Encyclopedia of Pure Tungsten Electrode

中钨智造科技有限公司

CTIA GROUP LTD

CTIA GROUP LTD

Global Leader in Intelligent Manufacturing for Tungsten, Molybdenum, and Rare Earth Industries

INTRODUCTION TO CTIA GROUP

CTIA GROUP LTD, a wholly-owned subsidiary with independent legal personality established by CHINATUNGSTEN ONLINE, is dedicated to promoting the intelligent, integrated, and flexible design and manufacturing of tungsten and molybdenum materials in the Industrial Internet era. CHINATUNGSTEN ONLINE, founded in 1997 with www.chinatungsten.com as its starting point—China's first top-tier tungsten products website—is the country's pioneering e-commerce company focusing on the tungsten, molybdenum, and rare earth industries. Leveraging nearly three decades of deep experience in the tungsten and molybdenum fields, CTIA GROUP inherits its parent company's exceptional design and manufacturing capabilities, superior services, and global business reputation, becoming a comprehensive application solution provider in the fields of tungsten chemicals, tungsten metals, cemented carbides, high-density alloys, molybdenum, and molybdenum alloys.

Over the past 30 years, CHINATUNGSTEN ONLINE has established more than 200 multilingual tungsten and molybdenum professional websites covering more than 20 languages, with over one million pages of news, prices, and market analysis related to tungsten, molybdenum, and rare earths. Since 2013, its WeChat official account "CHINATUNGSTEN ONLINE" has published over 40,000 pieces of information, serving nearly 100,000 followers and providing free information daily to hundreds of thousands of industry professionals worldwide. With cumulative visits to its website cluster and official account reaching billions of times, it has become a recognized global and authoritative information hub for the tungsten, molybdenum, and rare earth industries, providing 24/7 multilingual news, product performance, market prices, and market trend services.

Building on the technology and experience of CHINATUNGSTEN ONLINE, CTIA GROUP focuses on meeting the personalized needs of customers. Utilizing AI technology, it collaboratively designs and produces tungsten and molybdenum products with specific chemical compositions and physical properties (such as particle size, density, hardness, strength, dimensions, and tolerances) with customers. It offers full-process integrated services ranging from mold opening, trial production, to finishing, packaging, and logistics. Over the past 30 years, CHINATUNGSTEN ONLINE has provided R&D, design, and production services for over 500,000 types of tungsten and molybdenum products to more than 130,000 customers worldwide, laying the foundation for customized, flexible, and intelligent manufacturing. Relying on this foundation, CTIA GROUP further deepens the intelligent manufacturing and integrated innovation of tungsten and molybdenum materials in the Industrial Internet era.

Dr. Hanns and his team at CTIA GROUP, based on their more than 30 years of industry experience, have also written and publicly released knowledge, technology, tungsten price and market trend analysis related to tungsten, molybdenum, and rare earths, freely sharing it with the tungsten industry. Dr. Han, with over 30 years of experience since the 1990s in the e-commerce and international trade of tungsten and molybdenum products, as well as the design and manufacturing of cemented carbides and high-density alloys, is a renowned expert in tungsten and molybdenum products both domestically and internationally. Adhering to the principle of providing professional and high-quality information to the industry, CTIA GROUP's team continuously writes technical research papers, articles, and industry reports based on production practice and market customer needs, winning widespread praise in the industry. These achievements provide solid support for CTIA GROUP's technological innovation, product promotion, and industry exchanges, propelling it to become a leader in global tungsten and molybdenum product manufacturing and information services.

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Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).

Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.

Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.

High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.

Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips

Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection

Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

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Chapter 1 Introduction

1.1 Definition and overview of pure tungsten electrode

Pure tungsten electrode (WP electrode) is a welding electrode material made of high-purity tungsten (tungsten content ≥99.5%) as the main raw material, usually doped with rare earth oxides or other alloying elements, produced by advanced powder metallurgy process, and its surface is coated with green marks to meet the international standard identification specifications. As a rare metal, tungsten has an extremely high melting point (3422°C), high density (19.3 g/cm³), excellent electrical conductivity (about 30% IACS), thermal conductivity (173 W/m·K) and excellent chemical stability, making pure tungsten electrode one of the earliest electrode types used in tungsten argon arc welding (TIG welding). Its high electron work (about 4.52 eV) gives it good thermal electron emission ability at high temperatures, but its application is limited due to the difficulty of arc initiation and insufficient arc stability in DC welding (DC), and it is mainly used for AC welding (AC), especially for the welding of aluminum, magnesium and their alloys.

The preparation process of pure tungsten electrodes is complex and precise, involving multiple steps from tungsten ore purification to finished electrodes. First, high-purity tungsten powder is chemically extracted from tungsten ore (such as wolframite or scheelite), and then electrode bars are made by pressing and forming, sintering, forging, wire drawing and surface polishing. Finished electrodes are available in a variety of sizes, typically ranging from 0.5 to 6.4 mm in diameter and 75 to 600 mm in length, with common sizes including 1.0, 1.6, 2.4, 3.2, and 4.0 mm to meet different welding equipment and process needs. In addition, the surface quality and dimensional tolerance of pure tungsten electrodes are critical to welding performance, so the impurity content and grain structure need to be strictly controlled during the production process to ensure the stability and durability of the electrode in high-temperature arc environments.

1.2 The importance of pure tungsten electrode in the welding industry

Pure tungsten electrode has an irreplaceable position in the welding industry, especially in tungsten argon arc welding (TIG welding), because of its unique physical and chemical properties, it has become the preferred material for AC welding. First of all, the high melting point and excellent high-temperature stability of pure tungsten electrodes enable them to maintain structural integrity in high-current (typically 100-300 A) and high-temperature arc (about 6000-7000°C) environments, significantly reducing electrode consumption and extending service life, thereby improving welding efficiency and quality. Secondly, in AC welding, pure tungsten electrode can form a stable hemispherical electrode, which helps to evenly distribute arc energy, effectively remove the oxide film on the surface of light metals such as aluminum and magnesium and their alloys, and form a smooth and dense weld to meet the needs of high-precision welding.

Compared with tungsten electrodes doped with rare earth oxides (such as cerium tungsten electrode, lanthanum tungsten electrode or thorium tungsten electrode), pure tungsten electrode has significant cost advantages and environmentally friendly characteristics. Since it does not contain radioactive elements (e.g. thorium), pure tungsten electrodes have no radiation risk during use and disposal, and meet the requirements of modern green manufacturing and environmental protection regulations. This feature makes it highly desirable in industries with high safety requirements, such as aerospace and medical device manufacturing. In addition, the production process of pure tungsten electrode is mature, the raw material sources are wide, and the price is relatively stable, making it economical in large-scale industrial production.

The application fields of pure tungsten electrodes cover many high-end manufacturing industries. In the automotive industry, pure tungsten electrodes are used to weld aluminum bodies and parts; In the aerospace field, it is used for precision welding of titanium alloys and aluminum alloys; In the electrical and electronics industry, it is used for welding thin-walled metals and miniature components. Thanks to the transformation and upgrading of the global manufacturing industry and the growing demand for high-quality welding processes, the market demand for pure tungsten electrodes continues to expand. Although some of its limitations in DC welding have led to the replacement of doped electrodes in some applications, pure tungsten electrodes remain indispensable in AC welding, resistance welding, and some plasma cutting and spraying processes.

1.3 Background of pure tungsten electrode research and application

As a strategic rare metal, tungsten has been widely used in industrial and military fields since the end of the 19th century due to its excellent physical and chemical properties. The R&D and application of pure tungsten electrode began in the early 20th century, which is closely related to the birth and development of tungsten argon arc welding technology. In the 1910s, tungsten electrodes were first used in welding experiments, and their high melting point and thermal electron emission capabilities quickly made them the core material for TIG welding. However, due to the high electron escape work in the early pure tungsten electrode, there are problems of arc initiation and arc instability in DC welding, which limits its application range. To overcome these shortcomings, researchers have been exploring tungsten electrodes doped with rare earth oxides (e.g., cerium oxide, lanthanum oxide, thorium oxide) since the mid-20th century to reduce electron work and improve arc initiation performance and arc stability. Although doped electrodes perform well in DC welding, pure tungsten electrodes retain an important market position due to their non-radioactivity, low cost, and suitability for AC welding.

In the late 20th century, with the rapid development of aerospace, automobile manufacturing, nuclear industry and electronic and electrical industries, the demand for high-performance welding materials increased significantly, which promoted the continuous improvement of pure tungsten electrode production process. Modern production technologies include high-purity tungsten powder preparation, isostatic press forming, vacuum sintering, precision forging and automated wire drawing, etc., which significantly improve the purity, grain uniformity and mechanical properties of the electrode. In addition, international standards (e.g., AWS A5.12, ISO 6848) and Chinese national standards (e.g., GB/T 4190) specify the chemical composition, dimensional tolerance, surface quality and performance test methods of pure tungsten electrodes, which promotes their standardized production and application in the global market.

As the country with the world's largest tungsten resource reserves (about 1.9 million tons, accounting for more than 50% of the world's total) and production (about 80% of the world's in 2024), China has a complete industrial chain from tungsten mining, smelting to electrode manufacturing. Through technological innovation and large-scale production, domestic enterprises have significantly improved the international competitiveness of pure tungsten electrodes. At the same time, industry information platforms such as Chinatungsten Online Technology Co., Ltd. publish market trends, technical progress and price information through the website and WeChat official account, providing customized solutions for global customers and becoming an authoritative source of information in the tungsten products industry.

At present, the research directions of pure tungsten electrodes include optimizing grain structure to improve wear resistance and arc stability, developing efficient and environmentally friendly production processes to reduce energy consumption and emissions, and exploring new electrode materials to meet diverse welding needs. In addition, the global emphasis on green manufacturing and sustainable development has promoted the development and application of non-radioactive electrodes, and pure tungsten electrodes have an advantage in this trend due to their environmentally friendly characteristics. In the future, with the further development of new energy, aerospace and high-end equipment manufacturing, the application prospect of pure tungsten electrode will be broader.

pure tungsten electrodes from CTIA GROUP LTD

Chapter 2 Characteristics of Pure Tungsten Electrode

2.1 Physical properties of pure tungsten electrode

Pure tungsten electrode (WP electrode) occupies an important position in the welding industry due to its excellent physical properties. Its high melting point, high density, excellent thermal conductivity, low coefficient of thermal expansion and low vapor pressure make it an indispensable material in tungsten argon arc welding (TIG welding), especially in AC welding (AC). The following is a detailed discussion of the physical properties of pure tungsten electrodes.

2.1.1 Melting and boiling points of pure tungsten electrode

Tungsten is the element with the highest melting point of all metals, with a melting point of 3422 °C (about 3695 K) and a boiling point of 5660 °C (about 5933 K) for pure tungsten electrodes. This feature enables pure tungsten electrodes to maintain structural integrity in high-temperature arc environments (approximately 6000-7000°C), reducing the risk of electrode melting or excessive burnout. In TIG welding, the high melting point ensures that the electrode can maintain a stable end shape at high currents (100-300 A), especially when AC welding light metals such as aluminum and magnesium, the electrode can form a hemispherical end, which contributes to the uniform distribution of the arc. However, the high melting point also means that pure tungsten electrodes require a higher energy input during processing, increasing production costs.

2.1.2 Density of pure tungsten electrode

The density of pure tungsten electrodes is 19.3 g/cm³ at 25°C, which is close to gold (19.32 g/cm³) and 2.5 times that of steel (7.8 g/cm³). The high density gives the electrode excellent mechanical stability and vibration resistance, and can withstand the impact force generated by the arc during the welding process, reducing the risk of end deformation or breakage. In addition, the high density makes pure tungsten electrodes a potential application in counterweights and aerospace applications. However, the high density also increases the weight of the electrodes, which can be challenging for some welding equipment that requires a lightweight design.

2.1.3 Thermal and electrical conductivity of pure tungsten electrode

Pure tungsten electrode has good thermal and electrical conductivity, its thermal conductivity is about 173 W/m·K (room temperature), and its electrical conductivity is about 30% IACS (International Annealed Copper Standard). The excellent thermal conductivity allows the electrode to quickly dissipate the heat generated by the arc, reducing the risk of overheating the electrode and extending the service life. Good electrical conductivity ensures that the electrode can efficiently transmit current during the welding process and maintain a stable arc. However, pure tungsten has a lower electrical conductivity compared to copper (thermal conductivity of about 400 W/m·K and conductivity of 100% IACS), which can cause the electrode to overheat and affect arc stability in high-current DC welding (DC). Therefore, pure tungsten electrodes are more suitable for AC welding scenarios.

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2.1.4 Coefficient of thermal expansion of pure tungsten electrode

Pure tungsten electrodes have a low coefficient of thermal expansion of about 4.5×10^{-6}/K (20-1000°C). The low coefficient of thermal expansion means that the electrode has little dimensional change during high-temperature welding, maintaining shape and dimensional stability and reducing cracks or deformation due to thermal stress. This is especially important in precision welding, such as aerospace components. However, the low coefficient of thermal expansion also makes it possible for pure tungsten electrodes to generate interfacial stresses when the coefficient of thermal expansion is quite different from that of a substrate (e.g., steel or aluminum), which needs to be mitigated by process optimization (e.g., preheating).

2.1.5 Vapor pressure of pure tungsten electrode

The vapor pressure of pure tungsten electrodes at high temperatures is extremely low, only 0 Pa at 3000°C [2]. The low vapor pressure means that the electrode is extremely low in the high temperature arc environment, reducing the vaporization loss of the electrode material and extending the electrode life. This is particularly important in long-term continuous welding, such as automated welding in industrial production. However, at very high temperatures (e.g., near the boiling point), the vapor pressure increases significantly, which can lead to slight losses at the electrode and affect the stability of the arc.

2.2 Chemical properties of pure tungsten electrode

The chemical properties of pure tungsten electrodes are mainly reflected in their chemical stability, oxidation resistance and reactivity with other elements. These characteristics determine the suitability and durability of the electrode in different welding environments.

2.2.1 Chemical stability of pure tungsten electrode

Tungsten is extremely chemically stable at room and at medium-low temperatures, does not react with most acids, bases, or salt solutions, and only dissolves slowly in strongly oxidizing acids such as concentrated nitric or hydrofluoric acids. In TIG welding, pure tungsten electrodes typically work under the protection of an inert gas such as argon or helium, which is chemically stable and allows it to resist corrosion in the welding environment, maintaining a clean surface and arc stability. However, in non-inert gas atmospheres (e.g., atmospheres containing oxygen or aqueous vapor), the chemical stability of tungsten decreases, and process control is required to avoid oxidation of the electrode surface.

2.2.2 Oxidation resistance of pure tungsten electrode

Pure tungsten electrodes have poor oxidation resistance at high temperatures, and begin to react with oxygen at about 400°C or more to form tungsten trioxide (WO_3).), and the oxidation rate is significantly accelerated at higher temperatures (eg, above 800°C) [21]. In TIG welding, inert gas protection can effectively prevent electrode oxidation, but if the protective gas flow is insufficient or interrupted, a yellow or blue oxide layer will quickly form on the electrode surface, resulting in arc instability or even electrode failure. Therefore, it is necessary to ensure stable gas protection during welding operations and to check the surface condition of the electrodes regularly. In addition,

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pure tungsten electrodes are not as oxidation resistant as electrodes doped with rare earth oxides (such as cerium tungsten or lanthanum tungsten electrodes), which limits their application in some harsh environments.

2.2.3 Reactivity of pure tungsten electrode with other elements

Pure tungsten electrodes are less reactive with other elements (e.g., carbon, nitrogen, hydrogen) at high temperatures, but can react under certain conditions. For example, in carbon-containing atmospheres such as CO or CH_4, tungsten may form tungsten carbide (WC), resulting in increased surface hardness but increased brittleness, affecting weldability. In nitrogen-containing atmospheres, tungsten can form tungsten nitride (WN), but the reaction rate is slow and has limited effect on electrode performance. In addition, tungsten has little chemical reaction with metals in the molten pool (e.g. aluminum, magnesium), ensuring the purity of the weld. These properties make pure tungsten electrodes suitable for welding high-purity materials, but avoid direct contact with the active atmosphere.

2.3 Electrical characteristics of pure tungsten electrode

The electrical properties of pure tungsten electrodes directly affect their performance in TIG welding, including arc initiation performance, arc stability and electrode consumption rate. The following is analyzed from three aspects: electron work derivation, arc stability and electrode consumption rate.

2.3.1 Electron work of pure tungsten electrode

The electron work is a measure of the difficulty of emitting hot electrons from the material, and the electron work of pure tungsten electrode is relatively high, about 4.52 eV. High electron work means that the electrode needs a higher voltage to initiate an arc at the initial stage of welding, especially in DC welding, which has poor arc initiation performance and is prone to non-arcing or arc jumping. In alternating current (AC), the alternating effect of positive and negative half-cycles of alternating current can partially alleviate the difficulty of arcing, but a higher arcing voltage is still required. In contrast, electrodes doped with rare earth oxides (such as cerium tungsten electrodes, with electron work of about 2.7-3.0 eV) have better arc initiation performance, which is the main reason for the limited application of pure tungsten electrodes in DC welding.

2.3.2 Arc stability of pure tungsten electrode

Arc stability refers to the ability of the arc to remain continuous and uniform during the welding process. Pure tungsten electrode has good arc stability in AC welding, because its high melting point and thermal conductivity can maintain a stable electrode shape (hemispherical) to ensure uniform arc energy distribution. However, in DC welding, the arc is prone to drift or interruption due to the high electron work and low thermal electron emission efficiency, especially at low currents (<50 A) or high frequencies. In addition, electrode surface contamination (e.g. oxide or oil) can further reduce arc stability, so it is necessary to sharpen the electrode parts regularly to keep them clean.

2.3.3 Electrode consumption rate of pure tungsten electrode

Electrode consumption rate refers to the rate at which the electrode is reduced due to melting, evaporation, or mechanical loss during the welding process. Tungsten electrodes have a high electrode consumption rate, especially at high currents (>200 A) or long-term continuous welding, due to their high electron escape work, which leads to high electrode temperature, which accelerates material volatilization and burnout. In AC welding, the formation of hemispherical ends partially slows down the consumption, but in DC positive connection (DCSP), the electrode consumption rate is significantly higher than that of doped electrodes (e.g., cerium tungsten or lanthanum tungsten electrodes). To reduce the consumption rate, welding parameters (e.g. current, gas flow) need to be optimized and the electrode should be sharpened regularly to maintain the tip angle.

2.4 Mechanical properties of pure tungsten electrodes

The mechanical properties of pure tungsten electrodes include hardness, brittleness, ductility and high-temperature strength, which determine their performance in production, processing and use.

2.4.1 Hardness and brittleness of pure tungsten electrode

Pure tungsten electrodes have extremely high hardness, Vickers hardness (HV) at room temperature is about 350-450, close to tungsten carbide (HV about 500). Its high hardness gives it excellent wear resistance and is able to withstand arc impact and mechanical wear. However, the crystal structure of tungsten (body-centered cube) makes it highly brittle, especially at room temperature, and is prone to brittle fracture. During the production process, brittleness is reduced by high-temperature forging and annealing, but the finished electrode still needs to be handled with care to avoid fracture due to drops or impacts. In welding, the high hardness of the electrode helps to maintain the end morphology, but brittleness can cause microcracks at the ends, affecting arc stability.

2.4.2 Ductility of pure tungsten electrode

The ductility of pure tungsten electrodes is poor, there is almost no plastic deformation ability at room temperature, and the elongation at break is close to 0%. At high temperatures (>1200°C), tungsten has a slight improvement in ductility and can be formed by forging or wire drawing. However, ductility at high temperatures is still limited, and the temperature and deformation rate need to be tightly controlled during processing to avoid cracking. In welding applications, poor ductility makes it difficult for electrodes to adapt to the welding needs of complex shapes, but their high hardness and stability make up for this shortcoming.

2.4.3 High temperature strength and creep resistance of pure tungsten electrode

Pure tungsten electrodes have excellent high-temperature strength and creep resistance at high temperatures. At more than 2000°C, its tensile strength can still reach 100-200 MPa, and its creep resistance far exceeds that of most metals. This property allows the electrode to maintain mechanical stability in a high-temperature arc environment, reducing deformation or fracture due to thermal stress. Creep resistance ensures the stability of the terminal morphology and prolongs the service life during long-term continuous welding. However, grain growth at high temperatures may reduce strength, and grain refinement is required through production process optimization, such as controlling the sintering temperature.

2.5 Comparison of pure tungsten electrode with other tungsten electrode

There are significant differences in the performance of pure tungsten electrodes and other doped tungsten electrodes (such as cerium tungsten, lanthanum tungsten, thorium tungsten, yttrium tungsten and zirconium tungsten electrodes). The following is a comparison from the aspects of welding performance, application scenarios, advantages and disadvantages.

2.5.1 Pure tungsten electrode and cerium tungsten electrode

Cerium tungsten electrode (WC electrode) is doped with 2%-4% cerium oxide (CeO_2) in a tungsten matrix), the color scale is gray. The electron work of cerium-tungsten electrode is lower (about 2.7-3.0 eV), and the arc initiation performance is better than that of pure tungsten electrode, especially in low-current DC welding (<100 A). In addition, cerium tungsten electrodes have high arc stability and low electrode consumption rate, which is suitable for DC welding of stainless steel, carbon steel and other materials. In contrast, pure tungsten electrodes are difficult to arc and unstable in DC welding, but their cost is low and suitable for AC welding of aluminum and magnesium alloys. Cerium tungsten electrode is non-radioactive and meets environmental protection requirements, but in high-current AC welding, the end is easy to form irregular shape, and the arc stability is not as good as that of pure tungsten electrode.

2.5.2 Pure tungsten electrode and lanthanum tungsten electrode

Lanthanum tungsten electrodes (WL electrodes) are doped with 1%-2% lanthanum oxide (La_2O_3) and are colored blue or gold. The electron work of lanthanum tungsten electrode is about 2.8-3.2 eV, and the arc initiation performance and arc stability are better than those of pure tungsten electrode, which is suitable for DC and AC welding. Its low electrode consumption rate and stable end morphology at high temperatures make it suitable for high-precision welding (e.g. aerospace components). The pure tungsten electrode forms a stable hemispherical shape at the end in AC welding, which is suitable for aluminum alloy welding, but its performance is poor in DC welding. In addition, the production cost of lanthanum tungsten electrodes is higher than that of pure tungsten electrodes, which limits its promotion in low-cost applications.

