder characteristics, and complete performance verification.

Third category: heavily mixed, oxidized, or contaminated recycled materials

If they contain relatively high amounts of iron, nickel, cobalt, abrasives, oil contamination, or other difficult-to-control impurities, directly adding them to high-performance tungsten-copper alloy production without sufficient treatment may cause decreases in electrical and thermal conductivity, density, arc erosion resistance, and batch stability. Such materials usually require deep purification or should be directed to uses with higher impurity tolerance.

III. What indicators need to be tested emphatically for high-performance products?

For products such as electrical contacts, precision electrodes, and high-power electronic thermal management components, it is recommended to evaluate recycled materials from at least the following aspects.

Test item	Impact on product performance
W & Cu content & composition uniformity	Affects density, electrical and thermal conductivity, thermal expansion behavior, and arc performance
Iron, nickel, cobalt, and other impurities	May change electrical conductivity, phase composition, sintering behavior, and service life
Powder particle size, morphology, & oxygen content	Affects pressing and forming, sintering densification, and microstructural uniformity
Relative density, porosity	Affects mechanical strength, thermal conductivity, and electrical contact stability
Cu phase distribution & W skeleton structure	Affects conductive paths, heat transfer, and high-temperature working performance
Hardness, electrical conductivity, thermal conductivity	Used to judge whether basic physical properties meet grade requirements
Arc erosion resistance & actual working condition life	Used to verify the reliability of products such as electrical contacts and electrodes under target working conditions
Batch consistency and traceability	Determines whether stable supply can be achieved and customer quality audits can be passed

Among these, qualified chemical composition is only a basic condition. For high-performance products, it is also necessary to verify whether the recycled powder can form a qualified microstructure and whether the finished product can achieve target performance under actual working conditions.

IV. How to judge whether recycled materials are worth using in high-performance products?

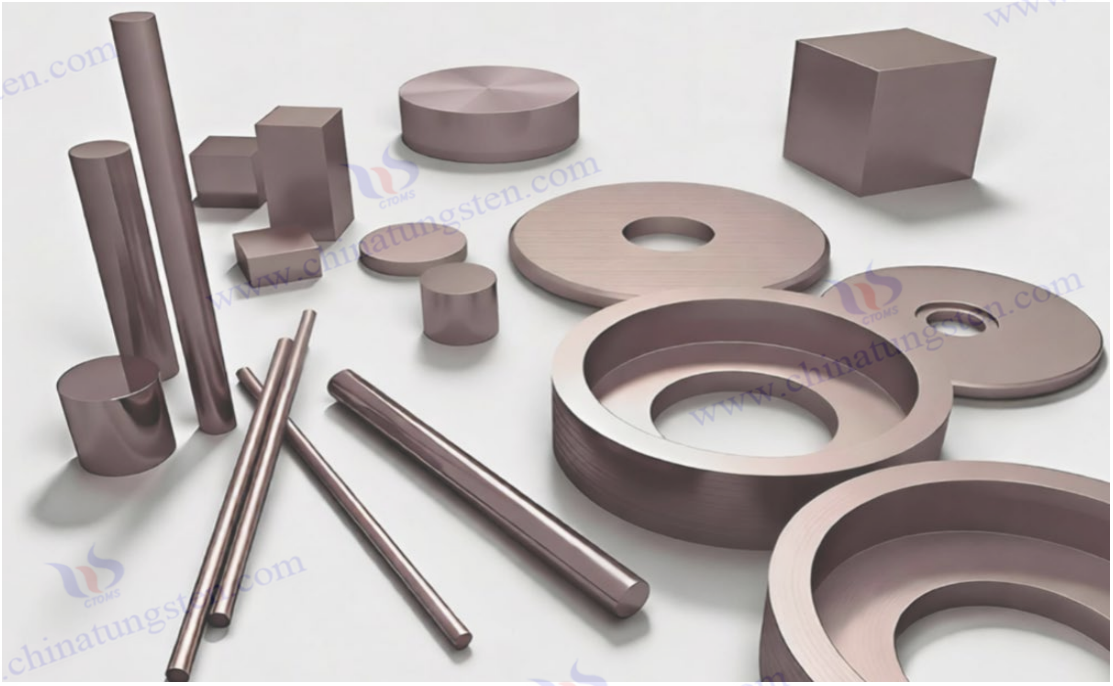
It is recommended to establish a classified management mechanism rather than mixing and processing all recycled materials together.