2.5.3 Pure tungsten electrode and thoriated tungsten electrode

Thorium tungsten electrodes (WT electrodes) are doped with 1%-2% thorium oxide (ThO_2) and are colored red or yellow. Thorium tungsten electrodes have the lowest electron work (about 2.6 eV) and excellent arc initiation performance and arc stability, and are widely used in DC welding of carbon steel, stainless steel and nickel alloys. Its low electrode consumption rate allows for a high permissible current density (>200 A). However, thorium oxide is radioactive (radiation dose of about 3.60×10^5Curie/kg) and is potentially harmful to humans and the environment [17]. Pure tungsten electrodes are non-radioactive, low cost, and suitable for AC welding, but their performance in DC welding is far inferior to that of thoriated tungsten electrodes. At present, thorium-tungsten electrodes are gradually replaced by cerium-tungsten or lanthanum tungsten electrodes in areas with strict environmental protection requirements.

2.5.4 Pure tungsten electrode and yttrium tungsten electrode

Yttrium tungsten electrode (WY electrode) doped with 2% yttrium oxide (Y_2O_3) with dark blue color code, is mainly used for DC welding in military and aerospace fields. The electron work of yttrium-tungsten electrodes is about 2.9 eV, with excellent arc initiation performance and arc stability, low electrode consumption, and suitable for high-current welding (e.g. titanium alloys). Pure tungsten electrodes are rarely used in these fields because of their difficult arc initiation and arc instability. Yttrium-tungsten electrodes have high production costs and a narrow range of market applications, while pure tungsten electrodes are still widely used because of their economy and suitability for AC welding.

2.5.5 Pure tungsten electrode and zirconium tungsten electrode

Zirconium-tungsten electrode (WZ electrode) doped with 0.3%-0.8% zirconia (ZrO_2), the color code is brown or white, and it is designed for AC welding. The electron work of zirconium tungsten electrode is about 4.0 eV, which is slightly lower than that of pure tungsten electrode, and the arc initiation performance is slightly better, and the arc stability is high, which is suitable for AC welding of aluminum and magnesium alloys. Its electrode consumption rate is lower than that of pure tungsten electrode, and the end shape is more stable. Pure tungsten electrodes are close to zirconium tungsten electrodes in AC welding, but at a lower cost and suitable for cost-sensitive applications. The production process of zirconium tungsten electrodes is complex and the price is high, which limits its market share.

2.6 Pure Tungsten Electrode MSDS from CTIA GROUP LTD

The Material Safety Data Sheet (MSDS) is an important document that describes the safe use, storage and disposal of pure tungsten electrodes. The following is a summary of the main contents of pure tungsten electrode MSDS:

Part I: Product Name

Name: Pure Tungsten Electrode (WP)
CAS No.:7440-33-7

Part II: Composition/Composition Information

Main content W≥99.95%
Total impurity content ≤0.05%

Part III: Overview of Hazards

Health hazards: This product is non-irritating to the eyes and skin.
Explosion hazard: This product is non-flammable and non-irritating.

Part IV: First Aid Measures

Skin-to-skin contact: Remove contaminated clothing and rinse with plenty of running water.
Eye contact: Lift the eyelid and rinse with running water or saline. Medical treatment.
Inhalation: Remove from the scene to fresh air. If you have difficulty breathing, give oxygen. Medical treatment.
Intake: Drink plenty of warm water to induce vomiting. Medical treatment.

Part V: Fire Protection Measures

Harmful Combustion Products: Natural decomposition products are unknown.
Fire extinguishing method: Firefighters must wear gas masks and full-body firefighting suits to extinguish the fire in the upwind direction. Fire extinguishing agent: dry leather powder, sand.

Part VI: Emergency Handling of Spills

Emergency treatment: Isolate the leakage contaminated area and restrict access. Cut off the source of fire. Emergency responders are advised to wear dust masks (full face masks) and protective clothing. Avoid dust, sweep it up carefully, put it in a bag and transfer it to a safe place. If there is a large amount of leakage, cover it with plastic cloth or canvas. Collect and recycle or transport to a waste disposal site for disposal.

Part VII: Handling, Handling and Storage

Precautions for operation: Operators must be specially trained and strictly follow the operating procedures. It is recommended that operators wear self-priming filtering dust masks, chemical safety glasses, anti-poison penetration overalls, and rubber gloves. Keep away from fire and heat sources, and smoking is strictly prohibited in the workplace. Use explosion-proof ventilation systems and equipment. Avoid dust generation. Avoid contact with oxidants and halogens. When handling, it is necessary to load and unload lightly to prevent damage to the packaging and containers. Equipped with corresponding varieties and quantities of fire-fighting equipment and leakage emergency treatment equipment. Empty containers may leave harmful substances behind.

Storage precautions: Store in a cool, ventilated warehouse. Keep away from fire and heat sources. It should be stored separately from oxidants and halogens, and should not be mixed. Equipped with the corresponding variety and quantity of fire-fighting equipment. The storage area should be equipped with suitable materials to contain the spill.

Part VIII: Exposure Control/Personal Protection

China MAC (mg/m3): 6
USSR MAC (mg/m3): 6

TLVTN:ACGIH 1mg/m3
TLVWN:ACGIH 3mg/m3
Monitoring method: potassium thiocyanide-titanium chloride spectroluminescence method
Engineering control: the production process is dust-free and fully ventilated.
Respiratory protection: When the dust concentration in the air exceeds the standard, a self-priming filtering dust mask must be worn. In the event of an emergency evacuation, air breathing apparatus should be worn.
Eye protection: Wear chemical safety glasses.
Body protection: Wear anti-poison penetration overalls.
Hand protection: Wear rubber gloves.

Part IX: Physicochemical properties

Main ingredient: Pure
Appearance and properties: solid, bright white metal
Melting Point (°C): N/A
Boiling point (°C): N/A
Relative density (water = 1): 13~18.5 (20 °C)
Vapor density (air = 1): No data
Saturation vapor pressure (kPa): no data available
Heat of combustion (kj/mol): no data
Critical temperature (°C): No data available
Critical pressure (MPa): No data available
Logarithm of water partition coefficient: no data
Flash point (°C): No data available
Ignition temperature (°C): No data
Explosion Limit % (V/V): No data
Lower explosion limit % (V/V): No data
Solubility: soluble in nitric acid, hydrofluoric acid
Main uses: used to make shielding parts, tungsten alloy dart shafts, tungsten alloy balls, etc

Part X: Stability and Reactivity
Prohibited substances: strong acid and alkali.
Part 11:

Acute toxicity: no data available
LC50: No data

Part XII: Ecological data

There is no data for this section

Part XIII: Disposal

Waste disposal method: Refer to relevant national and local laws and regulations before disposal. Recycle if possible.

Part XIV: Shipping Information

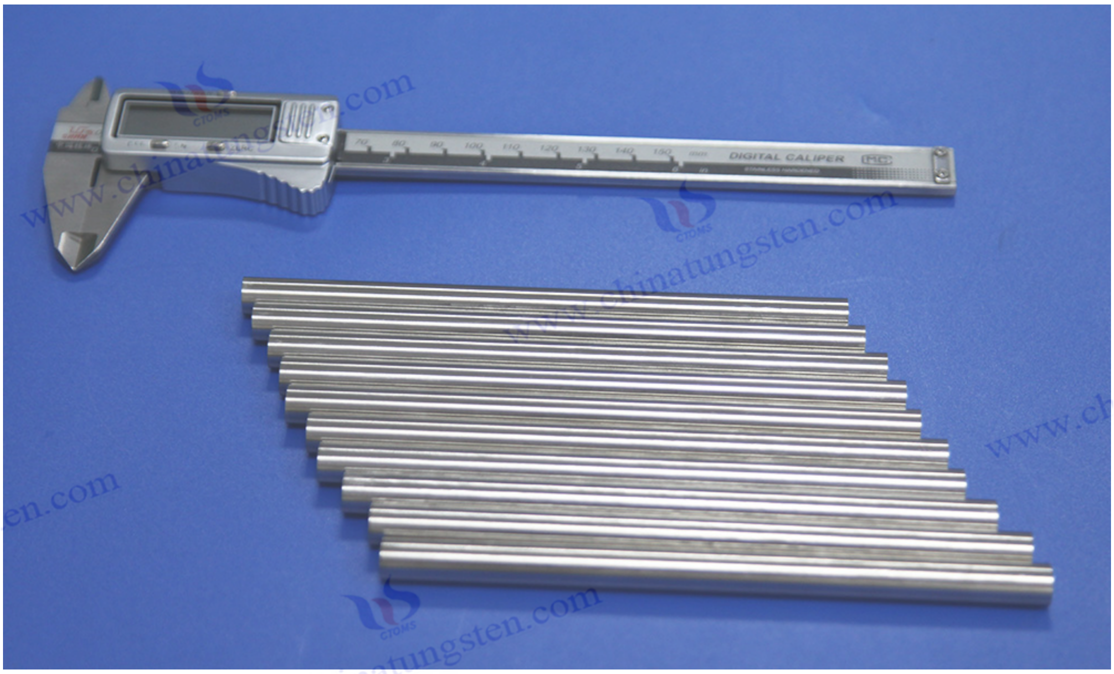
Dangerous goods number: no information
Packaging category: Z01
Precautions for transportation: The packaging should be complete when shipping, and the loading should be secure. During transportation, it is necessary to ensure that the container does not leak, collapse, fall, or damage. It is strictly forbidden to mix with oxidants, halogens, edible chemicals, etc. During transportation, it should be protected from exposure to sun, rain and high temperature. Vehicles should be thoroughly cleaned after transportation.

Part XV: Regulatory Information

Regulatory information: Regulations on the Safety Management of Dangerous Chemicals (promulgated by the State Council on February 17, 1987), Detailed Rules for the Implementation of the Regulations on the Safety Management of Dangerous Chemicals (Hua Lao Fa [1992] No. 677), Regulations on the Safe Use of Chemicals in the Workplace ([1996] Lao Bu Fa No. 423) and other laws and regulations, which have made corresponding provisions on the safe use, production, storage, transportation, loading and unloading of dangerous chemicals; The hygienic standard for tungsten in workshop air (GB 16229-1996) stipulates the maximum allowable concentration and detection method of this substance in workshop air.

Part XVI: Supplier Information

Supplier: CTIA GROUP LTD
Tel: 0592-5129696/5129595



pure tungsten electrodes from CTIA GROUP LTD

Chapter 3 Preparation and Production Technology of Pure Tungsten Electrode

The preparation of pure tungsten electrode (WP electrode) is a high-precision process involving multidisciplinary interdisciplinarity, covering mineral metallurgy, powder metallurgy, pressure processing and surface treatment from the extraction of raw materials to the molding of finished electrodes. Strict control of process parameters is required at every step to ensure high purity, uniformity and excellent welding performance of the electrode. This chapter will discuss in detail the preparation and production technology of pure tungsten electrodes, covering raw material preparation, powder metallurgy, pressure processing, surface treatment, quality control, as well as technical difficulties and innovation directions.

3.1 Preparation of raw materials for pure tungsten electrode

The preparation of pure tungsten electrodes begins with the selection and handling of raw materials. As a rare metal, tungsten mainly exists in nature in the form of tungsten ore, and its preparation process requires the extraction of high-purity tungsten compounds from the ore and further processing into high-purity tungsten powder. The process at this stage directly determines the purity and performance of the electrode.

3.1.1 Extraction and purification of tungsten ore

The extraction and purification of tungsten ore is the first step in the production of pure tungsten electrodes, which mainly involves taking tungsten ore from nature and converting it into high-purity tungsten compounds. The world's tungsten ore resources are mainly distributed in China, Russia, Canada and Australia, of which China accounts for more than half of the world's reserves. Common tungsten ores include wolframite (mainly $FeWO_4$ and $MnWO_4$) and scheelite (mainly $CaWO_4$).

Because of its high tungsten content and easy beneficiation characteristics, wolframite is the main raw material for the preparation of pure tungsten electrodes.

Tungsten ore is usually extracted by open-pit or underground mining methods, and the mined ore is crushed and ground to produce a small particle size fine for subsequent beneficiation. Beneficiation processes include gravity beneficiation, flotation and magnetic separation, through which tungsten minerals are separated from other impurities (e.g., silicates, sulfides) to obtain high-grade tungsten concentrates. The tungsten content of tungsten concentrate usually needs to meet certain standards to meet the purification requirements.

The purification process is mainly done by hydrometallurgy. First, tungsten concentrate is reacted with sodium hydroxide or sodium carbonate solution to produce sodium tungstate (Na_2WO_4) solution. This process needs to be carried out at high temperature and pressure to improve the efficiency of the reaction. Subsequently, insoluble impurities such as silicon, iron, etc. are removed from the solution by filtration. Next, sodium tungstate is converted to tungstic acid (H_2WO_4) precipitate by adding an acid, such as hydrochloric acid. After washing and drying, tungstic acid precipitate is further calcined to produce tungsten trioxide (WO_3), which is an intermediate product for the preparation of high-purity tungsten powder. The whole purification process needs to strictly control the pH value, temperature and reaction time of the solution to minimize the residue of impurities, ensure the purity of tungsten trioxide, and lay the foundation for the subsequent process.

3.1.2 Preparation of high-purity tungsten powder

High-purity tungsten powder is the core raw material for the preparation of pure tungsten electrode, and its purity, particle size and morphology directly affect the performance of the electrode. The preparation of tungsten powder is usually made from tungsten trioxide as the starting material, which is produced by hydrogen reduction method. The specific process consists of the following steps:

Firstly, tungsten trioxide is placed in a reduction furnace, and high-purity hydrogen is introduced at high temperature to gradually reduce tungsten trioxide to tungsten metal powder. The reduction process is divided into two stages: the first stage reduces tungsten trioxide to tungsten dioxide (WO_2) at a lower temperature, and the second stage further reduces tungsten metal to metallic at a higher temperature. This process requires precise control of temperature gradients, hydrogen flow rates, and reduction times to avoid excessive or agglomerated tungsten powder particles. The reduced tungsten powder is sieved and cleaned to remove residual oxides and impurities.

In order to meet the high purity requirements of pure tungsten electrodes, the purity of tungsten powder usually needs to reach more than 99.95%, and the content of impurities (such as iron, nickel, silicon, oxygen) needs to be strictly controlled at trace levels. In addition, the particle size distribution and morphology of tungsten powder are also crucial. Too large a particle size may result in a lack of density of the sintered body, while a too small particle size may increase the difficulty of compression. Therefore, the average particle size of tungsten powder is usually controlled in the range of 1-5 microns, and the particle morphology is preferably nearly spherical to improve the fluidity and compression performance.

In recent years, some enterprises have adopted advanced technologies such as plasma reduction or chemical vapor deposition to prepare ultrafine tungsten powder, which further improves the purity and uniformity of the powder. Although these technologies are costly, they offer significant advantages in the production of high-performance electrodes.

3.2 Powder metallurgy process of pure tungsten electrode

Powder metallurgy is the core process of pure tungsten electrode preparation, which converts tungsten powder into high-density and high-strength tungsten body through pressing, sintering and heat treatment. This process is carried out at high temperatures, pressures, and vacuums to ensure the density and mechanical properties of the electrodes.

3.2.1 Tungsten powder pressing molding

Tungsten powder pressing molding is the process of processing high-purity tungsten powder into a green body with a certain shape and strength. The goal of this stage is to form a green body with uniform density and sufficient strength to provide the basis for subsequent sintering. The pressing process mainly includes two methods: cold isostatic pressing and molding.

Cold isostatic pressing is currently the most commonly used pressing method, by loading tungsten powder into a flexible mold (such as a rubber mold) and placing it in a high-pressure liquid medium to apply a uniform pressure (usually 100-300 MPa) to make the powder particles tightly bind. The advantages of cold isostatic pressing are uniform pressure distribution and consistent density of green bodies, which is suitable for the production of large or complex shapes. Molding is suitable for small batch production, and the tungsten powder is formed by unidirectional pressure through the steel mold, but it is easy to produce density gradients, which requires subsequent process optimization.

A small amount of binder (e.g. polyvinyl alcohol or paraffin) is added during the pressing process to increase the forming strength of the green body, but the binder needs to be completely removed before subsequent sintering to avoid residual impurities. In order to ensure the uniformity of the green body, it is necessary to control the filling density and pressing speed of tungsten powder to avoid cracks or delamination.

3.2.2 Sintering process

Sintering is the process of heating the pressed body to a temperature below the melting point of tungsten so that the powder particles combine to form a dense material. The high melting point of tungsten makes it sinter at a high temperature, usually between 2000-2800°C. To avoid oxidation, sintering takes place in a vacuum or hydrogen shielding atmosphere, and common equipment includes vacuum sintering furnaces or hydrogen sintering furnaces.

The sintering process is divided into three stages: early, middle, and late. In the initial stage, at low temperatures (about 1000-1500°C) the binder in the green body evaporates, and neck connections begin to form on the surface of the particles. In the middle stage (1500-2200 °C), the inter-particle binding is enhanced, the green body shrinks, and the density gradually increases. In the later stage (2200-2800°C), the grain grows and the green body reaches the maximum density, which is usually 95%-98% of the theoretical density. The sintering time and temperature need to be precisely controlled, too high temperature or too long holding time may lead to excessive grain growth and reduce the mechanical properties of the green body.

In order to improve the sintering efficiency, some companies use active sintering technology, which reduces the sintering temperature by adding trace metals such as nickel or cobalt, but it is necessary to ensure that the additives do not affect the purity of the electrode. In addition, emerging technologies such as IF induction sintering and discharge plasma sintering (SPS) are gradually being applied to the production of high-performance tungsten electrodes, which can significantly shorten the sintering time and improve the density of the green body.

3.2.3 Heat treatment and annealing

The sintered tungsten body usually has internal stress and microscopic defects, which need to be relieved by heat treatment and annealing to improve the microstructure. The heat treatment is usually carried out in a vacuum or hydrogen atmosphere, the temperature is controlled at 1200-1800°C, and the holding time is adjusted according to the size and performance requirements of the green body. Heat treatment refines the grains and enhances the toughness and processability of the green body.

Annealing is an extension step of heat treatment designed to further reduce the hardness and brittleness of the green body and improve ductility. The annealing temperature is usually lower than the heat treatment temperature (about 800-1200°C) and is cooled slowly to avoid new stresses. The annealed body is more suitable for subsequent pressure machining, such as forging and wire drawing.

3.3 Pressure processing of pure tungsten electrode

Pressure machining is the process of machining a sintered body into an electrode bar with precise dimensions and shapes, including forging, rolling, drawing, and drawing steps. The high hardness and brittleness of tungsten make it difficult to process and need to be carried out at high temperatures to improve ductility.

3.3.1 Forging and rolling

Forging is the process of deforming the sintered blank at a high temperature (about 1500-1800 °C) by hammering or pressing to make a rod or plate blank. Forging refines the grains and increases the density and strength of the body, but the rate of deformation needs to be controlled to avoid cracking. Forging is usually carried out in a hydrogen protective atmosphere to prevent oxidation.

Rolling is a further processing step after forging in which the forged blank is rolled into finer bars or wires through a multi-pass rolling mill. The rolling temperature is gradually reduced (from 1500°C to 1000°C) in order to improve the surface quality and dimensional accuracy of the material. Periodic annealing is required during the rolling process to eliminate work hardening and internal stresses and ensure the machinability of the blank.

3.3.2 Drawing and drawing

Wire drawing is the process of stretching rolled bars through a die to make a smaller diameter tungsten wire or electrode blank. Wire drawing is carried out at high temperatures (about 800-1200°C) using carbide or diamond dies to withstand the high hardness of tungsten. Lubricants such as graphite or molybdenum disulfide are applied during the drawing process to reduce friction and die wear. The deformation of each drawing pass is usually controlled at 10%-20%, and several annealing sessions are required to restore ductility.

Drawing is an extension of wire drawing for the production of electrode blanks with a smaller diameter (0.5-6.4 mm). The accuracy of the drawing die directly affects the surface quality and dimensional tolerance of the electrode, so it is necessary to check and replace the mold regularly. Continuous production of wire drawing and drawing can significantly increase efficiency, but the temperature and drawing speed need to be tightly controlled to avoid wire breakage.

3.3.3 Electrode bar forming

Electrode bar forming is to cut, straighten and length the drawn tungsten wire to make an electrode rod that meets the specifications. Cutting is usually done mechanically or laser-cut to ensure that the cut is flat and burr-free. Straightening is done by a roller straightener to eliminate bending and internal stress of the bar. The cut-to-length is adjusted according to customer needs, and the common length is 75-600 mm. The formed rods are surface inspected to ensure that there are no cracks, scratches or oxidation marks.

3.4 Surface treatment of pure tungsten electrode

Surface treatment is the final stage of pure tungsten electrode preparation and aims to improve the surface quality, weldability and recognition of the electrode, including cleaning, polishing and green head marking.

3.4.1 Cleaning and polishing

Cleaning is the process of removing oil, oxides and impurities from the surface of the molded bar, usually using a combination of chemical cleaning and ultrasonic cleaning. Chemical cleaning uses an alkaline solution (e.g., sodium hydroxide) or an acidic solution (e.g., dilute nitric acid) to remove the oxide layer, which is then rinsed with pure water and dried. Ultrasonic cleaning uses high-frequency vibrations to remove tiny particles and ensure a clean surface.

Polishing is a critical step in improving the surface finish of an electrode, usually with mechanical or electrochemical polishing. Mechanical polishing uses a grinding wheel or polishing cloth to remove microscopic scratches on the surface, and electrochemical polishing makes the surface smoother through electrolysis. The surface roughness of the polished electrode reaches Ra1.6-3.2μm, which helps to improve the arc stability and welding quality.

3.4.2 Green smear markings

The green coating mark is the international standard identification method for pure tungsten electrodes, which is compliant with AWS A5.12 and ISO 6848 standards. The marking process is usually coated with a green non-toxic paint (such as water-based environmental protection paint) at one end of the electrode, which is uniform in thickness, wear-resistant and does not affect welding performance. Coating head marking is performed on a clean surface to ensure adhesion and durability. Some companies use automated spraying equipment to improve marking efficiency and consistency.

3.5 Quality control of pure tungsten electrodes

Quality control runs through every step of pure tungsten electrode production, from raw materials to finished products, and needs to be tested at multiple levels to ensure the performance and reliability of the electrode.

3.5.1 Raw material quality inspection

The quality inspection of raw materials is mainly for tungsten concentrate, tungsten trioxide and tungsten powder. Tungsten concentrate needs to be tested for tungsten content and impurities (e.g. sulfur, phosphorus, silicon). Tungsten trioxide is tested for purity and impurity by X-ray fluorescence analysis (XRF) or inductively coupled plasma spectroscopy (ICP-OES). Tungsten powder needs to be tested for particle size distribution, morphology and oxygen content to ensure that it meets production requirements.

3.5.2 Production process monitoring

Production process monitoring includes real-time detection of pressing, sintering, forging, wire drawing and surface treatment. The density and size of the pressed green body need to be checked by an ultrasonic detector, and the density and grain size of the sintered green body need to be analyzed by a metallographic microscope. During forging and drawing, temperature, deformation, and surface quality need to be monitored to avoid cracks or defects. After surface treatment, the surface roughness and coating quality are checked.

3.5.3 Finished product inspection

The finished product inspection includes a comprehensive inspection of chemical composition, physical properties, dimensional tolerances and weldability. The chemical composition is analyzed by ICP-OES or XRF to ensure a ≥ 99.5% tungsten content. Physical properties include density, hardness, and conductivity tests. Dimensional tolerances must conform to standards (e.g. ISO 6848) and diameter deviations must be controlled to ±0.05 mm. Welding performance: Arc initiation performance, arc stability, and electrode consumption rate are evaluated by simulating TIG welding tests.

CTIA GROUP LTD
Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).
Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.
Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.
High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.
Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips
Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection
Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696
Website: www.tungsten.com.cn

3.6 Technical difficulties and innovations of pure tungsten electrode

The preparation of pure tungsten electrode involves a number of technical difficulties, and significant progress has been made through technological innovation in recent years. The following is discussed from four aspects: high purity control, grain structure optimization, production efficiency improvement, and environmental protection and sustainable development.

3.6.1 High purity control

High purity is the core requirement of pure tungsten electrode, and the content of impurities (such as oxygen, iron, carbon) needs to be controlled at the ppm level. Technical difficulties include the purification of raw materials and the introduction of impurities in the production process. Innovations include the use of ion exchange and solvent extraction technologies to improve tungsten trioxide purity, the use of high-purity hydrogen and vacuum environments to reduce oxygen contamination during reduction and sintering, and the development of in-line impurity detection technologies such as laser-induced breakdown spectroscopy for real-time monitoring.

3.6.2 Optimization of grain structure

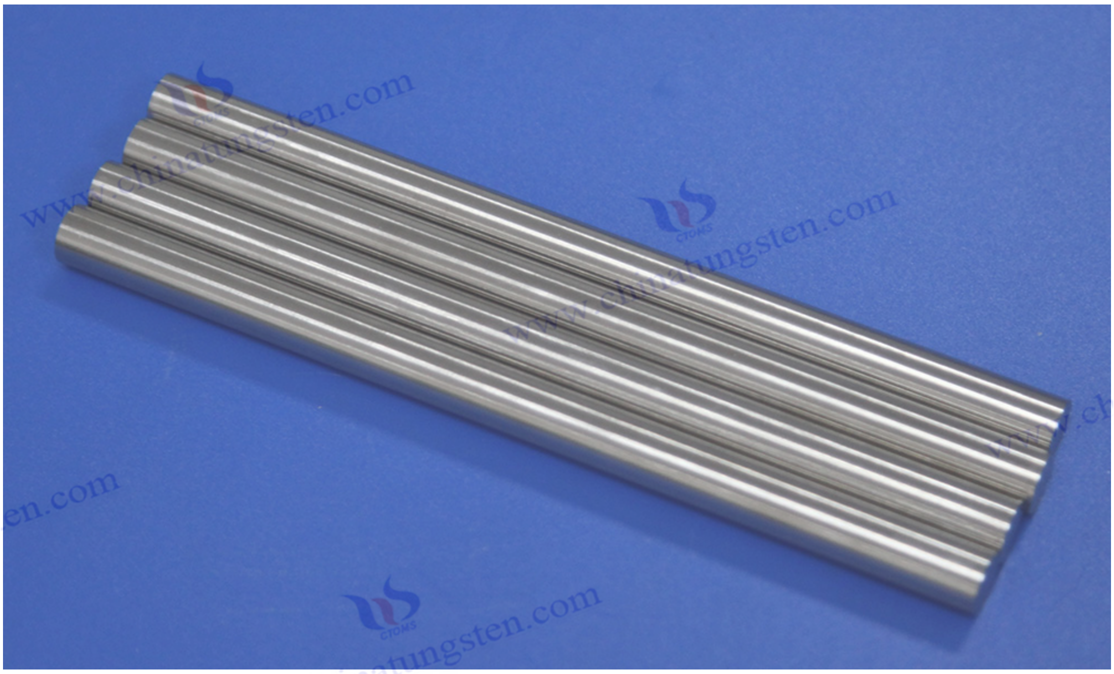
The grain structure directly affects the mechanical properties and welding performance of the electrode, with too large grains leading to increased brittleness, and too small grains reducing the strength at high temperatures. The technical challenge lies in controlling the grain growth during sintering and processing. Innovations include the use of nano-tungsten powder as raw material, grain refinement through rapid sintering technology (e.g., SPS), and the addition of trace inhibitors (e.g., alumina) to control grain growth.

3.6.3 Improvement of production efficiency

The production cycle of pure tungsten electrodes is long and the energy consumption is high, which limits the large-scale production. Technical difficulties include long sintering times, difficult processing and high equipment maintenance costs. Innovations include the development of continuous sintering furnaces to improve production efficiency, the use of automated wire drawing and surface treatment equipment to reduce labor costs, and the application of smart manufacturing technologies such as the Industrial Internet of Things (IIoT) to optimize production processes.

3.6.4 Environmental protection and sustainable development

The production of tungsten electrodes involves high energy consumption and waste water emissions, and is under environmental pressure. Technical challenges include reducing energy consumption and processing tungsten-containing waste. Innovations include the use of renewable energy to drive production equipment, the development of wastewater recycling technology, and the establishment of a tungsten waste recycling system to achieve resource recycling. Some companies have begun to explore green manufacturing models, such as the use of non-toxic solvents and low-emission equipment.



pure tungsten electrodes from CTIA GROUP LTD

Chapter 4 Uses of Pure Tungsten Electrodes

Pure tungsten electrodes (WP electrodes) have played an important role in a variety of industrial fields due to their high melting point, excellent electrical and thermal conductivity and chemical stability. Especially in the welding industry, pure tungsten electrode is the core material of tungsten argon arc welding (TIG welding), which is widely used in AC welding (AC) scenarios. In addition, it offers unique advantages in other industrial applications, special areas and certain non-welding applications. However, the application of pure tungsten electrodes also has certain limitations. This chapter will provide a comprehensive overview of the uses of pure tungsten electrodes, covering welding applications, other industrial applications, special field applications, and their limitations.

4.1 Welding Applications

Welding is the most important application field of pure tungsten electrode, especially in tungsten argon arc welding (TIG welding), pure tungsten electrode has become an indispensable material due to its high melting point and stable arc characteristics. The following elaborates its application from three aspects: TIG welding, AC welding, and welding of magnesium, aluminum and their alloys.

4.1.1 Tungsten Inert Gas Welding (TIG)

Tungsten Inert Gas Welding (TIG) is a welding process that uses tungsten electrodes to produce an arc under the protection of an inert gas such as argon or helium, and is known for its high precision, high-quality welds and wide material applicability. As an early electrode type for TIG welding, pure tungsten electrode can maintain structural integrity in the arc high temperature environment (about 6000-7000°C) due to its high melting point (3422°C) and excellent high temperature stability, reducing the risk of electrode melting or burning. This property makes it valuable in industrial scenarios where high-quality welds are required.

In TIG welding, the pure tungsten electrode acts as a non-melting electrode and is primarily responsible for initiating and maintaining the arc, while the filler metal (if required) is provided by the welding wire. The shape of the electrode end has a significant impact on the arc shape and welding quality. In operation, pure tungsten electrodes often need to be ground into a tapered or hemispherical shape to optimize the concentration and stability of the arc. The protective effect of the inert gas prevents oxidation of the electrodes and the molten pool, ensuring the purity and mechanical properties of the weld.

Pure tungsten electrodes are widely used in TIG welding, covering a variety of metal materials from thin plates to thick plates, especially in scenarios where the appearance and performance of the weld are high. For example, in the welding of stainless steel, aluminum alloys and magnesium alloys, pure tungsten electrodes provide a stable arc and a clean weld seam to meet the needs of precision manufacturing. In addition, the flexibility of TIG welding makes it suitable for both manual and automated welding, and pure tungsten electrodes show reliable performance in both modes.

Although pure tungsten electrodes are widely used in TIG welding, their high electron evolution work (about 4.52 eV) leads to poor arc initiation performance, especially in DC welding (DC). Therefore, its main application is concentrated in AC welding scenarios, while DC welding mostly uses electrodes doped with rare earth oxides (such as cerium tungsten or lanthanum tungsten electrodes). Even so, pure tungsten electrodes are an indispensable choice for TIG welding due to their low cost, non-radioactivity, and suitability to specific materials.

4.1.2 Applications in AC welding (AC).

AC welding (AC) is one of the main application scenarios of pure tungsten electrodes, because it can form a stable arc under the alternating action of positive and negative half-cycles of alternating current, and is especially suitable for welding light metals with oxide films. AC welding uses alternating currents to alternating between the electrode and the workpiece as the cathode and anode, thus achieving the dynamic equilibrium of the arc. The unique advantage of pure tungsten electrode in AC welding is that it can form a stable hemispherical electrode, and this end shape helps to evenly distribute the arc energy and improve the welding quality.

In AC welding, the hemispherical end of the pure tungsten electrode produces strong electron emission during the positive half-cycle (electrode is cathode), forming a high-temperature arc; In the negative half cycle (the workpiece is the cathode), the arc produces a "cathodic cleaning" effect on the oxide film on the surface of the workpiece, which effectively removes the oxide layer and ensures the cleanliness of the weld. This property makes pure tungsten electrodes excellent when welding aluminum, magnesium and their alloys. In addition, the current waveform of AC welding (such as square wave or sine wave) can be adjusted by welding equipment to optimize arc characteristics and penetration, and pure tungsten electrodes can adapt to a variety of waveform settings, showing strong process adaptability.

The application scenarios of pure tungsten electrodes in AC welding include construction, shipbuilding, automotive industry and aerospace. For example, in the construction industry, aluminum curtain walls and structural parts are often welded using AC TIG, and pure tungsten electrodes can provide high-quality welds that meet the appearance and strength requirements. In shipbuilding, the welding of aluminum hulls requires a stable arc and clean welds, and pure tungsten electrodes are ideal. In addition, its non-radioactive properties give it an advantage in environments where safety is critical, such as in the manufacture of food processing equipment.

Although pure tungsten electrodes perform well in AC welding, their arc stability may be slightly inferior to doped electrodes at high frequencies or low currents. To improve performance, the operator needs to regularly sharpen the electrode part to keep it clean and properly angled. In addition, the optimization of welding parameters (e.g. current, gas flow) is essential to ensure arc stability and weld quality.

4.1.3 Welding of magnesium, aluminum and their alloys

Magnesium, aluminum, and their alloys are widely used in the aerospace, automotive manufacturing, and electronics industries due to their light weight, high strength, and good corrosion resistance. However, these materials are prone to the formation of dense oxide films (e.g., Al_2O_3, melting point of about 2050°C) on the surface, which poses a challenge to the welding process. The "cathodic cleaning" effect of pure tungsten electrodes in AC TIG welding makes it the material of choice for welding magnesium, aluminum and their alloys.

In aluminum alloy welding, the pure tungsten electrode removes the oxide film through the negative half cycle of alternating current, while providing enough heat to melt the substrate during the positive half cycle to form a uniform molten pool. The welding of aluminum alloys (such as 6061 and 7075) requires a stable arc and moderate penetration, and the hemispherical end of the pure tungsten electrode can meet these requirements. In addition, the high thermal conductivity of aluminum (approx. 237 W/m·K) requires controlled heat input during welding, and the excellent thermal conductivity of pure tungsten electrodes helps to dissipate arc heat and reduce the risk of overheating.

Magnesium alloys (e.g., AZ31, AZ91) are widely used in lightweight designs due to their low density (about 1.74 g/cm^3), but their low melting point (about 650°C) and high chemical activity increase the difficulty of welding. Pure tungsten electrodes provide a stable arc in magnesium alloy welding, and together with appropriate inert gas protection (such as argon or argon-helium mixture), it can effectively prevent oxidation of the melt pool and ensure the quality of the weld. In the aerospace sector, pure tungsten electrodes are often used for the welding of magnesium alloy components (e.g. seat frames, fuselage panels) because they can meet the requirements of high precision and quality.

In order to optimize the welding effect of magnesium, aluminum and their alloys, the following points should be noted: firstly, the electrode diameter should be selected according to the thickness and current of the workpiece, and the commonly used diameter is 1.6-3.2 mm; Secondly, the shielding gas flow rate needs to be moderate (about 8-15 L/min) to ensure melt pool protection; Finally, the electrode part needs to be regularly polished into a hemispherical shape to maintain arc stability. The wide application of pure tungsten electrode in the welding of these materials fully reflects its unique advantages in the field of AC welding.

4.2 Other industrial applications

In addition to welding, tungsten electrodes are also widely used in other industrial fields, including resistance welding, plasma cutting and spraying, thermoelectron emission, sputtering targets, and counterweights and heating elements. These applications take advantage of tungsten's high melting point, high density, and excellent electrical properties.

4.2.1 Resistance welding electrodes

Resistance welding is a welding process in which resistance heat melts metal through the electrical current generated and is widely used in automobile manufacturing, electronics industry, and home appliance production. Pure tungsten electrodes are often used in resistance welding electrodes due to their high hardness, high conductivity and wear resistance, especially in spot welding and seam welding. In spot welding, a pure tungsten electrode acts as an electrode head and is in direct contact with the workpiece, transferring a high current (thousands of amperes) to produce a localized high temperature that melts the metal to form a solder joint. Its high melting point ensures that the electrode does not soften or adhere to the workpiece at high temperatures, extending the service life.

In the electronics industry, resistance welding is used to weld thin metal sheets (e.g. copper foil, nickel sheets) or miniature components, and the high conductivity and stability of pure tungsten electrodes provide precise thermal control to avoid overheating and damaging sensitive components. In addition, the wear resistance of pure tungsten electrodes makes them suitable for high-frequency welding operations, such as continuous spot welding of automotive parts. Although copper alloy electrodes are more common in some resistance welding scenarios, pure tungsten electrodes offer unique advantages in high-precision and high-temperature applications.

4.2.2 Plasma cutting and spraying

Plasma cutting is a process that uses a high-temperature plasma arc (up to 20,000°C) to melt metal and blow away molten material, and is widely used in cutting steel, aluminum alloys, and stainless steel. As the core component of the plasma cutting gun, the pure tungsten electrode is responsible for initiating and maintaining the plasma arc. Its high melting point and low vapor pressure allow it to remain stable at extremely high temperatures, reducing electrode consumption. In addition, the conductivity of the pure tungsten electrode ensures a fast arc response and is suitable for high-speed cutting applications.

In plasma spraying, pure tungsten electrodes are used to generate a high-temperature plasma gas stream to melt and spray ceramic or metal powders onto the surface of the substrate to form a wear-resistant, corrosion-resistant, or heat-insulating coating. The high temperature resistance and chemical stability of pure tungsten electrodes allow them to withstand the harsh conditions of the spraying process, ensuring uniformity and quality of the coating. The widespread use of plasma cutting and spraying is driving the demand for pure tungsten electrodes in the manufacturing industry, especially in heavy industry and surface engineering.

4.2.3 Thermoelectron emitting materials

Tungsten electrodes are commonly used in devices that require thermal electron emission, such as electron microscopes, cathode ray tubes (CRTs), and X-ray tubes, due to their high electron escape work and excellent thermal electron emission performance. In these devices, a pure tungsten electrode acts as a cathode that emits electrons at high temperatures (about 2000-2500°C) to form an electron beam or ray. Its high melting point and low vapor pressure ensure long-term stable operation of the electrode in a high-temperature vacuum environment, while its chemical stability prevents reactions with residual gases.

Although tungsten electrodes doped with rare earth oxides (e.g., lanthanum tungsten electrodes) perform better in some thermal electron emission applications, pure tungsten electrodes are still widely used in devices with high safety requirements due to their non-radioactivity and low cost. In addition, the mechanical strength of pure tungsten electrodes allows them to withstand high voltages and thermal shocks, making them suitable for applications in high-power electronics.

4.2.4 Sputtering targets

Sputtering is a physical vapor deposition (PVD) technique used to deposit thin films on the surface of a substrate and is widely used in the semiconductor, solar cell, and optical coating industries. Due to its high purity (≥99.95%) and high density, pure tungsten electrode can be used as a sputtering target to release tungsten atoms under the bombardment of high-energy ions to form a uniform tungsten film. These films offer excellent electrical conductivity, corrosion resistance, and high-temperature stability, making them suitable for the manufacture of microelectronics, sensors, and optical components.

The production of pure tungsten targets requires strict control of impurity content and grain structure to ensure the performance of the film. The high density and uniformity of pure tungsten electrodes make them ideal for high-quality targets. In addition, its high melting point and chemical stability ensure that the target can be used for a long time without degradation in a high vacuum and high-temperature sputtering environment. With the rapid development of the semiconductor and new energy industries, the demand for pure tungsten electrodes as sputtering targets continues to grow.

4.2.5 Counterweights and heating elements

The high density of pure tungsten electrodes (19.3 g/cm³) makes them ideal for counterweights and is widely used in aerospace, automotive, and precision instrumentation. For example, in airplanes and satellites, tungsten counterweights are used to balance structures and improve flight stability; In racing, tungsten weight weights are used to optimize the distribution of the vehicle's center of gravity. The high density of pure tungsten allows it to provide greater weight in a smaller volume, which is superior to traditional lead or steel counterweight materials. In addition, its non-toxicity and corrosion resistance meet environmental requirements.

In terms of heating elements, pure tungsten electrodes are often used in heating elements of high-temperature furnaces (such as vacuum furnaces and graphite furnaces) due to their high melting point and excellent conductivity. In these devices, tungsten electrodes are able to withstand temperatures above 2000°C, providing a stable heat source for metal melting, ceramic sintering and heat treatment processes. Although tungsten is susceptible to oxidation at high temperatures, inert gas or vacuum protection can effectively extend its service life.

4.3 Special field applications

Pure tungsten electrodes have important applications in special fields such as aerospace, military and nuclear industries, where the performance, safety and reliability of materials are extremely demanding.

4.3.1 Aerospace industry

The aerospace industry has extremely strict requirements for welding quality and material properties, and the application of pure tungsten electrodes in this field is mainly focused on TIG welding of aluminum alloys, magnesium alloys and titanium alloys. For example, in the manufacture of aircraft fuselages, engine components, and satellite structures, aluminum alloys (such as 7075, 6061) are widely used due to their light weight and high strength. Pure tungsten electrodes are welded by AC TIG to remove the oxide film to form a high-quality weld that meets the strength and corrosion resistance requirements of aerospace components.

In addition, magnesium alloys are increasingly used in aerospace, such as the manufacture of helicopter drivetrains and seat frames. The stable arc and clean weld characteristics of pure tungsten electrodes in magnesium alloy welding ensure the reliability and lightweight of components. In addition, the non-radioactivity of pure tungsten electrodes makes them suitable for the manufacture of spacecraft components with extremely high safety requirements, such as satellite enclosures and fuel tanks.

In the aerospace sector, tungsten electrodes are also used in plasma spraying and counterweight manufacturing. Plasma spraying is used to form a high-temperature resistant coating on the surface of engine blades, and the stability of pure tungsten electrodes ensures the quality of the coating. Counterweights are used to balance spacecraft structures, and the high density and non-toxicity of pure tungsten make it an ideal choice.

4.3.2 Military industry

The military industry requires high temperature resistance, corrosion resistance and high strength of materials, and the application of pure tungsten electrodes in this field includes the welding and processing of armored vehicles, missile components and weapon systems. For example, aluminum alloys and stainless steel are widely used in the manufacture of armored vehicles, and pure tungsten electrodes provide high-quality welds through TIG welding, enhancing structural strength. In the manufacture of missile components, such as seeker housings, precise arc control of pure tungsten electrodes meets the need for high-precision welding.

In addition, pure tungsten electrodes also play a role in plasma cutting and thermal electron emission applications in the military industry. Plasma cutting is used to process high-strength steel and titanium alloys, and the high temperature resistance of pure tungsten electrodes ensures cutting efficiency and precision. Thermal electron emission is used in military radars and electronic tubes for communication equipment, and the stability of pure tungsten electrodes ensures the long-term operation of the equipment. The non-radioactive nature of pure tungsten electrodes makes it even more advantageous in the military field, especially in scenarios where environmental and personnel safety requirements are strict.

4.3.3 Nuclear industry

The nuclear industry has extremely high requirements for radiation resistance, high temperature resistance and chemical stability of materials, and pure tungsten electrodes have important applications in the manufacture of nuclear reactor components, fuel rod housings and experimental equipment. For example, pure tungsten electrodes are often used for the welding of aluminum alloys and stainless steel in the cooling systems and structural parts of nuclear reactors, as they provide defect-free welds that meet the requirements for radiation resistance and corrosion resistance.

In nuclear fusion research (e.g., the International Thermonuclear Fusion Experimental Reactor (ITER), tungsten is used as a plasma-oriented material (PFM) due to its high melting point and low sputtering rate. Pure tungsten electrodes play a role in the welding and processing of these components, and their high purity and stability ensure the performance of the components. In addition, pure tungsten electrodes are also used in counterweights and heating elements in the nuclear industry, such as counterweights for radiation shielding and heating elements for high-temperature experimental furnaces.

The non-radioactive nature of pure tungsten electrodes makes it more advantageous in the nuclear industry, and it performs better in terms of safety and environmental protection than thoriated tungsten electrodes (containing radioactive thorium oxide). The rapid development of the nuclear industry provides a broad prospect for the application of pure tungsten electrodes.

4.4 Application Limitations

Although pure tungsten electrodes are widely used in a variety of fields, their performance limitations limit their use in certain scenarios. The following analyzes its shortcomings from two aspects: DC welding and electrode wear and life.

4.4.1 Deficiencies in DC welding (DC).

The main limitation of pure tungsten electrodes in direct current welding (DC) is their high electron work (about 4.52 eV), which leads to difficult arc initiation and arc instability. In DC positive connection (DCSP), the electrode as the cathode needs to emit a large number of electrons, and the high electron escape work makes the arc start at a higher voltage, which is prone to arc jumps or interruptions. In reverse DC polarity (DCRP), the electrode as the anode is subjected to a higher heat load, which can lead to overheating and rapid consumption.