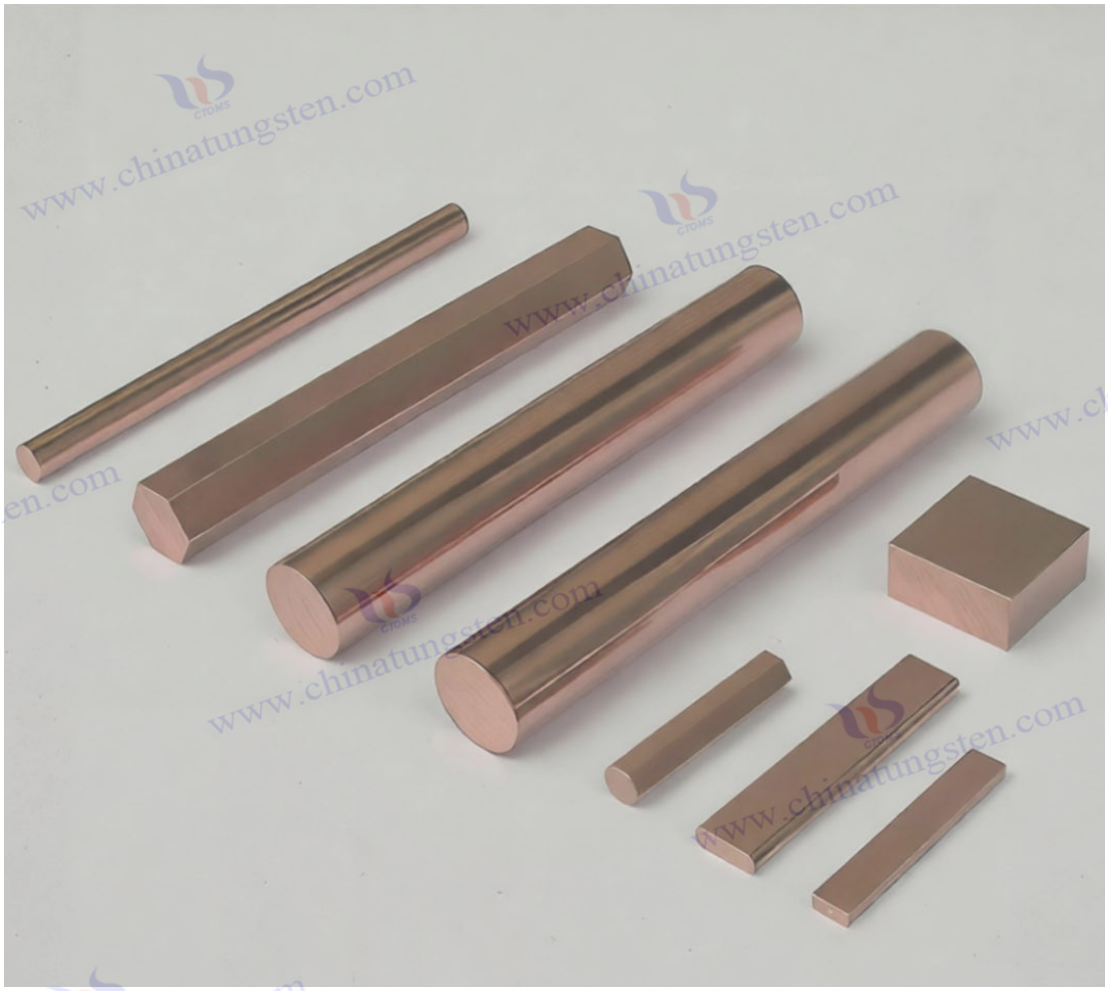
The first step is source classification, distinguishing clean processing offcuts, oil-containing chips, scrapped electrical contacts, and mixed-source scrap. The second step is composition testing and contamination screening, using chemical analysis, metallographic observation, and powder characteristic testing when necessary. The third step is small-batch trial production, comparing the density, electrical conductivity, thermal conductivity, hardness, and key working condition performance of products made from virgin materials and recycled materials. The fourth step is batch verification to confirm that composition, microstructure, and performance fluctuations in continuous production meet product requirements.