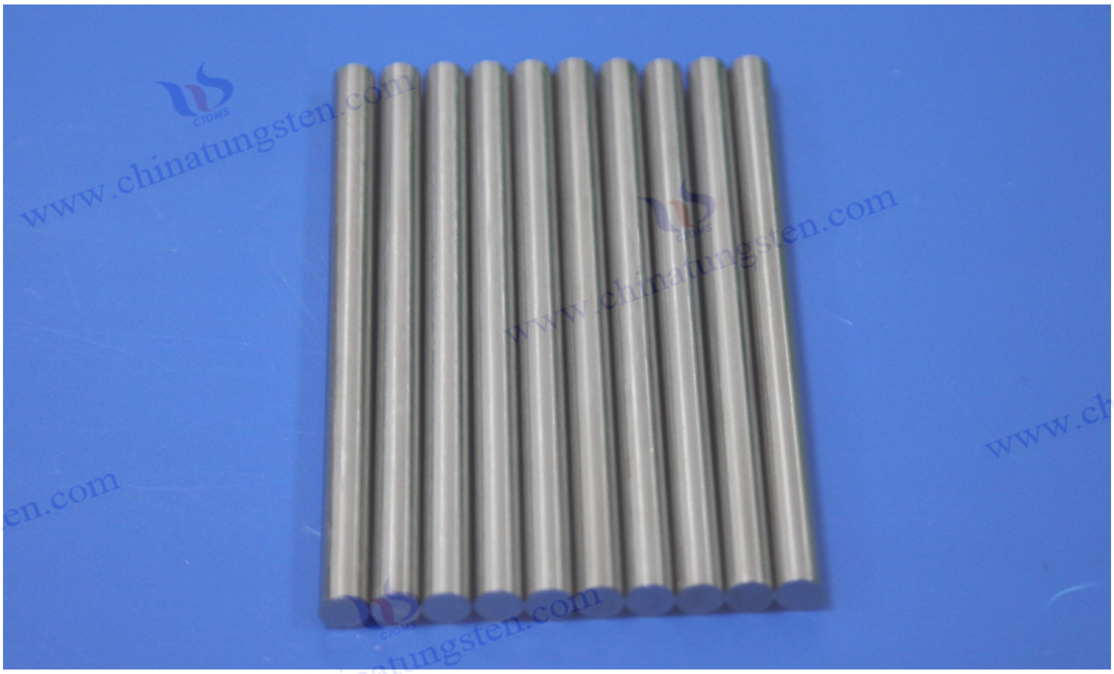
In contrast, electrodes doped with rare earth oxides (e.g., cerium tungsten and lanthanum tungsten electrodes) have lower electron escape work (about 2.7-3.2 eV) and have better arc initiation performance and arc stability in DC welding. Therefore, the application of pure tungsten electrodes in DC welding is mainly limited to low-demand scenarios, such as low-current welding or temporary repair, while high-precision or high-efficiency DC welding mostly uses doped electrodes. To alleviate this limitation, arc initiation performance can be improved by optimizing welding equipment (e.g., high-frequency arc starting) or adjusting the angle at the top of the electrode, but the effect is limited.

4.4.2 Electrode wear and life problems

Another major limitation of pure tungsten electrodes is the electrode wear and lifetime issues. In high current (>200 A) or long-term continuous welding, the high end temperature of pure tungsten electrode due to high electron work accelerates the volatilization and burning loss of the material, which is manifested by the gradual shortening of the electrode length and the change of end morphology. In AC welding, the formation of hemispherical ends partially slows down wear, but the wear rate remains high at high frequencies or under unstable currents.

In addition, electrode surface contamination (e.g., oxides, oil) or improper handling (e.g., electrode contact with the molten pool) can further exacerbate wear and reduce arc stability. In order to prolong the life of the electrode, the electrode part needs to be polished regularly to maintain its cleanliness and proper end shape. However, frequent grinding increases operating costs and time, especially in automated welding, which can affect productivity. In contrast, doped electrodes, such as lanthanum tungsten electrodes, typically have a longer lifetime due to their lower consumption rate and more stable end morphology.

To overcome wear and life issues, performance can be improved by optimizing welding parameters (e.g., reducing current, increasing gas protection), improving electrode production processes (e.g., grain refinement), or developing new electrode materials. However, these improvements can increase costs and require a trade-off between performance and economics.



pure tungsten electrode from CTIA GROUP LTD

Chapter 5 Production Equipment for Pure Tungsten Electrode

The production of pure tungsten electrodes (WP electrodes) involves a complex process chain from raw material handling to finished product inspection, each of which requires specialized equipment to ensure product quality and production efficiency. The production equipment covers raw material handling, powder metallurgy, pressure processing, surface treatment, testing and quality control, as well as automation and intelligent systems. These equipment need to have high precision, high reliability, and high temperature and corrosion resistance to accommodate the high melting point and high hardness characteristics of tungsten. This chapter will discuss in detail the various types of equipment used in the production of pure tungsten electrodes, and analyze their functions, characteristics, and technological development trends.

5.1 Raw material processing equipment for pure tungsten electrode

Raw material handling is the first step in the production of pure tungsten electrodes, which involves the conversion process from tungsten ore to high-purity tungsten powder, which requires the use of special equipment for crushing, grinding and chemical purification. These equipment needs to be efficient, stable and environmentally friendly to meet the production requirements of high-purity tungsten powder.

5.1.1 Tungsten ore crushing and grinding equipment

Tungsten ore (e.g. wolframite or scheelite) is mined from the mine and then crushed and ground to produce fine particles suitable for beneficiation. Crushing and grinding equipment mainly includes the following types:

Jaw crusher: used for primary crushing, crushing large pieces of tungsten ore (up to 1-2 m in size) into 50-100 mm particles. The jaw crusher crushes the ore through the extrusion of the moving jaw and the fixed jaw, and the equipment needs to use high-strength wear-resistant materials (such as manganese steel) to cope with the high hardness of tungsten ore. Modern jaw crushers are equipped with a hydraulic adjustment system, which can accurately control the discharge particle size and improve crushing efficiency.

Cone crusher: used for medium and fine crushing, further crushing the ore after primary crushing to 5-20 mm. The cone crusher achieves continuous crushing through the extrusion action of the rotating cone and the fixed cone, and is suitable for handling high hardness ores. Its advantages are large crushing ratio and high output, which is suitable for large-scale tungsten ore processing.

Ball mill: used for grinding, grinding the crushed ore into a fine powder of 0.1-1 mm in preparation for beneficiation. The ball mill grinds materials through the collision and friction between the steel balls and the ore, and the lining is made of wear-resistant ceramic or high-chromium steel to extend the service life. Wet ball mills are often used for tungsten ore grinding, which reduces dust pollution and improves grinding efficiency by adding water medium.

Vibrating screen: used for grading, screening out mineral powder with uniform particle size. The vibrating screen separates materials with different particle sizes through high-frequency vibration to ensure that the particle size of the mineral powder entering the beneficiation process is consistent. Modern vibrating screens are equipped with multi-layer screens, which can realize multi-stage sorting and improve the efficiency of mineral processing.

These plants need to be equipped with a dedusting system to reduce dust contamination and an automated control system to optimize operating parameters such as crushing pressure, grinding time and screening frequency. In recent years, intelligent crushing equipment has gradually become popular, and real-time monitoring and fault diagnosis through sensors and PLCs (programmable logic controllers) have improved production efficiency and safety.

5.1.2 Chemical purification equipment

Chemical purification is the process of converting tungsten concentrate into high-purity tungsten trioxide (WO_3) or tungstic acid (H_2WO_4), which involves steps such as dissolution, filtration, precipitation, and drying. Commonly used equipment includes:

Reaction kettle: It is used for the reaction of tungsten concentrate with sodium hydroxide or sodium carbonate to generate sodium tungstate solution. Reactors need to be manufactured with corrosion-resistant materials such as stainless steel or enamel to withstand high temperatures, pressures, and strong alkali environments. Modern reactors are equipped with agitation systems and temperature control devices to ensure uniform and efficient reactions.

Filter: used to remove insoluble impurities (such as silicate, iron compounds) in the solution.

Vacuum filters or filter presses are commonly used equipment to ensure the purity of the solution through multi-stage filtration. The filter needs to be equipped with a corrosion-resistant filter cloth and an automated cleaning system to extend service life and reduce manual handling.

Sedimentation tank: It is used to convert sodium tungstate solution into tungstic acid precipitate through acidification reaction. Sedimentation tanks need to be equipped with precise pH control and agitation to ensure the uniformity and purity of the precipitated particles. Some advanced equipment uses online pH monitors to adjust the amount of acid added in real time.

Drying oven: used for drying tungstic acid precipitation or tungsten trioxide, preparing dry intermediate products. Drying ovens are usually electrically or gas-heated, and need to have a uniform temperature field and inert gas protection to prevent oxidation of the material. Modern drying ovens are equipped with vacuum systems that allow drying at lower temperatures and reduce energy consumption.

Chemical purification equipment needs to strictly control process parameters (such as temperature, pressure, solution concentration) to ensure that the purity of tungsten trioxide reaches more than 99.95%. In addition, wastewater treatment equipment, such as neutralization tanks and sedimentation tanks, is an indispensable part of the purification process for the treatment of tungsten-containing waste liquids, which meets environmental requirements.

5.2 Powder metallurgy equipment for pure tungsten electrode

Powder metallurgy is the core process of pure tungsten electrode production, involving tungsten powder pressing, sintering and heat treatment, which requires high-precision, high-temperature resistant equipment to ensure the density and performance of the green body.

5.2.1 Presses

The press is used to press high-purity tungsten powder into a green body with a certain shape and strength, and common equipment includes:

Cold isostatic press: A uniform pressure (100-300 MPa) is applied to tungsten powder by a high-pressure liquid medium (such as water or oil) to make a green body with uniform density. Cold isostatic presses use flexible molds (e.g. rubber or polyurethane molds) and are suitable for the production of large or complex shapes. The equipment needs to be equipped with high-pressure pumps and sealing systems to ensure stable pressure and safe operation. Modern cold isostatic presses are equipped with automated loading and unloading systems to improve production efficiency.

Molding machine: one-way pressure is applied to tungsten powder through a steel die, which is suitable for the production of small batches or simple shape of green bodies. The molding machine needs to use a high-strength mold (such as cemented carbide) to withstand the high hardness of tungsten powder. The equipment is usually equipped with a hydraulic or mechanical drive system that allows precise control of the pressing force (50-200 MPa) and the pressing speed.

The press needs to be equipped with a powder filling device and a binder spraying system to ensure the uniformity of the tungsten powder and the molding strength of the green body. In addition, dust control during the pressing process is critical and requires a negative pressure suction system to protect the operating environment.

5.2.2 Sintering furnaces

The sintering furnace is used to heat the pressed green body to 2000-2800°C, so that the tungsten powder particles combine to form a high-density green body. Commonly used sintering furnaces include:

Vacuum sintering furnace: sintering in a vacuum environment (10^{-3}-10^{-5} Pa) to avoid oxidation of tungsten body. The vacuum sintering furnace uses molybdenum or graphite heating elements, and has a high temperature field uniformity, which is suitable for the production of high-purity electrodes. The equipment is equipped with a multi-stage vacuum pump and cooling system to quickly reach high vacuum and control the cooling rate.

Hydrogen sintering furnace: sintering under the protection of high-purity hydrogen, hydrogen can reduce residual oxides and improve the purity of the green body. Hydrogen sintering furnaces need to be equipped with gas circulation and purification systems to ensure hydrogen purity (≥ 99.999%) and prevent leakage. Modern sintering furnaces use medium-frequency induction heating technology to heat up quickly and reduce energy consumption.

The sintering furnace needs to be equipped with a precise temperature control system (e.g. infrared thermometer) and an atmosphere monitoring device to ensure the stability of the sintering process and the quality of the green body. In recent years, discharge plasma sintering furnaces (SPS) have been increasingly used in the production of high-performance tungsten electrodes, which use electrical pulses to heat up quickly to shorten the sintering time and refine the grains.

5.2.3 Vacuum heat treatment furnaces

The vacuum heat treatment furnace is used for heat treatment and annealing of the sintered green body, eliminating internal stress and improving the microstructure. Features include:

High temperature vacuum environment: the heat treatment temperature is 1200-1800 °C, and the vacuum degree is 10^{-3}-10^{-4} Pa to prevent oxidation of the green body. The furnace body adopts molybdenum or tungsten heating elements, and is equipped with a water cooling system to protect the furnace structure.

Precise temperature control: Thermocouples and PID controllers achieve a temperature accuracy of ±5°C to ensure consistent heat treatment results. Some of the advanced equipment is equipped with multi-stage temperature control programs, which can realize complex heat treatment processes.

CTIA GROUP LTD
Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).
Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.
Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.
High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.
Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips
Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection
Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696
Website: www.tungsten.com.cn

Inert Gas Protection: Some heat treatment furnaces support argon or nitrogen protection for specific process needs. The gas circulation system improves thermal efficiency and reduces gas consumption.

Vacuum heat treatment furnaces require regular maintenance of the heating elements and vacuum systems to ensure long-term stable operation. The intelligent heat treatment furnace monitors the billet temperature and stress distribution in real time through sensors to optimize the heat treatment parameters.

5.3 Pressure processing equipment for pure tungsten electrode

Pressure processing is a key step in the processing of sintered green bodies into electrode bars, involving processes such as forging, rolling and wire drawing, which requires the use of high-temperature and high-strength processing equipment.

5.3.1 Forging machines

The forging machine is used to deform the sintered blank body at high temperature (1500-1800°C) to make a rod or plate blank. Commonly used equipment includes:

Hydraulic forging machine: high pressure (1000-5000 kN) is applied by the hydraulic system to gradually deform the green body. The equipment needs to be equipped with a high-temperature heating furnace and a hydrogen protection system to prevent oxidation of the green body. The hydraulic forging machine is suitable for the production of large-size blanks with high deformation accuracy.

Air hammer: The hammer head is driven by pneumatics to make a rapid impact on the billet, which is suitable for forging small and medium-sized billets. The air hammer is flexible to operate, but the amount of deformation needs to be manually controlled, which is suitable for small batch production.

The forging machine needs to be equipped with a high-strength die and lubrication system to reduce the friction between the body and the die. Modern forging machines adopt an automatic control system, which can adjust the forging force and temperature in real time to improve production efficiency.

5.3.2 Rolling mills

Rolling mills are used to further process forged blanks into slender bars or wires, and common equipment includes:

Hot rolling mill: Blanks are rolled into bars with a diameter of 5-20 mm by multiple passes at 1000-1500°C. Hot rolling mills use tungsten carbide or ceramic rolls to withstand the high hardness of tungsten. The equipment is equipped with a heating furnace and cooling system to ensure the rolling temperature and surface quality.

Cold rolling mill: used for finishing rolling to further improve the dimensional accuracy and surface finish of the bar. Cold rolling mills need to be equipped with high-precision rolls and lubrication systems to reduce work hardening.

The rolling mill requires regular maintenance of the rolls and drive system to ensure long-term operational stability. Automated rolling mills use sensors to monitor rolling forces and bar sizes to improve processing consistency.

5.3.3 Wire drawing machines

Wire drawing machines are used to stretch rolled bars into electrode blanks with a diameter of 0.5-6.4 mm, common equipment includes:

Single-die wire drawing machine: stretches the bar one by one through a single mold, which is suitable for small batch production. The equipment needs to be equipped with carbide or diamond dies to withstand the high hardness and friction of tungsten.

Continuous wire drawing machine: continuous stretching through multiple dies to improve production efficiency. The continuous wire drawing machine is equipped with a lubrication system (such as graphite emulsion or molybdenum disulfide) and an annealing device to reduce the risk of wire breakage.

Drawing machines need to precisely control the tensile speed and temperature (800-1200°C) to avoid cracks or surface defects. Modern wire drawing machines are controlled by servo motors and PLC to achieve high-precision stretching.

5.4 Surface treatment equipment for pure tungsten electrode

Surface treatment equipment is used to improve the surface quality and recognition of electrodes, including cleaning, polishing, and coating head marking.

5.4.1 Cleaning equipment

Cleaning equipment is used to remove oil, oxides and impurities from the electrode surface, commonly used equipment includes:

Ultrasonic cleaner: Removal of fine surface particles by high-frequency ultrasonic vibration (20-40 kHz), usually in alkaline solution or pure water. The equipment needs to be equipped with a multi-tank cleaning system that supports multi-stage cleaning and rinsing.

Chemical cleaning bath: Uses dilute acids (e.g., dilute nitric acid) or alkaline solutions (e.g., sodium hydroxide) to remove the oxide layer. The cleaning tank should be made of a corrosion-resistant material (e.g. PTFE) and equipped with agitation and heating.

The cleaning equipment needs to be equipped with a waste liquid treatment system to recover tungsten-containing waste liquid to meet environmental protection requirements. The automated cleaning line can realize continuous cleaning and improve efficiency.

5.4.2 Polishing machines

Polishing machines are used to improve the surface finish of electrodes, and common equipment includes:

Mechanical polishing machine: Surface scratches are removed by means of a grinding wheel or polishing cloth with a surface roughness of up to Ra 0.2-0.4 μm. The equipment needs to be equipped with a multi-stage polishing head to support rough polishing and fine polishing.

Electrochemical polishing machine: Smooths the surface through electrolysis, improving the finish and corrosion resistance. The electrochemical polishing machine needs to be equipped with a stable power supply and an electrolyte circulation system to ensure uniform polishing.

The polishing machine needs to change the polishing medium and check the electrolyte composition regularly to maintain the polishing quality. The automated polishing equipment is operated precisely by means of a robot arm.

5.4.3 Applicator equipment

The applicator is used to apply a green mark at one end of the electrode and complies with AWS A5.12 and ISO 6848 standards. Commonly used equipment includes:

Automatic spraying machine: The water-based green paint is evenly applied to the electrode through the spray gun. The machine is equipped with a precise positioning system to ensure a uniform coating thickness (approx. 0.1-0.2 mm).

Drying oven: used for curing coatings, the temperature is controlled at 100-150°C, using hot air circulation or infrared heating. The drying furnace needs to have a fast heating and uniform temperature field to ensure the adhesion of the coating.

The applicator equipment needs to clean the nozzles and check the quality of the paint regularly to avoid coating defects. The intelligent coating head equipment can automatically adjust the spraying position through the visual recognition system.

5.5 Testing and quality control equipment for pure tungsten electrode

Testing and quality control equipment is used to ensure that the chemical composition, microstructure and physical properties of electrodes meet standards, covering the testing of raw materials, semi-finished products and finished products.

5.5.1 Chemical composition analyzers

Chemical composition analyzers are used to test the purity and impurity content of tungsten powder and electrodes, and commonly used equipment includes:

Inductively Coupled Plasma Spectrometer (ICP-OES): Spectroscopy of elements is analyzed by excitation of the sample by plasma, and the content of tungsten and impurities (such as iron, nickel, oxygen) can be detected with an accuracy of ppm. The equipment needs to be equipped with a high-purity gas supply and sample preparation system.

X-ray fluorescence analyzer (XRF): Excitation of the sample by X-ray to analyze the fluorescence spectrum, suitable for rapid non-destructive testing. XRF equipment is highly portable and suitable for real-time analysis on the production floor.

Chemical composition analyzers need to be calibrated regularly to ensure detection accuracy. The intelligent analyzer can automatically generate analysis reports to improve detection efficiency.

5.5.2 Microstructure analysis equipment

Microstructure analysis equipment is used to detect grain size, defects, and microstructure uniformity of electrodes, and commonly used equipment includes:

Optical microscopy: used to observe the grain structure and microscopic defects of the electrode cross-section with a magnification of 50-1000x. The equipment needs to be equipped with image analysis software to quantify grain size and defect distribution.

Scanning electron microscopy (SEM): Scanning samples with electron beams to analyze surface topography and microstructure with nanometer resolution. SEMs are often equipped with an energy dispersive spectrometer (EDS) for the analysis of local chemical compositions.

Microstructure analysis equipment requires regular maintenance of the electron beam source and vacuum system to ensure image quality. The state-of-the-art equipment supports 3D reconstruction and in-depth analysis of the internal structure of the electrode.

5.5.3 Physical performance test equipment

Physical performance testing equipment is used to test the density, hardness, conductivity and dimensional tolerance of electrodes, commonly used equipment includes:

Density tester: The electrode density is measured by the Archimedean principle to ensure that the theoretical density (19.3 g/cm³) is more than 95%. The equipment needs to be equipped with a high-precision balance and a thermostatic water tank.

Hardness tester: Vickers or Brinell hardness tester is used to measure the hardness of the electrode (HV 350-450). The equipment needs to be equipped with a diamond indenter and a high-precision load system.

Conductivity Tester: Evaluates the conductivity of electrodes by measuring the resistivity of electrodes by the four-probe method. The equipment needs to be equipped with a constant current source and a microvoltmeter to ensure measurement accuracy.

Dimensional measuring instrument: Laser rangefinder or image measuring instrument is used to detect the electrode diameter (±0.05 mm) and length tolerance. The device supports non-contact measurement and is suitable for high precision requirements.

Physical performance testing equipment needs to be calibrated regularly to ensure data reliability. The automated test system can realize multi-parameter synchronous detection and improve efficiency.

5.6 Automation and intelligent equipment for pure tungsten electrode

Automation and intelligent equipment is an important trend in the modernization of pure tungsten electrode production, which improves production efficiency and quality stability through the integration of sensors, control systems and data analysis technologies.

5.6.1 Application of automated production lines

The automated production line integrates crushing, pressing, sintering, processing and surface treatment, and realizes continuous production through robots, conveyor belts and automatic control systems. Key equipment includes:

Automatic Charging System: Used for automatic filling and pressing of tungsten powder, equipped with robotic arm and load cell to ensure charging uniformity and accuracy.

Continuous sintering line: The green body is continuously fed into the sintering furnace through a conveyor belt, and is equipped with a multi-stage temperature control system to achieve efficient sintering. The system supports online monitoring of billet body temperature and atmosphere.

Automatic processing line: integrated forging, rolling and wire drawing equipment, continuous processing through PLC control. The system is equipped with a visual recognition device to detect blank size and surface defects.

Automated production lines reduce operational errors and safety risks by reducing manual intervention, while increasing production efficiency. Some advanced production lines support modular design, which can flexibly adjust the process flow according to production needs.

5.6.2 Intelligent monitoring system

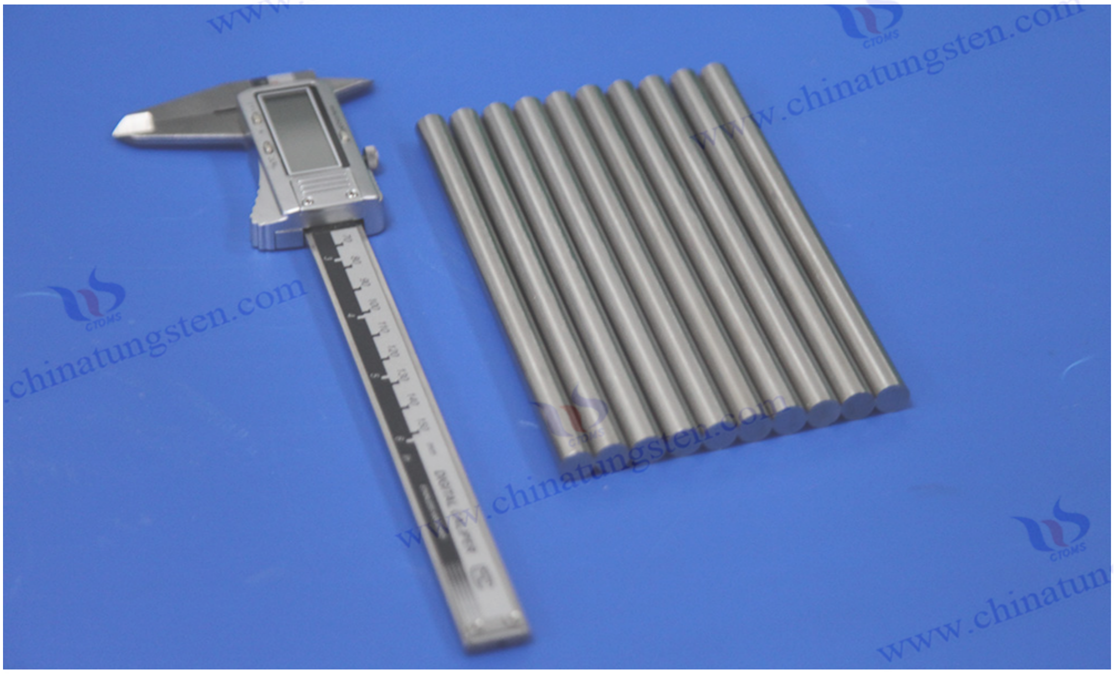
The intelligent monitoring system monitors the parameters of the production process in real time through sensors, Internet of Things and big data analysis technology to improve the efficiency of quality control and equipment maintenance. Key technologies include:

On-line monitoring sensors: including temperature sensors, pressure sensors and gas analyzers, real-time monitoring of sintering furnace temperature, wire drawing machine tension and protective atmosphere composition. The data is transmitted to the central control system via the Internet of Things.

Fault diagnosis system: Analyzes equipment operation data through machine learning algorithms, predicts potential failures, and provides maintenance recommendations. The system reduces equipment downtime and increases production continuity.

Quality traceability system: record the production parameters and testing data of each batch of electrodes, and establish a traceability database. The system supports barcode or RFID technology, which is convenient for quality management and customer inquiry.

The intelligent monitoring system provides real-time feedback to the operator through a data visualization platform (such as a SCADA system), supporting remote monitoring and optimized decision-making. In the future, with the development of Industry 4.0 technology, the intelligent monitoring system will further integrate artificial intelligence and cloud computing to realize the intelligent management of the whole process.



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Chapter 6 Domestic and Foreign Standards for Pure Tungsten Electrode

As an important material for tungsten argon arc welding (TIG welding), the performance and quality of pure tungsten electrode (WP electrode) directly affect the welding effect. To ensure product consistency and market availability, a number of standards have been developed worldwide, covering chemical composition, dimensional tolerances, performance requirements, and test methods. These standards are formulated by international organizations, national institutions and industry associations, forming a relatively complete normative system. This chapter will discuss in detail the international standards, Chinese national standards, and other national standards for pure tungsten electrodes, analyze their differences, and look forward to the development trend of standards.

6.1 International standards for pure tungsten electrode

International standards provide a unified specification for the global trade and application of pure tungsten electrodes, and are mainly developed by the American Welding Society (AWS), the International Organization for Standardization (ISO) and the European Committee for Standardization (CEN). The following focuses on the AWS A5.12, ISO 6848, and EN 26848 standards.

6.1.1 AWS A5.12 (American Welding Institute Standard)

AWS A5.12 is a tungsten electrode standard developed by the American Welding Society, the full name is "Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting", and the latest version is AWS A5.12/A5.12M:2009. This standard is widely used in the North American and global welding industry, covering the classification, chemical composition, size and performance requirements of pure tungsten electrodes and other doped electrodes.

For pure tungsten electrodes (code EWP, marked in green), AWS A5.12 requires a tungsten content of ≥ 99.5% and trace impurities (e.g., iron, nickel, oxygen). The electrode surface should be smooth, free of cracks, porosity or inclusions, and the ends should be marked in green for easy identification. The standard specifies the diameter range (0.5-6.4 mm) and length (75-610 mm) of the electrodes, with tolerances that meet the requirements of precision manufacturing. In addition, AWS A5.12 has clear regulations on the packaging and labeling of electrodes, requiring lot number, specification, and manufacturer information to be labeled to ensure traceability.

AWS A5.12 emphasizes the welding performance of electrodes, and it is recommended that pure tungsten electrodes are mainly used for AC welding (AC), especially suitable for welding of aluminum, magnesium and their alloys. The standard does not specify test methods for arc stability or electrode consumption rates, but requires manufacturers to provide performance data for user reference. This standard is authoritative in the North American market, and many international manufacturers also produce pure tungsten electrodes according to its requirements.

CTIA GROUP LTD
Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).

Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.

Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.

High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.

Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips

Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection

Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.tungsten.com.cn

6.1.2 ISO 6848 (International Organization for Standardization)

ISO 6848 is the tungsten electrode standard formulated by the International Organization for Standardization, the full name is "Arc-welding and cutting — Non-consumable tungsten electrodes — Classification", and the latest version is ISO 6848:2015. This standard is applicable to the global welding industry, aiming to unify the classification, marking and performance requirements of tungsten electrodes, and promote international trade and technical exchanges.

ISO 6848 classifies pure tungsten electrodes as WP (green marking) and requires a tungsten content of ≥ 99.5% and strict control of impurities. The standard specifies in detail the chemical composition, dimensional tolerance and surface quality of the electrode, requires that there are no obvious defects on the electrode surface, and the coating mark needs to be wear-resistant and does not affect the welding performance. Electrode diameters range from 0.5 to 10 mm, and lengths are typically 50 to 175 mm, and the specific dimensions can be customized according to user needs. ISO 6848 also requires that the electrodes be cleaned and dried prior to packaging to prevent contamination or oxidation.

Similar to AWS A5.12, ISO 6848 recommends pure tungsten electrodes for AC welding due to their excellent "cathodic cleaning" effect in aluminum and magnesium alloy welding. The standard has a brief description of the performance test method of the electrode, such as arc initiation performance and arc stability to be evaluated under standard welding conditions, but does not specify specific test parameters. Due to its international nature, ISO 6848 is widely used in Europe, Asia and Africa and is an important reference standard for the global tungsten electrode trade.

6.1.3 EN 26848 (European standard)

EN 26848 is a tungsten electrode standard developed by the European Committee for Standardization (CEN), which is highly consistent with ISO 6848, and the full name is "Welding consumables — Tungsten electrodes for inert gas shielded arc welding and for plasma welding". The standard is mainly used in EU member states, and the latest version is updated in sync with ISO 6848:2015.

EN 26848 requires the same chemical composition as ISO 6848 for pure tungsten electrodes (WP, green marking), with a tungsten content of ≥ 99.5% and impurities to be controlled at trace levels. The standard has requirements for the size, surface quality and marking of the electrodes in line with ISO 6848, emphasizing the uniformity and cleanliness of the electrodes. EN 26848 also recommends the storage and transport of electrodes, requiring the use of moisture-resistant, shock-proof packaging to protect electrode performance.

In terms of applications, EN 26848 recommends pure tungsten electrodes for AC TIG welding and plasma welding, especially in the automotive, aerospace and shipbuilding industries in Europe. The standard does not specify performance test methods in detail, but requires manufacturers to provide technical data sheets that describe the application scenarios and operational recommendations for the sensors. The implementation of EN 26848 has promoted the standardization of the European welding industry and the application of pure tungsten electrodes in the field of high-precision manufacturing.

6.2 Chinese national standard for pure tungsten electrode

As the world's largest tungsten resource and tungsten electrode producer, China has formulated a number of national standards and industry standards to regulate the production and application of pure tungsten electrodes. Among them, GB/T 4190 is the main standard, and the relevant industry standards supplement the specific requirements.

6.2.1 GB/T 4190 (tungsten electrode standard)

GB/T 4190 is a Chinese national standard, the full name is "Tungsten and tungsten alloy electrodes for non-melting electrode TIG welding", and the latest version is GB/T 4190-2017. This standard is applicable to tungsten electrodes for TIG welding and plasma welding, covering the classification, chemical composition, size and performance requirements of pure tungsten electrodes and other doped electrodes.

For pure tungsten electrodes (code WP), GB/T 4190 requires a tungsten content of ≥ 99.5%, and the content of impurities (such as iron, silicon, carbon) should be controlled at trace levels to ensure the purity and welding performance of the electrode. The surface of the electrode should be smooth, free of cracks, oxide layers or oil stains, and the ends should be marked with green marking, in line with international practice. The standard specifies the diameter (0.5-6.0 mm) and length (50-300 mm) of the electrode to meet the tolerances required for precision machining. Packaging requires the electrodes to be packaged in plastic or metal boxes with specifications, lot numbers and production dates.

GB/T 4190 recommends pure tungsten electrodes for AC welding, especially in the welding of aluminum, magnesium and their alloys. The standard has brief provisions for performance testing, such as arc stability to be evaluated by simulated welding tests, and electrode consumption to be measured at standard currents. GB/T 4190 also requires manufacturers to provide a certificate of quality stating the chemical composition and performance data of the electrode. This standard is mandatory in the Chinese market and is the main basis for the production and application of tungsten electrodes in China.

6.2.2 Relevant Industry Standards

In addition to GB/T 4190, China has also developed a number of industry standards, supplementing the specifications for pure tungsten electrodes in specific fields. For example:

YS/T 626-2018 "Tungsten Electrode": formulated by the non-ferrous metal industry, specifies in detail the chemical composition, dimensional tolerance and surface quality of tungsten electrode, and is suitable for aerospace and electronics industries. This standard has stricter requirements for the impurity content of pure tungsten electrodes, which is suitable for high-precision welding applications.

JB/T 12839-2016 "Technical Conditions for Tungsten Electrodes for Welding": formulated by the Ministry of Machinery Industry, focusing on the welding performance and test methods of tungsten electrodes. This standard requires pure tungsten electrodes to have good arc initiation performance and arc stability in AC welding, which is suitable for shipbuilding and pressure vessel welding.

QJ 2088-2005 "Tungsten Electrodes for Aerospace": formulated by the Ministry of Aerospace Industry, specially formulated for high-reliability welding in the aerospace field. The standard requires extremely high purity, grain structure and dimensional accuracy of pure tungsten electrodes to ensure their performance in extreme environments.

These industry standards complement GB/T 4190, covering a variety of scenarios from general manufacturing to high-end applications, and promote the standardization development of China's tungsten electrode industry.

6.3 Other national standards for pure tungsten electrode

In addition to international standards and Chinese standards, tungsten electrode standards have also been developed in other countries to meet the needs of the local market. The following focuses on the Japanese JIS Z 3233 and the German DIN EN ISO 6848 standard.

6.3.1 JIS Z 3233 (Japanese Industrial Standard)

JIS Z 3233 is a Japanese industrial standard, the full name is "Tungsten Electrodes for Inert Gas Shielded Arc Welding", and the latest version is JIS Z 3233:2017. This standard is applicable to tungsten electrodes for TIG welding, which are widely used in the automotive, electronics, and precision machinery industries in Japan.

JIS Z 3233 classifies pure tungsten electrodes as WP, requiring a tungsten content of ≥99.5% and strict control of impurities. The surface of the electrode should be clean and free of defects, and the ends should be marked with green. The standard specifies the diameter (0.5-6.0 mm) and length (50-200 mm) of the electrodes to tolerances consistent with ISO 6848. JIS Z 3233 recommends pure tungsten electrodes for AC welding, especially in aluminum and magnesium alloys.

Compared with international standards, JIS Z 3233 has higher requirements for the surface quality of electrodes, and it is required to be free of any visible defects to meet the high-precision needs of Japanese manufacturing industries. The standard also imposes specific requirements on the packaging and storage of electrodes, such as the use of moisture-proof packaging and storage in a dry environment. JIS Z 3233 has an important influence in the Japanese market, and many Japanese welding equipment manufacturers design their products according to its requirements.

6.3.2 DIN EN ISO 6848 (German standard)

DIN EN ISO 6848 is a localized version of the international standard ISO 6848 adopted in Germany, published by the German Institute for Standardization (DIN) in accordance with ISO 6848:2015. The standard is widely used in Germany and Central Europe, especially in the automotive, aerospace and heavy industry sectors.

DIN EN ISO 6848 has the same chemical composition, size and performance requirements for pure tungsten electrodes (WP, marked in green) as ISO 6848, emphasizing the high purity and surface quality of the electrodes. Pure tungsten electrodes are recommended for AC TIG welding as standard, and are suitable for welding of aluminum, magnesium and their alloys. DIN EN ISO 6848 also requires manufacturers to provide detailed technical documentation, including analysis of the chemical composition of the electrodes and data on the welding properties.
As a manufacturing center in Europe, Germany has extremely high requirements for the quality of welding consumables. The implementation of DIN EN ISO 6848 has led to the standardization of tungsten electrodes in the German market, especially in high-end manufacturing (e.g. Mercedes-Benz and BMW).

6.4 Standard comparison and differences of pure tungsten electrode

Although domestic and foreign standards have a high degree of consistency in the classification and application of pure tungsten electrodes, there are slight differences in chemical composition, dimensional tolerances, and performance test methods. The following is a comparative analysis from three aspects.

6.4.1 Chemical Composition Requirements

The chemical composition requirements of pure tungsten electrodes are basically the same in each standard, and the tungsten content needs to be ≥ 99.5%, but the control range of impurities is slightly different. For example:

AWS A5.12: There is no clear upper limit on the total amount of impurities such as iron, nickel, silicon, etc., but impurities are required to not affect welding performance. The standard pays more attention to the practical application effect of the electrode.

ISO 6848 and EN 26848: Specifies that impurities (e.g. iron, carbon, oxygen) must be less than 0.05% for each item and 0.5% for the total amount ≤ ensure high purity and arc stability of the electrode.

GB/T 4190: The control of impurities is stricter, and the individual content of iron, silicon, carbon and other items should be less than 0.03%, and the oxygen content should be less than 0.02%, which is suitable for high-precision welding applications.

JIS Z 3233: Impurity requirements are similar to ISO 6848 but have stricter requirements for oxygen content (≤0.015%) to meet the needs of the Japanese electronics industry.

These differences reflect the country's focus on welding scenarios and industry needs. ISO 6848 and GB/T 4190 pay more attention to purity control and are suitable for high-end manufacturing; AWS A5.12 is more flexible and adaptable to a wide range of applications.

6.4.2 Dimensions and tolerances

The size range and tolerance requirements of the electrode are relatively consistent among the standards, but the specific details are different:

Diameter range: AWS A5.12 and ISO 6848 support 0.5-10 mm, GB/T 4190 and JIS Z 3233 are limited to 0.5-6.0 mm, reflecting the mainstream needs of different markets.

Tolerances: AWS A5.12 allows diameter tolerances from ±0.05 mm (small diameter) to ±0.13 mm (large diameter); ISO 6848 and GB/T 4190 have stricter requirements and are unified to ±0.05 mm; JIS Z 3233 has a tolerance of ±0.03 mm for small-diameter electrodes (< 2.0 mm), reflecting Japan's emphasis on precision manufacturing.

Length: AWS A5.12 supports large welding equipment up to 610 mm in length for the North American market; ISO 6848 and GB/T 4190 are mainly 50-300 mm, which are suitable for general equipment; JIS Z 3233 is mainly 50-200 mm, which is suitable for small precision welding.

These differences are related to the welding equipment and process habits of various countries. For example, precision welding in Japan tends to favor small-diameter short-electrodes, while large-diameter long-electrodes are more commonly used in large-scale industrial welding in North America.

6.4.3 Performance Test Methods

Another difference between the performance test method is the standard, and each standard has different degrees of specification for testing:

AWS A5.12: Test methods for arc initiation performance, arc stability, or electrode consumption rate are not specified, only performance data is required from the manufacturer. Testing relies heavily on industry practices, such as simulated welding at standard currents.

ISO 6848 and EN 26848: Arc initiation performance and arc stability are recommended to be tested under standard welding conditions, but detailed test parameters are not provided. The electrode consumption rate test is performed in AC welding, and the length loss per unit time is recorded.

GB/T 4190: Specifies more detailed test methods, such as arc initiation performance to be tested at 50-150 A current, arc stability to be evaluated by arc voltage fluctuation, and electrode consumption to be measured in 200 A AC welding.

JIS Z 3233: The test method is similar to ISO 6848, but requires that arc initiation performance be tested at low currents (<50 A) to meet the needs of the electronics industry.

These differences reflect the focus of each country on welding performance. GB/T 4190 and JIS Z 3233 have stricter test requirements and are suitable for high-precision applications; AWS A5.12 is more pragmatic and more flexible in testing.

6.5 The development trend of pure tungsten electrode standard

With the transformation and upgrading of the global manufacturing industry and the enhancement of environmental awareness, pure tungsten electrode standards are developing in the direction of higher performance, safer and more environmentally friendly. The following is a look forward to future trends from two aspects: environmental and safety requirements and high-performance electrode standards.

6.5.1 Environmental and safety requirements

Environmental protection and safety are the core driving forces for the development of tungsten electrode standards. Traditional thorium-tungsten electrodes are gradually limited due to their radioactive thorium oxide (ThO_2), and pure tungsten electrodes are environmentally friendly alternatives because they are non-radioactive. In the future, the standard will further strengthen the following requirements:

Harmless materials: The standard will strictly limit the content of potentially harmful impurities (e.g., lead, cadmium) in electrodes, and promote non-toxic coatings (e.g., water-based green marker paint) to reduce environmental pollution.

Environmental protection of the production process: The standard may introduce environmental requirements in the production process, such as reducing energy consumption, reducing waste water and exhaust emissions, and promoting waste recycling. Future revisions to ISO 6848 and GB/T 4190 may refer to ISO 14001 (Environmental Management System).

Safety labeling: The standard will improve the packaging and labeling specifications of electrodes, requiring clear labeling of non-radioactive and safe use guidelines for easy identification and operation by users. AWS A5.12 has started requiring detailed Safety Data Sheets (SDS).

The improvement of environmental protection and safety requirements will promote the application of pure tungsten electrodes in green manufacturing, especially in regions with strict environmental regulations such as the European Union and China.

6.5.2 High Performance Electrode Standards

With the rapid development of aerospace, new energy and semiconductor industries, the performance requirements for tungsten electrodes are constantly increasing. Future standards will focus on the following directions:

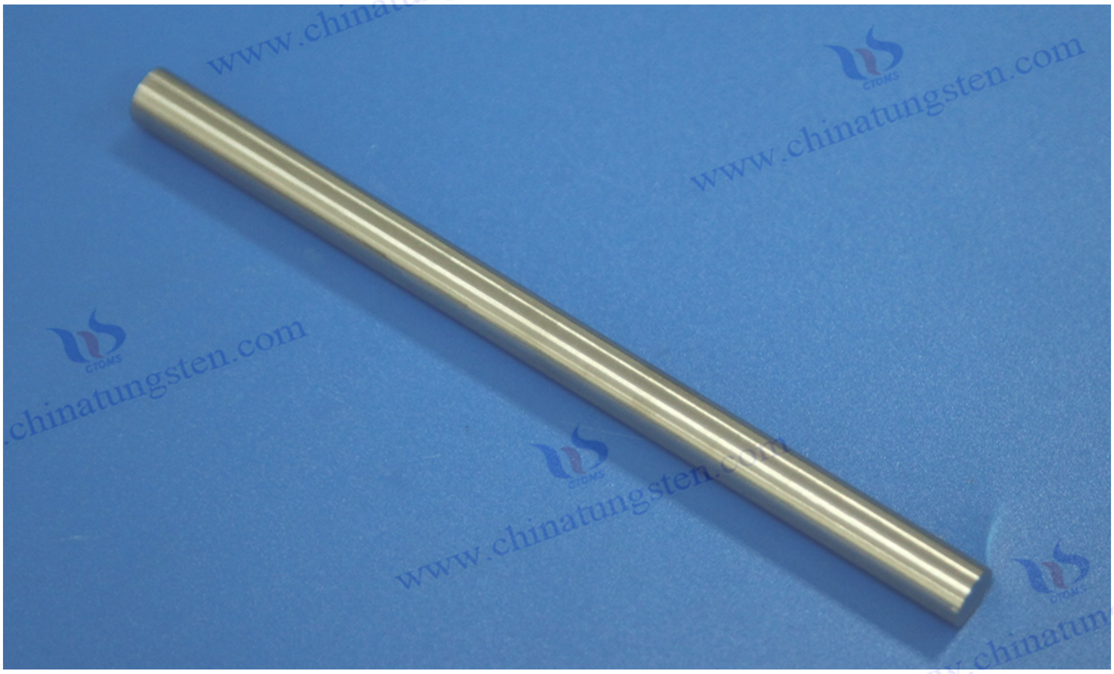
High purity requirements: The standard may increase the tungsten content requirement to 99.99% and further reduce the impurity content to meet the ultra-high purity requirements of the semiconductor and nuclear industries.

Standardization of performance testing: The standard will develop more detailed test methods, such as arc initiation performance to be tested in the multi-current range (10-300 A), arc stability to be quantified by a high-frequency arc analyzer, and electrode consumption to be evaluated under multiple welding conditions.

New material compatibility: The standard may be extended to new tungsten-based electrodes (e.g., nanocrystalline tungsten electrodes) to specify their chemical composition, grain structure and performance requirements to meet the needs of high-performance welding.

Intelligent application: The standard may introduce requirements that are compatible with intelligent welding equipment, such as the size and surface quality of the electrode need to be adapted to the automated welding robot to improve production efficiency.

The development of high-performance electrode standards will promote the application of pure tungsten electrodes in high-end manufacturing fields, and at the same time promote the innovation of production processes, such as ultra-fine tungsten powder preparation and rapid sintering technology.



pure tungsten electrode from CTIA GROUP LTD

Chapter 7 Detection Methods and Technologies of Pure Tungsten Electrode

Quality testing of pure tungsten electrodes (WP electrodes) is a key part of ensuring their performance and reliability, covering the evaluation of chemical composition, physical properties, microstructure, welding properties, and environmental and safety performance. Detection methods need to incorporate high-precision instrumentation and standardized procedures to meet the requirements of international standards (e.g., AWS A5.12, ISO 6848) and Chinese national standards (e.g., GB/T 4190). This chapter will discuss in detail the detection methods and techniques of pure tungsten electrodes, including chemical composition testing, physical property testing, microstructure analysis, welding performance testing, environmental and safety testing, and calibration and standardization of testing equipment.

7.1 Chemical composition detection of pure tungsten electrode

Chemical composition testing is the core means to evaluate the purity and impurity content of pure tungsten electrodes, ensuring that the tungsten content is ≥ 99.5% and impurities (e.g. iron, nickel, oxygen) are within a controllable range. Common methods include spectroscopy, X-ray fluorescence analysis, and chemical titration.

7.1.1 Spectroscopic analysis (ICP-OES)

Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) is a high-precision method for detecting the chemical composition of pure tungsten electrodes, which is widely used in laboratories and production sites. ICP-OES excites sample atoms with a high-temperature plasma (about 8000-10,000°C) to generate an emission spectrum of a specific wavelength to analyze the content of tungsten and tramp elements.