Cost evaluation cannot compare only the procurement prices of recycled materials and virgin materials. A more reasonable calculation method is: comprehensive cost of recycled materials = scrap procurement cost + sorting and pretreatment cost + purification or powder making cost + remanufacturing cost + testing and waste treatment cost – recoverable by-product income. If recycled materials still cannot stably meet high-performance requirements after multiple

processes, even if the raw material price is lower, they may lose economic advantage due to decreased yield, increased testing costs, and customer certification risks.

Tungsten-copper alloy scrap definitely has recycling value. Some high-cleanliness production scrap with clear composition has the opportunity to be used in high-performance products after appropriate treatment; scrap with complex sources or heavy contamination is more suitable for re-preparing raw materials after separation and purification of tungsten and copper. The key to determining whether recycled materials can enter high-end applications is not whether they come from scrap, but whether their purity, powder quality, microstructure, final performance, and batch consistency meet the requirements of the corresponding products.





Q85 How will the manufacturing process, material performance, and application technology of tungsten-copper alloy be upgraded in the future?

The future technological upgrade of tungsten-copper alloy will no longer be limited to improving material density or adjusting the tungsten-copper ratio, but will gradually shift toward powder refinement, controllable microstructure, complex structure manufacturing, synergistic performance optimization, and integrated application components. Traditional powder metallurgy and copper infiltration processes will remain an important manufacturing foundation, while additive manufacturing, gradient structure design, precision machining, and digital quality control are expected to expand their performance boundaries and application scope. As of 2026, related research has begun to use tungsten-copper composite materials for laser powder bed fusion, complex tungsten skeleton manufacturing, and functionally graded structure design. For example, research in 2026 has prepared additively manufactured copper-tungsten composites for high-power electronic heat dissipation, and some research has explored controlling the thermal expansion and thermomechanical properties of materials by adjusting the tungsten skeleton structure.

I. Manufacturing process: from traditional powder metallurgy to refinement and complex structure manufacturing

More refined powder preparation and microstructure control

The performance of tungsten-copper alloy is closely related to tungsten powder particle size, particle morphology, powder dispersibility, tungsten skeleton pore structure, and copper phase distribution. Future manufacturing processes will pay more attention to raw material batch stability, powder particle size distribution, and interface state control, and reduce defects such as pores, local copper enrichment, and microstructural non-uniformity by optimizing powder mixing, forming, sintering, and infiltration parameters. Among these, technologies such as electroless copper plating on tungsten powder, core-shell composite powder, and refined powder mixing are expected to improve the distribution uniformity of the tungsten and copper phases and reduce performance fluctuations caused by insufficient powder mixing in traditional processes. In 2025, research has used chemical plating to prepare tungsten-copper composite powder and explored complex part manufacturing by combining powder metallurgy and injection molding concepts.

Further optimization of sintering and copper infiltration processes

Traditional tungsten-copper alloy usually first prepares a tungsten skeleton with a certain porosity and then fills the pores by liquid copper infiltration. Future upgrade focuses include improving the controllability of tungsten skeleton pore distribution, improving copper liquid wetting and filling capability, reducing residual porosity, and improving dimensional consistency of complex-shaped parts. Processes such as spark plasma sintering, hot pressing sintering, and rapid sintering can also be used according to material grade, part size, and performance requirements to shorten the manufacturing cycle or improve microstructure. However, these processes do not have the same advantages for all tungsten-copper grades, and equipment cost, production efficiency, size limitations, and subsequent processing requirements still need to be comprehensively evaluated.

Additive manufacturing opens up design space for complex structures

Additive manufacturing (AM) is expected to become an important supplement to tungsten-copper alloy manufacturing. Compared with traditional pressing, sintering, and infiltration, additive manufacturing is more suitable for preparing components with complex internal channels, thin-walled structures, lattice skeletons, and locally adjustable material distribution. Laser powder bed fusion (LPBF) and other metal additive manufacturing routes are being explored in different ways for tungsten-copper composite materials. One approach is to first manufacture a porous tungsten skeleton and then perform copper infiltration; another approach is to directly process copper-tungsten composite powder suitable for specific additive equipment. A 2026 study on heat dissipation components for high-power electronics prepared copper-tungsten composites with a relative density of 99.4% by optimizing the laser powder bed fusion process and demonstrated the manufacturing potential of complex heat dissipation structures. However, such results are research results under specific material ratios and process conditions and cannot be directly regarded as having achieved the same level for all traditional tungsten-copper grades.