The assay process includes sample preparation, dissolution, analysis, and data processing. First, the electrode sample is cut into small pieces and dissolved into a solution with an acid, such as a mixture of nitric acid and hydrofluoric acid. After the solution is injected into the ICP-OES instrument, it is atomized and excited by the plasma, and the emission spectrum is divided by the spectrometer and recorded by the detector. The instrument calculates elemental concentrations from standard curves (based on standard solutions of known concentrations) with detection limits up to ppb (parts per billion) and is suitable for the detection of trace impurities (e.g., iron, nickel, silicon, carbon).

The advantages of ICP-OES are high sensitivity, simultaneous analysis of multiple elements, and wide dynamic range, which is suitable for the stringent requirements of high-purity tungsten electrodes. The disadvantages are that the sample needs to be dissolved destructively and the instrument is expensive. Modern ICP-OES instruments are equipped with automated sampling systems and data processing software to improve detection efficiency and accuracy.

7.1.2 X-ray fluorescence analysis (XRF)

X-ray fluorescence (XRF) is a non-destructive testing method used to quickly analyze the chemical composition of pure tungsten electrodes. XRF irradiates the sample by X-rays to excite the electron transitions in the inner layers of the atoms, resulting in characteristic fluorescence, and analyzing the content of tungsten and impurity elements.

For testing, the electrode sample is placed directly on the XRF instrument stage, eliminating the need for complex preparation. The instrument emits high-energy X-rays (such as Rh or W targets), and the fluorescence emitted by the sample atoms is collected by the detector and converted into a spectrum. XRF can detect a wide range of elements, from aluminum (Al) to uranium (U), with detection limits in the ppm (parts per million) range, making it suitable for rapid quality control at the production site.

The advantages of XRF are non-destructive, fast (within minutes), and easy to operate, making it suitable for batch testing. The disadvantage is that the sensitivity is lower than that of ICP-OES, and the detection ability of light elements (e.g., oxygen, carbon) is limited. In addition, surface contamination can affect the results, so it is important to ensure that the sample surface is clean. Portable XRF equipment has been widely used in field testing in recent years, increasing flexibility.

7.1.3 Chemical titration

Chemical titration is a traditional analytical method used to determine the main amount of tungsten in a tungsten electrode, suitable for laboratory validation or detection in the absence of high-precision instrumentation. Titration quantifies the amount of tungsten by chemical reactions, usually using tungstate precipitation-titration.

The testing process includes sample dissolution, tungstic acid precipitation, and titration analysis. First, the electrode sample is dissolved in an acid solution (such as a mixture of hydrochloric acid and nitric acid) and sodium hydroxide is added to generate a sodium tungstate solution. Subsequently, tungsten acid is precipitated by the addition of acid, filtered and washed with a standard alkaline solution (e.g., NaOH) and the tungsten content is calculated. The titration endpoint is usually determined by an indicator (e.g., phenolphthalein) or a potentiometric titrator.

The advantages of chemical titration are that the equipment is simple, the cost is low, and it is suitable for small and medium-sized enterprises. The disadvantage is that the operation is cumbersome, time-consuming, and can only detect the main element (tungsten), and cannot analyze trace impurities. In addition, manual handling can introduce errors, and the experimental conditions need to be tightly controlled. Modern laboratories mostly rely on ICP-OES or XRF, and chemical titration is used as a supplementary verification method.

7.2 Physical properties of pure tungsten electrode

The physical properties test evaluates the density, hardness and conductivity of pure tungsten electrodes to ensure that their mechanical and electrical properties meet the welding requirements. Common methods include density measurement, hardness testing, and conductivity testing.

CTIA GROUP LTD
Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).
Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.
Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.
High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.
Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips
Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection
Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696
Website: www.tungsten.com.cn

7.2.1 Density measurement

Density is an important indicator to measure the ultimate density of pure tungsten electrodes, the theoretical density is 19.3 g/cm³, and the density of qualified electrodes usually needs to reach 95%-98% theoretical density. Density measurement is based on the Archimedean principle, which calculates density by measuring the difference in the mass of a sample in air and liquid, usually water or ethanol.

The testing equipment includes a high-precision electronic balance (accuracy ±0.0001 g) and a thermostatic liquid tank. The sample is first weighed in air and the mass m_1 is recorded; It is then weighed by immersion in a liquid and the mass m_2 is recorded. The density is calculated as: $\rho = m_1 / (m_1 - m_2) \times \rho_0$, where ρ_0 is the density of the liquid. The test needs to ensure that the surface of the sample is clean and free of air bubbles.

The advantage of density measurement is that it is simple, accurate, and suitable for both production sites and laboratories. The disadvantage is that the sample shape is required to be high, and irregular samples need to be processed additionally. Modern density testers are equipped with automated measuring systems that allow for fast multi-batch inspections and record data for traceability.

7.2.2 Hardness Testing

The hardness reflects the wear resistance and mechanical strength of pure tungsten electrodes, and is commonly tested with Vickers (HV) or Brinell (HB). The hardness of pure tungsten electrodes is typically HV 350-450, depending on the production process and grain structure.

The Vickers hardness test uses a diamond pyramid indenter to apply a load (usually 5-10 kg) to the surface of the sample, measure the indentation diagonal length, and calculate the hardness value. The equipment includes a Vickers hardness tester and a microscope to ensure that the surface of the sample is flat and polished. Brinell hardness testing uses a carbide ball indenter, which is suitable for larger samples, but is slightly less accurate than Vickers.

The advantages of hardness testing are intuitive, reliable, and reflect the processing quality and durability of the electrode. The disadvantage is that the test points are highly localized and need to be averaged over multiple measurements to represent the overall performance. The automated hardness tester automatically measures the indentation size through image analysis software, which improves the detection efficiency.

7.2.3 Conductivity test

The conductivity test evaluates the electrical properties of pure tungsten electrodes, reflecting their ability to transmit current during welding. The conductivity of pure tungsten electrodes is about 30% IACS (International Annealed Copper Standard). The four-probe method is commonly used to measure the resistivity of the electrode and then calculate the conductivity.

The four-probe method uses four probes to make contact with the surface of the sample, with a constant current applied to the outer two probes and two inner probes to measure the voltage. The resistivity is calculated as ρ = (V/I) × S/L, where V is the voltage, I is the current, S is the sample cross-sectional area, and L is the probe spacing. Conductivity is the reciprocal of resistivity, which is converted to IACS percentage.

The testing equipment includes a four-probe tester, a constant current source, and a microvoltameter to ensure that the probes are in good contact and that the sample surface is clean. The advantages of the four-probe method are high accuracy, wide measurement range, and suitability for highly conductive materials. The disadvantage is that the sample shape and surface quality are required to be high. Modern conductivity testers support automated data acquisition and analysis, making them suitable for batch inspections.

7.3 Microstructure analysis of pure tungsten electrode

Microstructure analysis is used to evaluate the grain size, defects, and microstructure uniformity of pure tungsten electrodes, reflecting the quality and performance stability of their production processes. Common methods include optical microscopy, scanning electron microscopy (SEM) analysis, and grain size analysis.

7.3.1 Light microscopy observation

Optical microscopy is used to observe the grain structure, pores, and inclusions of the electrode cross-section with magnifications of 50-1000x. The testing process includes sample preparation, observation, and documentation. First, the electrode sample is cut, mounted, polished, and corroded with a corrosive agent such as a mixture of sodium hydroxide and potassium ferricyanide to reveal the grain boundaries. Subsequently, the grain morphology, defect distribution, and tissue uniformity were recorded under an optical microscope.

The advantages of optical microscopes are their low equipment cost, simple operation, and suitability for rapid inspection. The disadvantage is that the resolution is limited (about 0.2 μm), making it difficult to observe nanoscale defects. Modern light microscopes are equipped with image analysis software that automatically identifies grain boundaries and generates tissue reports.

7.3.2 Scanning electron microscopy (SEM)

Scanning electron microscopy (SEM) scans the surface of a sample with an electron beam to produce high-resolution images (down to the nanometer resolution) that can be used to analyze the microscopic topography, fracture features, and defects of the electrode. SEMs are often equipped with an energy dispersive spectrometer (EDS) for local chemical composition analysis.

For testing, samples are cut, polished, and coated with a conductive layer such as gold or carbon to enhance electrical conductivity. SEM generates signals such as secondary electrons and backscattered electrons through the interaction of the electron beam with the sample, and generates surface topography or component distribution images. SEM can detect microcracks, porosity and impurity distribution on the electrode surface to evaluate the defect control capability of the production process.

The advantages of SEM are high resolution, clear imaging, and in-depth analysis of microstructures. The disadvantages are expensive equipment, complex sample preparation, and the need to operate in a high vacuum. Modern SEM supports 3D reconstruction and automated scanning, improving analysis efficiency.

7.3.3 Grain size analysis

Grain size is an important parameter that affects the mechanical properties and welding performance of the electrode, and fine and uniform grains can improve strength and toughness. Grain size analysis is usually performed in conjunction with optical microscopy or SEM, where the average grain size is measured by image analysis software.

Detection methods include linear intercept method and area method. The linear intercept method calculates the average grain size by drawing random straight lines on the microscopic image and counting the number of grain boundary intersection points. The area method counts the size distribution by measuring the area of each grain. Standards such as ASTM E112 provide specifications for grain size ratings, and pure tungsten electrodes typically have a grain size of 10-50 μm.

The advantages of grain size analysis are quantitative, intuitive, and a direct reflection of the quality of the sintering and heat treatment processes. The disadvantage is that a large amount of statistical data is required to ensure representativeness. Automated image analysis software enables rapid processing of microscopic images, improving analysis efficiency and accuracy.

7.4 Welding performance test of pure tungsten electrode

The weldability test evaluates the performance of pure tungsten electrodes in actual welding, including arc initiation performance, arc stability and electrode consumption rate. These tests are carried out under standard welding conditions and simulate real-world application scenarios.

7.4.1 Arc performance test

The arc initiation performance reflects the difficulty of the electrode to initiate the arc, and the pure tungsten electrode is more difficult to arc in DC welding (DC) due to its high electron work (about 4.52 eV), but it performs better in AC welding (AC). Test methods include:
Standard welding test: Tested on standard current (50-150 A), argon protection (8-15 L/min) and aluminum alloy substrate using TIG welding equipment. The lower the arc voltage and the shorter the time, the better the performance.

High-frequency arc initiation test: The high-frequency arc initiation device is used to assist in arc initiation to evaluate the response speed of the electrode under different currents. The test needs to be repeated several times, averaged to reduce errors.

The inspection equipment includes a TIG welder, a voltmeter and a timer to ensure that the electrode is ground into a hemispherical shape (AC welding) or a conical shape (DC welding). The advantage of arc starting performance testing is that it is intuitive and close to the actual application, and the disadvantage is that the results are greatly influenced by the equipment and operator. The automated test system can record the arc start parameters through the sensor, which improves the reliability of the data.

7.4.2 Arc stability test

Arc stability reflects the continuity and uniformity of the arc during the welding process, which directly affects the quality of the weld. Pure tungsten electrode has good arc stability in AC welding, but it is prone to drift in DC welding. Test methods include:

Voltage fluctuation analysis: Recording of arc voltage fluctuations under standard welding conditions (100-200 A, argon protection). The smaller the voltage fluctuation, the more stable the arc will be. Test equipment includes oscilloscopes and voltage sensors.

Visual observation: The arc shape is recorded with a high-speed camera and the length, shape and drift of the arc are analyzed. The stabilization arc should be tapered with no significant jumps or interruptions.

Weld quality assessment: Weld breadboards are used to check weld uniformity, penetration and surface defects. A stable arc produces a smooth, porosity-free weld.

Arc stability testing requires control of parameters such as substrate, current, and gas flow to ensure comparability of results. Modern test systems provide quantitative evaluations by analyzing arc images and voltage data through artificial intelligence.

7.4.3 Electrode consumption rate test

The electrode consumption rate reflects the loss rate of the electrode in welding, and the pure tungsten electrode has a higher work consumption rate due to high electron escape, especially at high current (>200 A). Test methods include:

Length loss measurement: Measuring electrode length reduction under standard welding conditions (200 A, AC welding, 30 minutes). The consumption rate is expressed in mm/h and is typically 0.1-0.5 mm/h.

Mass loss measurement: Mass loss per unit time is calculated by measuring the mass difference between the electrodes before and after welding with a high-precision balance. The mass loss method is more accurate and suitable for laboratory testing.

End morphology analysis: Observe the morphology of the electrode after welding through a microscope to evaluate the degree of burning loss and volatilization. A stable tip morphology, such as a hemispherical shape, indicates a low consumption rate.

Electrode consumption rate testing requires controlling the welding time, current, and angle of the electrode to ensure consistent results. The automated test system can record changes in electrode length and quality in real time to improve inspection efficiency.

7.5 Environmental and safety testing of pure tungsten electrode

Environmental and safety testing evaluates the environmental protection and safety of pure tungsten electrodes in the production and use process, with a focus on radioactivity testing and dust and exhaust emission testing.

7.5.1 Radioactivity detection (comparison of thorium-tungsten electrode)

Pure tungsten electrodes are non-radioactive, which is a significant advantage over thoriated tungsten electrodes (containing thorium oxide, ThO_2). Radioactivity testing is used to verify the safety of pure tungsten electrodes and to compare them with thoriated tungsten electrodes. Assays include:

Gamma ray detection: Gamma ray dose rate (μSv/h) is recorded by measuring the radioactivity level of the electrode using a Geiger counter or scintillation detector. The dose rate of pure tungsten electrodes should be close to the background radiation level (about 0.1 μSv/h), while thorium-tungsten electrodes may reach 1-10 μSv/h.

Radionuclide analysis: Radionuclides (e.g., Th-232, U-238) in electrodes are analyzed by a high-purity germanium detector (HPGe) to ensure that there are no radioactive impurities. The detection needs to be performed in a shielded room to reduce background interference.

Radioactivity detection has the advantage of being fast and reliable, ensuring that the electrodes comply with safety standards (e.g., ISO 6848). The disadvantage is that the equipment is expensive and needs to be operated professionally. The non-radioactive nature of pure tungsten electrodes makes it even more advantageous in scenarios with high environmental and safety requirements.

7.5.2 Dust and exhaust emission detection

The grinding, polishing and sintering processes in the production of pure tungsten electrodes can generate tungsten dust and exhaust gases (e.g. tungsten oxide vapor), and emission levels need to be tested to comply with environmental regulations. Assays include:

Dust concentration detection: Dust concentration in the production floor is measured using a laser dust meter or gravimetric method to ensure that it is below the occupational exposure limit (e.g., 4 mg/m^3 in the Chinese standard). The sampling point needs to cover the grinding and polishing areas.

Exhaust gas analysis: The composition of the exhaust gas emitted from the sintering furnace is detected by a gas analyzer (e.g. infrared spectrometer) to analyze the concentration of tungsten oxide, nitrogen oxides and volatile organic compounds (VOCs). The exhaust gas needs to be discharged after dust removal and adsorption treatment.

Wastewater testing: Tungsten and other heavy metals in the wastewater of cleaning and purification processes are analyzed by ICP-OES or spectrophotometry to ensure compliance with discharge standards (e.g. China GB 25466-2010).

Dust and exhaust gas detection should be carried out on a regular basis, and an online monitoring system should be equipped to record emission data in real time. Modern environmental equipment, such as HEPA filters and wet scrubbers, can significantly reduce emissions and meet green manufacturing requirements.

7.6 Calibration and standardization of pure tungsten electrode testing equipment

The calibration and standardization of testing equipment is the key to ensuring the accuracy and comparability of inspection results, which directly affects the reliability of quality control.

7.6.1 Equipment Calibration Methods

The calibration of testing equipment is carried out regularly and in accordance with international or national standards (e.g. ISO/IEC 17025). Common calibration methods include:

ICP-OES calibration: Calibrate instrument sensitivity and linearity range by plotting a standard curve using a multi-element standard solution (containing known concentrations of tungsten, iron, nickel, etc.). Calibration is performed weekly, and calibration factors are recorded.

XRF calibration: Calibrate fluorescence intensity as a function of elemental concentration using a standard sample such as a high-purity tungsten block. Calibration is performed monthly to ensure consistent testing.

Hardness tester calibration: Indentation size and load are calibrated using standard hardness blocks (e.g., HV 400) with an error of ±2%. Calibration is done quarterly.

Microscope calibration: Use a standard scale to calibrate magnification and image resolution with an error of ±1%. Calibration is performed annually.

The calibration is performed by a professional and the calibration date, parameters and results are recorded. The automated calibration system can improve calibration efficiency by controlling the injection and data analysis of standard samples through software.

7.6.2 International testing standards

Tungsten electrodes are tested in accordance with international standards to ensure global comparability of results. Relevant standards include:

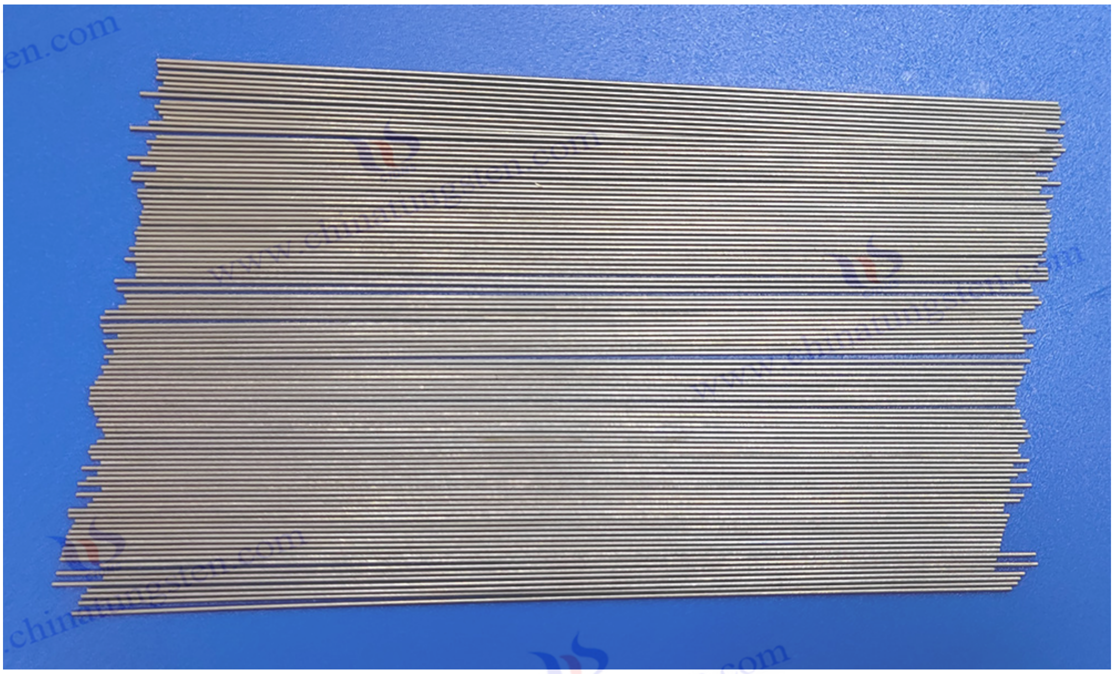
ISO 6848:2015: specifies the requirements for testing the chemical composition and properties of tungsten electrodes, and recommends the use of ICP-OES or XRF for the detection of components and microscopic analysis of tissues.

AWS A5.12:2009: Requires checking the chemical composition and surface quality of electrodes, recommending non-destructive methods such as XRF for rapid analysis.

ASTM E112: Provides a standard method for grain size measurement for microstructure analysis.

ISO 14001: Provides environmental management guidelines for dust and exhaust gas detection, with an emphasis on emission control and monitoring.

These standards provide a basis for the standardization of detection methods. In the future, international testing standards may further integrate artificial intelligence and big data technologies to develop more accurate test specifications.



pure tungsten electrodes from CTIA GROUP LTD

Chapter 8 Analysis of the Advantages and Disadvantages of Pure Tungsten Electrode

As a traditional material for tungsten argon arc welding (TIG welding), pure tungsten electrode (WP electrode) occupies an important position in the welding industry due to its unique physical and chemical properties. However, its application range and performance are limited, especially when compared with doped tungsten electrodes (such as cerium tungsten and lanthanum tungsten electrodes). This chapter will systematically analyze the advantages and disadvantages of pure tungsten electrodes and discuss the direction of their improvement, in order to provide guidance for production and application.

8.1 Advantages of pure tungsten electrode

Pure tungsten electrodes have irreplaceable value in specific scenarios due to their cost advantages, high-temperature stability and suitable for AC welding. The following elaborates on its advantages from three aspects.

8.1.1 Low cost

One of the main advantages of pure tungsten electrodes is their relatively low production cost, making them ideal for welding applications with high economic requirements. The pure tungsten electrode is made of high-purity tungsten (≥99.5%) and is not doped with rare earth oxides (such as cerium oxide, lanthanum oxide or thorium oxide), avoiding the use of expensive additives and complex formulations. As a rare metal with abundant reserves in the world (China accounts for about 50% of the world's reserves), tungsten has a stable raw material supply chain and low price fluctuations. In addition, the production process of pure tungsten electrode (such as powder metallurgy and pressure processing) has been highly mature, the equipment is highly versatile, and the large-scale production further reduces the cost.

Compared with doped electrodes, the production of pure tungsten electrodes does not require additional rare earth purification and doping processes, which significantly reduces energy consumption and labor costs. For example, cerium tungsten electrodes require precise control of the uniform distribution of cerium oxide, which adds complexity to sintering and quality control, while the production process of pure tungsten electrodes is much simpler. The cost advantage makes pure tungsten electrodes widely used in cost-sensitive industries such as construction, shipbuilding and general machining. In addition, the non-radioactive nature of pure tungsten electrodes avoids the requirements of special storage and disposal, further reducing the cost of use, and is in line with the trend of green manufacturing.

In practice, the low cost of tungsten electrodes makes them suitable for high-volume welding tasks such as aluminum curtain walls, automotive parts and pressure vessels. Although its performance is not as good as that of doped electrodes in some respects, pure tungsten electrodes provide a cost-effective option for AC welding scenarios with moderate quality requirements.

8.1.2 High temperature stability

Due to its extremely high melting point (3422°C) and excellent high temperature stability, pure tungsten electrodes are able to maintain structural integrity and stable performance in harsh welding environments. Tungsten has the highest melting point of any metal, enabling pure tungsten electrodes to withstand thermal shock at high arc temperatures (about 6000-7000°C), reducing the risk of melting, burning, or deformation. This feature ensures that the electrode maintains a stable end shape even at high currents (100-300 A) or during long periods of continuous welding, resulting in a long service life.

In AC welding, pure tungsten electrodes usually form hemispherical ends, which help to evenly distribute arc energy, reduce local overheating, and improve welding quality. Its low vapor pressure (close to 0 Pa at 3000°C) further reduces material evaporation at high temperatures, maintaining dimensional stability and arc consistency of the electrode. In addition, the excellent thermal conductivity of the pure tungsten electrode (approx. 173 W/m·K) enables it to quickly dissipate arc heat and prevent end softening or cracking caused by overheating.

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Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).

Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.

Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.

High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.

Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips

Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection

Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.tungsten.com.cn

The high temperature stability of pure tungsten electrodes makes them excellent for welding light metals (e.g. aluminum, magnesium) and their alloys, especially in the aerospace, automotive and electronics industries. The high thermal conductivity and oxide film properties of aluminum alloys require the electrode to remain stable at high temperatures, and the performance of pure tungsten electrodes can meet these requirements. In addition, its chemical stability makes it less susceptible to reacting with the environment under the protection of inert gases such as argon or helium, ensuring the purity of the weld.

8.1.3 Suitable for AC welding

The excellent performance of pure tungsten electrode in AC welding (AC) is its most important application advantage, especially suitable for welding light metals with oxide films such as aluminum, magnesium and their alloys. AC welding realizes the dynamic equilibrium of the arc through the alternating positive and negative half-cycle of alternating current. The pure tungsten electrode emits electrons during the positive half-cycle (the electrode is the cathode), generating a high-temperature arc; During the negative half-cycle (the workpiece is the cathode), the arc produces a "cathodic cleaning" effect on the oxide film (such as Al_2O_3, melting point of about 2050 °C) on the surface of the workpiece, effectively removing the oxide layer and forming a clean weld.

Pure tungsten electrodes form stable hemispherical ends in AC welding, which optimizes arc distribution and energy transfer, reducing the risk of arc drift or interruption. Its high melting point and thermal conductivity ensure that the electrode remains stable during the thermal cycling of alternating currents, making it suitable for high-frequency or high-current welding conditions. In addition, the non-radioactive nature of pure tungsten electrodes makes it more advantageous in industries with high safety requirements (e.g., food processing equipment, medical device manufacturing), and is more compliant with environmental regulations than thoriated tungsten electrodes (containing radioactive thorium oxide).

AC welding applications for pure tungsten electrodes cover the construction, marine, aerospace and automotive industries. For example, in the welding of aluminium ship structures, pure tungsten electrodes provide smooth, defect-free welds that meet corrosion resistance and strength requirements. In the aerospace sector, the precision welding of aluminum and magnesium alloys relies on the stable arc of pure tungsten electrodes, which ensures high reliability of components. In conclusion, the expertise of pure tungsten electrodes in AC welding makes it the material of choice for light metal welding.

8.2 Disadvantages of pure tungsten electrode

Despite the significant advantages of pure tungsten electrodes, their performance limitations limit their application in certain welding scenarios, especially in DC welding and high temperature and high load conditions. The following analyzes its disadvantages from three aspects.

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8.2.1 Poor DC welding performance

The performance of pure tungsten electrodes in DC welding (DC) is poor, mainly due to its high electron work (about 4.52 eV), which leads to difficult arc initiation and arc instability. In DC positive connection (DCSP), the electrode needs to emit a large number of electrons as the cathode, and the high electron work requires a higher arcing voltage, which is prone to no arcing or arc jumping. In reverse DC polarity (DCRP), the electrode acts as an anode under a higher thermal load, which can lead to overheating, burning, or end deformation.

In contrast, electrodes doped with rare earth oxides (e.g., cerium-tungsten electrodes, have about 2.7-3.0 eV; Lanthanum tungsten electrode, approx. 2.8-3.2 eV) has a lower arc starting voltage and a more stable arc in DC welding, and is widely used in the welding of stainless steel, carbon steel and nickel alloys. Due to the limitations of pure tungsten electrodes in DC welding, their applications are mainly limited to low-demand scenarios, such as temporary repair or low-current welding, while doped electrodes are mostly used in high-precision or high-efficiency DC welding.

To alleviate this shortcoming, arc initiation performance can be improved by means of a high-frequency arc striking device or by optimizing the angle at the end of the electrode (e.g., a cone), but the effect is limited. In addition, arc instability in DC welding can lead to uneven welds or increased defects, limiting the competitiveness of pure tungsten electrodes in high-performance welding.

8.2.2 High electrode consumption rate

Tungsten electrodes have a high electrode consumption rate, especially in high currents (>200 A) or long-term continuous welding, because of the high electron work escape, which leads to a high end temperature, which accelerates the volatilization and burning loss of the material. The consumption is manifested by the gradual shortening of the electrode length and the change of end morphology, such as from hemispherical to irregular shape, which affects the stability of the arc and the quality of the weld.

In AC welding, the formation of hemispherical ends partially slows down consumption, but the consumption rate is still high at high frequencies or unstable currents. In DC welding, the consumption rate is even more significant, especially in DC forward connection (DCSP), where the high temperature operation of the electrodes results in rapid material loss. In contrast, doped electrodes (e.g., lanthanum tungsten electrodes) typically have lower consumption rates than pure tungsten electrodes due to lower electron escape work and more stable end morphology.

The high consumption rate increases the frequency of electrode changes and operating costs, which can lead to production interruptions, especially in automated welding. In order to extend the life of the electrode, the ends need to be sharpened regularly to maintain the proper shape and the welding parameters (e.g., reduced current, increased gas protection) should be optimized. However, frequent grinding increases labor and time costs, which limits the application of pure tungsten electrodes in high-load welding.

8.2.3 Difficulty in arcing and unstable arc

Difficult arc initiation and arc instability are the main disadvantages of pure tungsten electrode, which are closely related to its high electron escape work. In DC welding, high arcing voltages and erratic electron emission make it difficult to initiate or maintain an arc, especially at low currents (<50 A) or high frequencies. In AC welding, the alternating effect of positive and negative half-cycles of alternating current can partially alleviate the difficulty of arcing, but a higher arcing voltage is still required.

Arc instability is manifested as arc drift, jumping, or interruption, affecting the uniformity and quality of the weld. Surface contamination (e.g., oxides, oils) or improper end morphology (e.g., excessive wear) can further exacerbate instability, requiring regular cleaning and sanding of the electrode. In addition, pure tungsten electrodes have high requirements for welding equipment, which need to be equipped with high-frequency arc striking device or stable power supply to improve arc initiation performance.

Compared with doped electrodes, pure tungsten electrodes have poor arc stability, especially in DC welding. Cerium-tungsten and lanthanum tungsten electrodes reduce the electron work through the doping of rare earth oxides, which significantly improves the arc initiation performance and arc stability, and is suitable for a variety of welding scenarios. This shortcoming of pure tungsten electrodes limits its application in high-precision and high-efficiency welding, which needs to be compensated for by process optimization or equipment improvement.

8.3 Improvement direction of pure tungsten electrode

In order to overcome the shortcomings of pure tungsten electrodes and improve their competitiveness, researchers and enterprises are exploring improvement paths from three directions: process optimization, alloying research and development of new electrode materials. These improvements are aimed at improving the welding performance of the electrodes, reducing the consumption rate and broadening the range of applications.

8.3.1 Process optimization

Process optimization is a direct way to improve the performance of pure tungsten electrodes, focusing on production process improvement and welding parameter optimization. On the production side, the quality of the electrodes can be improved by:

High purity control: The purity of tungsten powder is increased to 99.99% by using advanced purification technologies such as ion exchange and solvent extraction, and the influence of impurities on arc initiation performance and arc stability is reduced. Optimize the reduction and sintering processes, reduce the oxygen content (e.g., ≤0.01%), and improve the conductivity and high temperature resistance of the electrode.

Grain refinement: Grain growth is controlled by rapid sintering techniques (e.g., discharge plasma sintering, SPS) or the addition of trace inhibitors (e.g., alumina) to obtain a fine and uniform grain structure (10-20 μm). Grain refinement improves the hardness and toughness of the electrode and reduces the consumption rate at high temperatures.

Surface quality improvement: Improve polishing and cleaning processes, reduce surface roughness, and reduce the interference of surface defects on arc stability. Automatic polishing equipment is used to ensure surface consistency and improve the welding performance of the electrode.

In welding applications, the performance of pure tungsten electrodes can be improved by optimizing parameters and equipment. For example, the current waveform (e.g., square wave AC) can be adjusted to reduce the arcing voltage and the flow rate of argon or helium shielding gas (10-20 L/min) can be increased to enhance arc stability. In addition, the high-frequency arc initiation device and the advanced TIG welding machine can significantly improve the difficulty of arcing, which is suitable for DC welding scenarios.

The advantages of process optimization are low cost, proven technology, and rapid implementation on top of existing production. The disadvantage is that the improvement range is limited, and it is difficult to completely overcome the fundamental limitation of high electron work outcome.

8.3.2 Alloying studies

Alloying studies improve the electrical and mechanical properties of pure tungsten by adding trace elements to its matrix, while retaining cost advantages and non-radioactive properties. The goal of alloying is to reduce the work of electron evolution, improve arc stability, and reduce the consumption rate, and common research directions include:

Trace rare earth doping: Rare earth oxides (e.g., lanthanum oxide, cerium oxide) are added to pure tungsten at a low content (<0.5%) to reduce electron work (to 4.0-4.2 eV) and improve arc initiation performance and arc stability. Trace doping retains the cost advantage of pure tungsten while improving DC welding performance.

Non-rare earth element doping: Explore the addition of non-rare earth oxides such as zirconia (ZrO_2) or yttrium oxide (Y_2O_3) to enhance the high-temperature strength and creep resistance of the electrode, and reduce the consumption rate. These elements are non-radioactive and meet environmental requirements.

Composite doping: Combine a variety of oxides (such as lanthanum oxide + zirconia) for compound doping to optimize the comprehensive performance of the electrode. Composite doping balances arc initiation performance, arc stability and durability, making it suitable for high-load welding.

Alloying studies need to accurately control the distribution and content of doped elements to avoid performance fluctuations caused by inhomogeneous doping. Modern production techniques (e.g. plasma doping, chemical vapor deposition) enable highly homogeneous doping and improved electrode quality. However, alloying can increase production costs and process complexity, requiring a trade-off between performance gains and economics.

8.3.3 Development of new electrode materials

The development of new electrode materials aims to fundamentally overcome the limitations of pure tungsten electrodes, and explore materials with lower electron escape work, higher durability and wider applicability. His research interests include:

Nanocrystalline tungsten electrode: Nano-tungsten powder (particle size < 100 nm) is used to prepare electrodes, and the hardness, toughness and arc stability are improved by ultra-fine grain structure. The electron work of the nanocrystalline tungsten electrode is slightly lower than that of the traditional tungsten electrode, and the arc initiation performance is improved. Rapid sintering techniques, such as SPS, are the key to the realization of nanocrystalline electrodes.

Tungsten matrix composites: The development of composite electrodes of tungsten and highly conductive materials (such as copper and graphene) combined with the high melting point of tungsten and the excellent conductivity of composite materials (>50% IACS) significantly reduces the arcing voltage and electrode consumption. Composites need to address the challenges of interfacial bonding and high-temperature stability.

Novel non-radioactive electrodes: Explore alternative materials other than tungsten, such as molybdenum-based or hafnium-based alloys, as non-melting electrodes with low electron work of escape. These materials need to have a high melting point (>2000°C) and chemical stability, while remaining low cost and environmentally friendly.

The advantage of the development of new materials is that there is great potential to significantly improve electrode performance and broaden the field of application, such as semiconductor manufacturing, nuclear fusion equipment and welding of ultra-high-strength materials. The disadvantages are that the R&D cycle is long, the cost is high, and the promotion of new materials needs to go through strict industry certification and market verification. In the future, the development of new electrode materials will promote the innovation of welding technology, and it is necessary to accelerate the implementation of technology in combination with industry-university-research cooperation.

pure tungsten electrode with sharp tip

Chapter 9 Market and Development Trend of Pure Tungsten Electrode

As an important consumable for tungsten argon arc welding (TIG welding), pure tungsten electrode (WP electrode) occupies an important position in the global welding industry. Its market development is affected by multiple factors such as raw material supply, production technology, environmental protection requirements and international competition. This chapter will analyze the global market overview, the current situation of the Chinese market, the technology development trend and the challenges faced by the pure tungsten electrode, and provide a comprehensive reference for industry practitioners and researchers.

9.1 Overview of the global tungsten electrode market

The global market for pure tungsten electrodes is closely related to the development of the welding industry, which is widely used in aerospace, automobile manufacturing, shipbuilding and construction. The following is a review of the current state of the global market in terms of major producing countries and market size and demand.

9.1.1 Major producing countries

The global production of pure tungsten electrodes is concentrated in countries with abundant tungsten resources and technologically advanced industrial powers, mainly including China, the United States, Germany, Japan and Russia.

China: As the world's largest tungsten resource (accounting for about 50% of global reserves), China dominates the production of pure tungsten electrodes. Hunan, Jiangxi and Henan have abundant tungsten ore resources, forming a complete industrial chain from tungsten ore mining to electrode production.

United States: The United States is an important producer of pure tungsten electrodes, with advanced production technology and strict quality standards. The company focuses on high-performance tungsten electrodes, which are widely used in the aerospace and nuclear industries. The U.S. market is dominated by high-end applications, focusing on the promotion of non-radioactive electrodes such as pure tungsten and cerium tungsten electrodes.

Germany: Germany is known for its precision manufacturing, producing high-quality pure tungsten electrodes for the automotive, aerospace and mechanical engineering industries. The company uses advanced powder metallurgy and surface treatment technologies to export to Europe and the world in accordance with DIN EN ISO 6848.

Japan: Tungsten electrode production in Japan is mainly high-precision and miniaturized to meet the needs of the electronics, automotive, and precision machinery industries. The company pays attention to the surface quality and welding performance of the electrode, and the products meet the JIS Z 3233 standard. There is a high demand for small-diameter electrodes (0.5-2.0 mm) in the Japanese market.

Russia: Russia has abundant tungsten ore resources and low production costs, and its pure tungsten electrodes are mainly supplied to the domestic and Eastern European markets. Enterprises have advantages in the production of low-cost electrodes, but their technical level and brand influence are relatively weak.

These countries have formed a competitive pattern in the global pure tungsten electrode market, with China leading the way in terms of output and cost, the United States, Germany and Japan occupying the high-end market with technology and services, and Russia supplementing the low-end market with resource advantages.

9.1.2 Market size and demand

The global tungsten electrode market size has kept pace with the growth of the welding industry, driven by manufacturing, infrastructure construction and new energy industries. According to industry data, the global tungsten electrode market size will be about $1.5 billion in 2024, of which pure tungsten electrodes will account for about 30%-35%, or $4.5-525 million. The market size is expected to grow at a compound annual growth rate (CAGR) of 3%-5% to reach $6-700 million by 2030, driven by:

Aerospace demand: The increasing demand for precision welding of aluminum and magnesium alloys in the aerospace sector is driving the application of pure tungsten electrodes in AC welding. For example, Boeing and Airbus' aircraft manufacturing requires high-reliability welds, and pure tungsten electrodes are key consumables.

Development of the automotive industry: The global automotive industry is transforming to lightweighting, and the welding demand for aluminum alloy and stainless steel is growing. Pure tungsten electrodes are widely used in the production of automotive parts (such as car bodies and battery housings), especially in the field of new energy vehicles.

Infrastructure: Infrastructure construction (e.g., high-speed rail, bridges, buildings) in Asia, Africa and Latin America has driven the demand for welding of aluminum structural parts, and pure tungsten electrodes are favored due to their cost advantages.

New energy industry: The manufacture of solar cells and wind power equipment involves thin film deposition and metal bonding, and the demand for pure tungsten electrodes as sputtering targets and welding materials is growing steadily.

In terms of geographical distribution, the Asia-Pacific region (mainly China, India and Southeast Asia) accounts for about 50% of the global market share, benefiting from the rapid development of manufacturing and low-cost production. North America and Europe each account for 20%-25%, with high-end applications dominantly. The Middle East and Africa has a smaller market share (around 5%), but demand potential is becoming apparent as industrialization accelerates.

9.2 China Tungsten Electrode Market Analysis

China is the world's largest producer and consumer of pure tungsten electrodes, and its market development is affected by the advantages of domestic tungsten resources, manufacturing upgrading and environmental protection policies. The following analyzes the Chinese market from two aspects: production capacity and market demand and application fields.

9.2.1 Domestic production capacity

China's pure tungsten electrode production capacity ranks first in the world, relying on rich tungsten ore resources and perfect industrial chain. In 2024, China's annual production capacity of tungsten electrodes will be about 25,000 tons, of which pure tungsten electrodes will account for about 40%, or 10,000 tons. Zhuzhou in Hunan, Ganzhou in Jiangxi Province and Luoyang in Henan Province are the main production bases, forming a complete industrial chain from tungsten ore mining, tungsten powder preparation to electrode processing.

The advantages of China's production capacity are low cost, large scale and stable supply chain. In recent years, domestic enterprises have improved production efficiency and product quality by introducing advanced equipment (such as vacuum sintering furnaces in Germany and automatic wire drawing machines in Japan). At the same time, some enterprises have increased R&D investment, developed ultra-fine tungsten powder and nanocrystalline electrodes, and gradually narrowed the technological gap with European and American countries.

However, China's production capacity is also facing environmental pressures and overcapacity. Tungsten mining and purification involves high energy consumption and wastewater discharge, which is subject to the requirements of the Environmental Protection Law and the National

Hazardous Waste List. Overcapacity has led to fierce competition in the low-end market, and price wars have compressed profit margins, prompting enterprises to transform into high-end markets.

9.2.2 CLP Market Needs and Demand Areas

China's pure electric market demand is about 12,000 tons, accounting for about 60% of the domestic electricity market.

Construction and infrastructure: The construction of high-speed rail, bridges and curtain walls has driven the growth of demand for aluminum alloy welding, and pure electric electricity is widely used in the construction field due to its cost advantage. For example, the welding of aluminum structural parts of the Beijing-Xiong'an Intercity Railway and the Shenzhen Bay Supertall Building relies on pure tungsten electrodes.

Automobile manufacturing: The battery shell, body and aluminum alloy parts of new energy vehicles need to be welded with high precision, and pure tungsten electrodes occupy an important position in AC welding. In 2024, China's new energy vehicle production will exceed 8 million units, driving the growth of electrode demand.

Aerospace: COMAC (e.g., C919 aircraft) and aerospace programs (e.g., Long March series rockets) have strict welding requirements for aluminum alloys and magnesium alloys, and pure tungsten electrodes are favored for their non-radioactive and stable performance.

Marine & Offshore Engineering: Shipbuilding and offshore platform construction in coastal areas involve a large number of aluminum alloy welding, and pure tungsten electrodes are in stable demand in these scenarios.

Electronics and new energy: In the manufacture of solar cells and semiconductors, the application of pure tungsten electrodes as sputtering targets and welding materials is gradually increasing.

The Chinese market is characterized by a diverse range of demands, ranging from low-cost general-purpose welding to high-performance precision welding. In the future, with the upgrading of the manufacturing industry and the advancement of the "Belt and Road" initiative, China's pure tungsten electrode market is expected to continue to expand at an average annual growth rate of 3%-4%, especially in high-end applications.

9.3 Development trend of pure electric electrode technology

The development of pure electric electrodes is driven by high-efficiency power generation, environmental requirements, and new material research and power, with the aim of improving performance, reducing costs, and meeting regulatory requirements. The following three aspects of technology trends are discussed.

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Pure Tungsten electrode Introduction

1. Overview of Pure Tungsten Electrode

Pure tungsten electrodes are electrode materials made primarily from high-purity tungsten (content ≥99.95%) through powder metallurgy processes, including pressing, sintering, forging, and precision machining. They contain no rare earth or alloying elements, making them the most basic type of tungsten electrodes. They are widely used in welding and plasma applications that require high temperatures and high current density.

2. Main Applications of Pure Tungsten Electrode

TIG Welding (Tungsten Inert Gas Welding): Especially suitable for DC welding of reactive metals such as magnesium, aluminum, and titanium (using DCEN).

Plasma Cutting and Spraying: Used as electrode materials for high-temperature ion sources.

Electronic Devices: Serves as cathodes or supporting components in vacuum devices such as electron tubes and discharge tubes.

High-Temperature Furnace Electrodes: Used as heating electrodes in resistance furnaces operating in inert atmospheres or vacuum environments.

Scientific Research and Experimental Applications: Involved in high-temperature and high energy-density experiments.

3. Basic Data of Pure Tungsten Electrode

Item	Parameter
Chemical Composition (W)	≥99.95%
Melting Point	3410°C
Density	19.3 g/cm³
Electrical Conductivity (20°C)	~30% IACS
Hardness (HV)	340 – 400 HV
Thermal Conductivity	170 W/(m·K)
Operating Current Range	DCEN, depends on diameter and base metal
Electrode Diameter Range	Ø0.5 mm ~ Ø6.4 mm (customizable)
Electrode Length	Standard lengths: 150 mm and 175 mm (customizable)
Applicable Standard	ISO 6848 (Tungsten electrodes for welding)

4. Supply Form and Packaging of Pure Tungsten Electrode

Form: Polished rods, with customized ground tips

Standard Packaging: 10 pieces per plastic box, outer carton with shock-resistant protection

Customization: Dimensions, packaging, and tips can be customized

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696

Website: www.tungsten.com.cn

9.3.1 Technologies for efficient electricity production

Efficient production technologies aim to shorten cycle times, reduce energy consumption and improve product quality, and the main technologies include:

Continuous production: develop continuous sintering furnace and automatic wire drawing equipment to achieve continuous production from pressing to processing, and shorten the production cycle by 20%-30%. For example, the medium frequency induction continuous sintering furnace heats up quickly and improves the homogeneity of the green body.

Smart manufacturing: Optimize equipment operating efficiency by monitoring production parameters with the Industrial Internet of Things (IIoT) and sensors. The intelligent production equipment line equipment can detect the density and size deviation of the green body in real time to reduce the scrap rate.

Rapid sintering technology: Discharge plasma sintering (SPS) uses electrical pulses to shorten the sintering time to minutes, refine the grain (<10 μm), and improve the strength and durability of the electrode. SPS has been piloted in the production of high-end electrodes.

The application of these technologies will promote the improvement of production efficiency, reduce unit costs, and enhance market competitiveness. However, high equipment investment and maintenance costs may limit its promotion in SMEs.

9.3.2 Environmentally-friendly production processes

Eco-friendly processes are the focus of responding to regulatory pressures and green manufacturing needs, and key technologies include:

Low-energy purification: Ion exchange and membrane separation technology are used to replace traditional hydrometallurgy and reduce wastewater and exhaust gas emissions. The new purification equipment can recover more than 90% of tungsten-containing waste liquid and reduce environmental pollution.

Waste recycling: Establish a tungsten waste recycling system to recover tungsten powder through high-temperature roasting and electrolytic reduction to reduce resource waste. Some companies in China have developed processes with a recycling rate of 80 percent.

Non-toxic process substitution: Promote water-based cleaning agents and non-toxic green paints (such as acrylic-based paints) to replace traditional organic solvents and lead-containing paints, in line with the EU REACH regulation and China's RoHS standards.