II. Material performance: from single indicator improvement to multi-performance synergistic optimization

More precise balance among electrical conductivity, thermal conductivity, and low thermal expansion

The core advantage of tungsten-copper alloy lies in utilizing the high melting point and relatively low thermal expansion characteristics of tungsten and the high electrical and thermal conductivity of copper. Future material design will pay more attention to the balance among different properties rather than maximizing a single indicator. For example, increasing tungsten content usually helps reduce the coefficient of thermal expansion and improve hardness and arc erosion resistance but may also reduce electrical conductivity and thermal conductivity; increasing copper content is favorable for electrical and thermal conductivity but may weaken the performance of the material under high temperature and high arc load. Therefore, the focus of material upgrading is to optimize the tungsten-copper ratio, tungsten particle distribution, and copper phase continuity according to actual working conditions.

Future tungsten-copper alloy will further develop toward application-oriented formulations, for example, focusing on thermal expansion matching and heat conduction for semiconductor packaging, focusing on arc erosion resistance, contact resistance, and mechanical stability for high-voltage electrical contacts, and focusing on the comprehensive performance of heat transfer, thermal stress, and thermal cycle life for high heat flux density environments.

More refined microstructure and interface control

The solid-state mutual solubility of tungsten and copper is limited, and material performance is highly dependent on the spatial distribution of the two phases, pore state, and interface quality. In the future, local defects may be reduced and material performance consistency improved through finer tungsten powder, a more uniform tungsten skeleton, optimized copper infiltration paths, and refined interface design. However, refining tungsten particles does not necessarily bring simultaneous improvement in all properties. Particle size, sintering behavior, porosity, and copper phase distribution interact with each other, and excessive refinement may also increase powder processing difficulty and production cost. Therefore, material design needs to find a reasonable microstructural scale around target performance, rather than simply pursuing the finer the better.

From homogeneous structures to gradient materials and designable structures

Functionally graded materials (FGM) are a direction worth attention. Their characteristic is that the material composition or microstructure changes continuously or in stages along a specified direction, thereby improving the sudden performance change at the interface of traditional materials. In tungsten-copper alloy, it can be considered that the side close to the high temperature or plasma has a higher tungsten content, while the side close to the cooling structure has a higher copper content, so as to balance surface high-temperature resistance and internal heat conduction. For plasma-facing components of nuclear fusion devices, this design may also help alleviate interfacial stress caused by the thermal expansion difference between tungsten and copper. In 2026, research has prepared tungsten-copper composites with a tungsten content gradient by adjusting the porosity of the tungsten skeleton and the amount of copper infiltration. This indicates that gradient structures have entered the

experimental research stage, but large-scale application under complex working conditions still requires long-term thermal cycling, interface reliability, and manufacturing repeatability verification.

III. Application technology: extending from material supply to precision functional components

Application field	Main upgrade direction	Key technical requirements
High-voltage power equipment	High-reliability electrical contacts, arc-resistant components, and long-life switch contacts	Arc erosion resistance, stable contact resistance, thermal shock resistance
Semiconductor packaging	Heat sinks, heat spreader components, and packaging substrate-related components	Thermal conductivity, thermal expansion matching, flatness, and interface reliability
High-power electronics	High heat flux density heat sinks, complex cooling structures, and customized thermal management components	Thermal resistance control, thermal cycle life, structural design, and precision machining
Aerospace and extreme environments	High-temperature, high thermal load, and specific electrical functional components	High-temperature stability, thermomechanical performance, and environmental adaptability
Nuclear fusion and plasma devices	Plasma-facing components and gradient structure composite materials	High heat flux bearing capacity, interface reliability, and long-term service stability

Power equipment: from conventional contacts to higher reliability

Power equipment will remain an important application field for tungsten-copper alloy. The future upgrade focus is to reduce material loss under arc action, stabilize contact resistance, and improve life performance under the combined action of thermal shock and mechanical load. In addition to material formulation, contact geometry, surface processing quality, connection method, and thermal management under service conditions also need to be optimized. For high-reliability products, the evaluation focus will expand from single performance testing to long-term electrical testing and batch life consistency.