Powered by renewable energy: Reducing the carbon footprint by using solar or wind power to power sintering and thermal processing equipment. Pilot projects have shown that renewable energy can reduce production energy consumption by 30%.

The promotion of environmentally friendly processes needs to balance cost and compliance, but with the tightening of environmental protection regulations and the enhancement of consumers' green awareness, its market acceptance has gradually increased.

9.3.3 Research and development of new tungsten electrode

The research and development of new tungsten electrodes aims to overcome the performance limitations of pure tungsten electrodes and meet the needs of high-performance welding, and the main directions include:

Nanocrystalline tungsten electrode: The electrode is prepared by using nano-tungsten powder to improve the hardness and arc stability by ultra-fine grains (<50 nm). The arc initiation performance and consumption rate of nanoelectrodes are better than those of conventional electrodes, making them suitable for the aerospace and semiconductor industries.

Microalloyed electrode: Trace oxidation (e.g., zirconia, yttrium oxide) is added to pure tungsten to reduce the work of electron evolution (to 4.0-4.2 eV) and improve DC welding performance. The microalloyed electrode retains the cost advantage and non-radioactive properties of pure tungsten.

Tungsten-based composite electrodes: Development of composite materials of tungsten and graphene or carbon nanotubes, combined with high melting point and excellent electrical conductivity (>40% IACS), significantly improve curing and durability. The composite electrode needs to solve the problem of interfacial stability at high temperatures.

The research and development of new electrodes needs to be combined with market demand and production feasibility, for example, the production cost of nanoelectrodes needs to be further reduced to achieve large-scale application. In the future, industry-university-research cooperation and international technical exchanges will accelerate the industrialization process of new electrodes.

9.4 Challenges of surface electricity for pure electric electrode

Although the pure electric electrode market is developing rapidly, it faces multiple challenges, including fluctuating raw material prices, environmental regulatory pressures and technological competition.

9.4.1 Fluctuations in the price of raw materials

As a rare metal, the price of tungsten is affected by global supply and demand, geopolitics and mineral policies. In 2024, the price of tungsten concentrate will fluctuate between RMB 120,000 and RMB 150,000 per ton, affecting the production cost of pure tungsten electrodes. The main reasons for the price increase include:

Resource constraints: China's quota management for tungsten mining has limited supply growth.
Export demand: The increased demand for non-radioactive electrodes in Europe and the United States has pushed up the international price of tungsten.

Geopolitical risks: Geopolitical events such as the Russia-Ukraine conflict could disrupt Russian tungsten supply.

Price fluctuations increase the uncertainty of production costs, especially for small and medium-sized enterprises. Strategies include long-term contracts with suppliers, development of tungsten scrap recycling technologies and the exploration of alternative materials, but raw material price volatility will remain a major risk in the near term.

9.4.2 Environmental Regulatory Pressure

Tungsten electrode production involves high energy consumption and polluting emissions, and is subject to increasingly stringent environmental regulations, such as China's Environmental Protection Law and the European Union's Waste Framework Directive. Challenges include:
Wastewater treatment: Tungsten-containing wastewater from tungsten purification and cleaning needs to be treated to a heavy metal content of less than 0.01 mg/L, which increases the treatment cost.
Exhaust gas control: The dust and tungsten oxide gas generated by sintering and grinding need to be treated by high-efficiency filtration and adsorption, and the equipment investment is high.
Energy consumption constraints: China's "dual carbon" goals (carbon peaking and carbon neutrality) require enterprises to reduce unit energy consumption, and traditional energy-intensive processes are at risk of being phased out.

The cost of compliance with environmental regulations can crowd out R&D funding and affect technological innovation. Companies need to reduce compliance costs through green processes and renewable energy applications, while securing government subsidies and green financial support.

9.4.3 International Competition and Technological Barriers

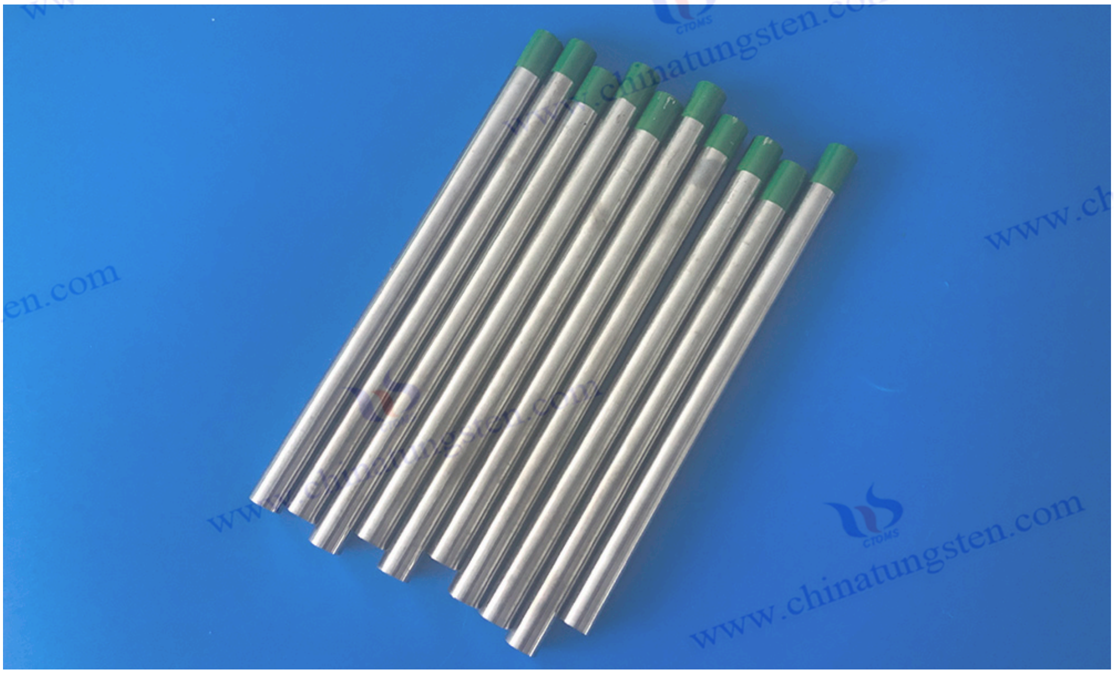
The pure electric electrode market is highly competitive, and international competition and technical barriers are the main challenges:

High-end market barriers: American, German, and Japanese companies occupy the high-end market with advanced technologies (such as SPS sintering and nanocrystalline processing), and brand effect and technology patents limit the entry of Chinese companies.

Low-end market competition: Low-cost producers in countries such as China, Vietnam, and India are engaged in price wars in low-end markets, and profit margins continue to decline.

Technology gap: European and American companies are leading in the field of new electrode materials (such as composite tungsten electrodes) and intelligent manufacturing, while Chinese companies still need to make breakthroughs in core equipment (such as high-precision wire drawing machines) and high-end processes.

To cope with international competition, it is necessary to strengthen technology research and development, brand building and international cooperation. For example, by cooperating with German companies to introduce advanced equipment, or by participating in the development of international standards such as ISO, we can raise our voice. In addition, differentiated competitive strategies (e.g., customized electrodes, green certification) can help companies break through market barriers.



pure tungsten electrodes from CTIA GROUP LTD

Chapter 10 Conclusions

As the core consumable of tungsten argon arc welding (TIG welding), pure tungsten electrode (WP electrode) has played an important role in welding and other industrial fields due to its high melting point, cost advantage and non-radioactive characteristics. This book systematically expounds the preparation process, production equipment, testing methods, domestic and foreign standards, market status and advantages and disadvantages of pure tungsten electrodes, and comprehensively demonstrates its technical characteristics and application value. This chapter will make a comprehensive evaluation of pure tungsten electrodes, look forward to its future development direction, and put forward suggestions for research and application, in order to provide reference for industry practitioners and researchers.

10.1 Comprehensive evaluation of pure tungsten electrode

As the earliest non-melting electrode type used in TIG welding, the performance and application characteristics of pure tungsten electrode have been fully verified in long-term practice. The following is a comprehensive evaluation from four aspects: technical performance, application scenarios, economy and environmental protection.

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Technical performance

The pure tungsten electrode is composed of high-purity tungsten (≥99.5%), which has a very high melting point (3422°C), excellent thermal conductivity (about 173 W/m·K) and low vapor pressure, which enables it to maintain structural stability and end morphological integrity in high-temperature arc environment (6000-7000°C). These properties make it particularly good in AC welding (AC), especially for welding light metals with oxide films, such as aluminum, magnesium and their alloys. In AC welding, pure tungsten electrodes achieve the effect of "cathodic cleaning" through the alternating action of positive and negative half-cycles, effectively removing the oxide layer (such as Al_2O_3, melting point of about 2050°C), forming a clean, high-quality weld.

However, the high electron work (about 4.52 eV) of pure tungsten electrodes leads to its arc initiation and arc instability in direct current welding (DC), which limits its competitiveness in welding applications of stainless steel, carbon steel and other materials. In addition, the electrode consumption rate is high, especially at high currents (>200 A) or during long continuous welding, where the end material is volatile, resulting in shorter lengths and reduced performance. Compared with doped electrodes (such as cerium tungsten and lanthanum tungsten electrodes, the electron work of about 2.7-3.2 eV) is slightly inferior in comprehensive welding performance, but it still has irreplaceable advantages in specific scenarios.

The high density (19.3 g/cm³), hardness (HV 350-450) and chemical stability of pure tungsten electrodes make them ideal for resistance welding electrodes, plasma cutting electrodes, thermoelectron emission materials, sputtering targets and counterweights in non-welding applications. For example, in semiconductor manufacturing, pure tungsten electrodes can be used as sputtering targets to form high-quality tungsten films; In the aerospace sector, its high-density counterweights are used to optimize structural balancing. Overall, the technical performance of pure tungsten electrodes is excellent in applications requiring high temperature, high precision and non-radioactivity, but its versatility needs to be further improved through process optimization.

Economical

One of the significant advantages of pure tungsten electrodes is their low production costs. Compared with doped electrodes, pure tungsten electrodes do not need to add rare earth oxides (such as cerium oxide, lanthanum oxide), which avoids expensive raw materials and complex doping processes, and reduces production costs. The global tungsten resources are abundant (China accounts for about 50% of the reserves), the supply chain is stable, and the price fluctuation of tungsten concentrate is relatively controllable (about 12-150,000 yuan/ton in 2024). In addition, the production process of pure tungsten electrodes (such as powder metallurgy, pressure processing) has been highly mature, and large-scale production has further reduced the unit cost.

In applications, the low cost of pure tungsten electrodes makes them widely attractive in cost-sensitive industries such as construction, shipbuilding, and general machining. For example, pure tungsten electrodes are often used for the welding of aluminum curtain walls, ship structures and automotive parts to balance quality and cost. However, its high consumption rate and frequent grinding requirements increase the cost of use, especially in high-load welding, which requires more frequent electrode replacement, which indirectly increases the operating cost. Overall, pure tungsten electrodes have obvious advantages in cost-sensitive applications, but there is a trade-off between performance and economy in high-performance scenarios.

Environmental friendliness and safety

The non-radioactive nature of pure tungsten electrodes is that they are more radioactive than thoriated tungsten electrodes (containing radioactive thorium oxide, ThO_2) of significant advantages. The radioactivity of thorium-tungsten electrodes (gamma dose rate of about 1-10 μSv/h) poses a safety hazard in production, storage and disposal, while the dose rate of pure tungsten electrodes is close to the background radiation level (about 0.1 μSv/h), which is in line with the EU REACH regulation and China's RoHS standard. This property makes it even more attractive in safety-critical fields such as food processing equipment, medical devices, and aerospace.

However, the environmental protection issues in the production process of pure tungsten electrodes cannot be ignored. Tungsten ore purification and sintering involves high energy consumption and waste water emissions, such as tungsten-containing waste liquid and tungsten oxide vapor need to be strictly treated to comply with the requirements of the Environmental Protection Law and other regulations. In recent years, companies have reduced their environmental impact by adopting technologies such as ion exchange, waste recycling, and renewable energy sources such as solar power, but the cost of compliance remains a challenge for SMEs. Overall, pure tungsten electrodes have inherent advantages in terms of environmental protection and safety, but the production process needs to be further optimized to achieve green manufacturing.

Application scenarios

The application scenarios of pure tungsten electrodes are mainly focused on AC TIG welding, especially suitable for the welding of aluminum, magnesium and their alloys, and are widely used in aerospace, automobile manufacturing, shipbuilding and construction industries. For example, in the aerospace field, pure tungsten electrodes are used for the welding of aluminum alloy fuselages and magnesium alloy parts of C919 aircraft; In the automotive industry, it plays an important role in the welding of battery housings for new energy vehicles. In addition, tungsten electrodes are also widely used in non-welding applications such as plasma cutting, sputtering targets and counterweights, demonstrating their versatility.

However, its limitations in DC welding limit its welding applications in stainless steel, nickel alloys, and other materials, and doped electrodes are more advantageous in these scenarios. In addition, the rapid consumption and high maintenance requirements of pure tungsten electrodes in high-load or high-frequency welding also limit their competitiveness in automated production. Overall, pure tungsten electrodes have unique advantages in AC welding and specific non-welding areas, but further improvement is needed in general-purpose and high-performance applications.

10.2 Future development prospect of pure tungsten electrode

With the transformation and upgrading of the global manufacturing industry, the rise of the new energy industry and the increasingly stringent environmental protection regulations, the future development of pure tungsten electrodes will be driven by technological innovation, market demand and policy guidance. The following is an outlook on its future trends from three aspects: technological progress, market expansion and green development.

Technological advancements

Technological progress is the key to improving the performance and competitiveness of pure tungsten electrodes, and future development will focus on the following directions:

High purity and grain optimization: Through advanced purification technologies such as ion exchange and solvent extraction, the purity of tungsten powder is increased to 99.99%, and the influence of impurities (such as oxygen and iron) on arc stability is reduced. Rapid sintering technologies such as Discharge Plasma Sintering (SPS) can refine grains to less than 10 μm, improve the hardness and durability of the electrode, and reduce the consumption rate. The research and development of nanocrystalline tungsten electrode will further enhance the arc initiation performance and arc stability, and expand its application in DC welding.

Smart Manufacturing & Automation: The Industrial Internet of Things (IIoT) and sensor technology will drive the intelligent transformation of production lines. For example, intelligent systems that monitor sintering furnace temperature, wire drawing machine tension and electrode surface quality in real time reduce scrap rates and increase productivity. The popularization of automated production lines (such as continuous sintering furnaces, robotic polishing equipment) will shorten the production cycle by 20%-30% and reduce labor costs.

Development of new materials: Microalloyed electrodes (such as adding zirconia or yttrium oxide) and tungsten-matrix composites (such as tungsten-graphene composite electrodes) will become hot spots in R&D. These materials reduce the work of electron evolution (to 4.0-4.2 eV) and improve DC welding performance while retaining the cost advantage and non-radioactive properties of pure tungsten. The industrialization of new electrodes needs to solve the problems of cost control and process stability, and it is expected to achieve large-scale application in the next 5-10 years.

Technological advancements will significantly improve the performance of pure tungsten electrodes, making them more competitive in high-precision and high-load welding, and at the same time promote their application in emerging fields such as semiconductors and the nuclear industry.

Market expansion

The global pure tungsten electrode market is expected to grow at a compound annual growth rate (CAGR) of 3%-5%, and the market size is expected to reach $6-700 million by 2030. Drivers of market expansion include:

Growth in emerging markets: Rapid growth in manufacturing and infrastructure construction in the Asia-Pacific region (China, India, Southeast Asia) is driving the demand for pure tungsten electrodes. For example, high-speed rail projects in India and port construction in Southeast Asia will increase the demand for aluminum alloy welding, and the cost advantage of pure tungsten electrodes makes it dominant in these markets.

New energy and high-tech industries: The demand for high-purity tungsten materials in solar cells, wind power equipment and semiconductor manufacturing is increasing, and pure tungsten electrodes are used as sputtering targets and welding materials. For example, thin-film deposition in the photovoltaic industry and battery manufacturing for new energy vehicles will drive demand for electrodes.

Breakthrough in high-end applications: With the optimization of the production process, pure tungsten electrodes will gain more opportunities in precision welding in the aerospace and nuclear industries. For example, the demand for non-radioactive, high-performance electrodes in projects such as the International Thermonuclear Experimental Reactor (ITER) will promote the technological upgrading and market expansion of pure tungsten electrodes.

However, market expansion needs to deal with competition and international trade barriers for doped electrodes. European and American companies occupy the high-end market with their technological advantages, and Chinese companies need to enhance their competitiveness through brand building and differentiated products such as customized electrodes. In addition, the Belt and Road Initiative (BRI) provides Chinese companies with access to markets in the Middle East, Africa and Latin America, and needs to seize policy dividends to expand exports.

Green development

Environmental protection and sustainable development are long-term trends in the pure tungsten electrode industry, driven by the global "carbon neutrality" goal and environmental regulations. Future directions include:

Green production process: Adopt low-energy purification technology (such as membrane separation) and waste recycling system to reduce wastewater and exhaust gas emissions. The pilot project has shown that the waste recycling rate can reach 80%, significantly reducing resource waste. The use of renewable energy (e.g. solar, wind power) in sintering and thermal processing can reduce carbon emissions by 30%.

Promotion of non-toxic materials: Promote water-based green paints and non-toxic cleaning agents to replace traditional lead-containing paints and organic solvents, in line with EU REACH regulations and China RoHS standards. These materials reduce environmental pollution and health risks, and increase product market acceptance.

Circular economy model: establish a recycling system for tungsten electrodes, recycle used electrodes through high-temperature roasting and electrolytic reduction, and reduce dependence on primary tungsten ore. The circular economy model can reduce the cost of raw materials by 20%-30% while enhancing the green image of enterprises.

Green development not only meets regulatory requirements, but also enhances corporate social responsibility and market competitiveness. In the future, green certifications (e.g. ISO 14001) will be the passport for pure tungsten electrodes to enter the international market.

10.3 Research and application suggestions of pure tungsten electrode

Based on the comprehensive evaluation and future development trend of pure tungsten electrode, the following research and application suggestions are put forward from four aspects: technology research and development, production optimization, application promotion and policy support.

Technology research and development

Development of high-performance electrodes: Increase R&D investment in nanocrystalline tungsten electrodes and microalloyed electrodes, and reduce electron work by adding trace oxides (such as yttrium oxide and zirconia) to improve DC welding performance. Industry-university-research cooperation can accelerate the laboratory validation and industrialization of new electrodes.

Process optimization research: develop rapid sintering technology and intelligent production equipment to refine the grain structure and improve production efficiency. For example, SPS sintering technology is promoted to shorten the sintering time to the minute level and reduce energy consumption. The application of sensors and artificial intelligence technology enables real-time optimization of production parameters.

Detection technology upgrade: Develop online detection technology (such as laser-induced breakdown spectroscopy, LIBS) to achieve real-time analysis of chemical composition and microstructure, and improve quality control efficiency. Establish a unified database of testing standards to promote international mutual recognition of test results.

Production optimization

Automation and intelligence: Promote automated production lines and intelligent monitoring systems, covering the whole process from tungsten powder pressing to surface treatment. For example, continuous wire drawing machines and robotic polishing equipment can increase production efficiency by 15%-20%. Data analysis platforms, such as SCADA systems, optimize process parameters and reduce scrap rates.

Green manufacturing implementation: Invest in environmentally friendly equipment (e.g., high-efficiency filters, wet scrubbers) to treat production wastewater and exhaust gases to ensure compliance with environmental regulations. Promote renewable energy to reduce your carbon footprint. Establish a waste recycling system to improve resource utilization.

Supply chain management: Signed long-term contracts with tungsten ore suppliers to stabilize raw material prices. Develop tungsten scrap recycling technology to reduce dependence on primary tungsten ore. Strengthen the digital management of the supply chain, monitor inventory and logistics in real time, and improve the response speed.

App promotion

Customized products: According to the needs of aerospace, automotive and new energy industries, we develop customized pure tungsten electrodes, such as small diameter electrodes (0.5-1.0 mm) for the electronics industry, and large diameter electrodes (4.0-6.4 mm) for shipbuilding. Customized products can enhance market competitiveness.

International market expansion: Take advantage of the "Belt and Road" initiative to enter the Middle East, Africa and Latin American markets to promote low-cost, high-performance pure tungsten electrodes. Participate in international exhibitions (such as the Welding Exhibition in Essen, Germany) and apply for green certification (such as ISO 14001) to enhance brand influence.

Technical training and support: Provide users with welding parameter optimization and electrode use training to improve the performance of pure tungsten electrodes in DC welding. For example, high-frequency arc striking and square wave AC current settings are recommended to improve arc initiation performance and arc stability.

Policy support

Environmental policy guidance: The government can introduce subsidy policies to encourage enterprises to adopt green production technologies and renewable energy. Establish stricter tungsten mining and emission standards to promote the industry's transition to green manufacturing.

Technology R&D funding: Set up a special fund to support the R&D and industrialization of new tungsten electrodes, such as nanocrystalline electrodes and composite electrodes. Encourage industry-university-research joint research to accelerate technology transformation.

International cooperation and standard formulation: Participate in the revision of ISO and AWS standards to enhance China's voice in the formulation of tungsten electrode standards. Promote the international mutual recognition of test results, lower trade barriers, and promote export growth.

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Appendix

A. Glossary

WP Electrode: A tungsten electrode with a ≥ content of 99.5% tungsten, usually used for AC welding, with a green color code.

TIG Welding: The process of welding tungsten electrodes under the protection of inert gas.

Work function: The minimum amount of energy required for electrons to escape from the surface of a material.

Arc Stability: The ability of the arc to remain continuous and uniform during the welding process.

Powder Metallurgy: The technology of preparing materials by pressing and sintering metal powders.

Rare Earth Oxide: such as cerium oxide, lanthanum oxide, etc., additives used to improve the performance of tungsten electrodes.

Sintering: The process of heating powder particles to a temperature below the melting point to combine them into a dense material.

Arc Starting Performance: How easily the electrode can initiate an arc at the start of welding.

Penetration Depth: The melting depth of the arc to the workpiece material during welding.

Thermionic Emission: The phenomenon in which a material emits electrons at high temperatures.

Grain Growth: The phenomenon of increasing grain size at high temperatures, which may lead to a decrease in material properties.

AWS A5.12: Tungsten electrode standard developed by the American Welding Society.

ISO 6848: Standard for tungsten electrodes developed by the International Organization for Standardization.

Green Tip: The international color marking of pure tungsten electrodes.

DC Welding: A welding process that uses a DC power source.
AC Welding: A welding process that uses AC power.
Electrode Consumption Rate: The rate at which an electrode is lost during the welding process.
Thermal Expansion Coefficient: The rate of dimensional change of a material with temperature.
Electrical Conductivity: The ability of a material to conduct an electric current.
Creep Resistance: The ability of a material to resist slow deformation at high temperatures.

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