Semiconductors and high-power electronics: more integrated thermal management design

As power density increases, thermal management of electronic devices is no longer just about selecting high thermal conductivity materials but also requires simultaneous consideration of thermal expansion matching among chips, insulating layers, soldering or connection layers, heat sinks, and cooling systems. Tungsten-copper alloy is expected to continue to be used in some components requiring low thermal expansion and relatively high thermal conductivity. Additive manufacturing may provide new manufacturing methods for complex cooling channels, thin-walled heat dissipation structures, and local material optimization. However, if the application focus is extremely high thermal conductivity, low density, or large-scale low-cost production, other material systems may still be more suitable, and tungsten-copper alloy will not completely replace them.

Extreme thermal load fields: collaborative design of materials, structures, and cooling systems

In nuclear fusion, plasma equipment, and other high heat flux density environments, simply

increasing material thermal conductivity cannot completely solve the problem. Components must also withstand temperature gradients, thermal cycling, mechanical stress, and stress concentration at material interfaces. Therefore, future application technology will pay more attention to the joint design of material structure, cooling channels, connection interfaces, and actual working conditions. The process combining gradient tungsten-copper materials, additively manufactured tungsten skeletons, and copper infiltration may provide new solutions for such applications, but it still needs to pass severe thermal load tests and service verification.

IV. Manufacturing and quality management: digitalization and whole-process control will become basic capabilities

In the future, the competitiveness of tungsten-copper alloy manufacturing will be reflected not only in material formulation but also in whether products meeting requirements can be produced stably and repeatably. On the one hand, the manufacturing process will pay more attention to the correlation control among powder batches, pressing parameters, sintering temperature, infiltration state, and processing dimensions; on the other hand, testing will gradually expand from finished product sampling to whole-process quality tracking, including composition analysis, density and porosity testing, microstructure inspection, electrical conductivity and thermal conductivity measurement, and key working condition performance verification.

Digital process management can also correlate raw material data, production parameters, and finished product inspection results to identify defect sources, optimize process windows, and reduce batch fluctuations. For complex-shaped or high-reliability components, the combination of computational simulation and experimental verification can also help evaluate thermal stress, temperature distribution, and structural weak areas in advance.

For manufacturing enterprises, the future technological upgrade path will gradually shift from simply selling standard grades to overall solutions combining material formulation, manufacturing process, precision machining, and application verification. Tungsten-copper alloy manufacturers such as CTIA GROUP (https://www.ctia.com.cn) can combine material design and processing manufacturing capabilities around customers' electrical, thermal management, and dimensional requirements to promote product development from standard materials to customized functional components.

V. Main bottlenecks of future upgrades

Although new processes have expanded the manufacturing space of tungsten-copper alloy, several issues still need to be continuously solved. First, the physical properties of tungsten and copper differ greatly, and additive manufacturing is prone to problems such as unstable melt pools, porosity, uneven composition distribution, and residual stress. Second, the inspection, post-processing, and precision machining of complex structures may offset some of the efficiency advantages brought by additive manufacturing. Third, gradient materials and high-performance composite structures need to verify long-term thermal cycling, interface stability, and batch consistency. Fourth, the equipment investment, powder cost, yield, and quality certification cycle of new processes will all affect their commercialization progress.

Therefore, technological upgrading does not mean that all tungsten-copper products must adopt the latest processes. For mature electrical contacts and standard-shaped parts, traditional powder metallurgy and copper infiltration may still have advantages in cost, quality, and production capacity; for complex heat dissipation structures, gradient materials, and extreme thermal load components, the value of new processes is more likely to be reflected.

In summary, tungsten-copper alloy will develop along three main lines in the future: manufacturing processes will extend from traditional powder metallurgy to refined control and complex structure manufacturing, material performance will develop from single indicator optimization to synergistic design of electrical conductivity, thermal conductivity, thermal expansion, and service life, and application technology will upgrade from providing standard materials to providing functional components that have undergone precision machining and working condition verification. What truly determines technical competitiveness will be whether stable manufacturing, reliable verification, and reasonable cost can be achieved while meeting actual performance requirements.

