Encyclopedia of Tungsten Rods

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.

CTIA GROUP LTD
Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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Directory

Chapter 1 Introduction

1.1 Definition and overview of tungsten rods

Tungsten rod is a rod-shaped metal material made of tungsten (chemical element symbol W, atomic number 74) or its alloy as the main component, through powder metallurgy, forging, drawing or extrusion processes. Tungsten rods are known for their excellent physical, chemical and mechanical properties, including an extremely high melting point (3410°C), high density (19.25 g/cm³), excellent corrosion resistance and excellent mechanical strength. These properties make tungsten rods indispensable in many demanding industrial sectors such as aerospace, electronics, military, medical, and high-temperature manufacturing.

The basic composition of tungsten rod

Tungsten rods can be divided into three categories according to their composition: pure tungsten rods, high-purity tungsten rods and doped tungsten rods.

Pure tungsten rod: with high-purity tungsten (purity≥99.9%) as the main component, it is suitable for high-temperature, high-strength and corrosion-resistant environments, such as vacuum tube cathodes, X-ray tube targets and high-temperature furnace core rods in the electronics industry.
High Purity Tungsten Rod (≥ 99.95%): Tungsten with a purity of 99.95% or more and a very low impurity content (<50 ppm) is designed for semiconductor, medical and high-end electronic devices that require high cleanliness and precision, such as ion implantation device components and sputtering targets.
Doped tungsten rod (rare earth doping, oxide doping): Rare earth elements (such as cerium, lanthanum, yttrium) or oxides (such as thorium oxide, zirconia) are added to the tungsten matrix to improve arc stability, creep resistance and processing performance, and are widely used in welding electrodes (such as argon arc welding electrodes) and high-temperature furnace elements.

Shape and specification of tungsten rod

Tungsten rods come in a variety of forms, with diameters ranging from microns (e.g., drawn tungsten rods for filaments) to tens of millimeters (e.g., large-scale industrial tungsten rods). Their lengths are often customized to the needs of the application, ranging from a few centimeters to several meters. The surface condition also varies depending on the machining process, including black rods (unfinished with an oxide layer), polishing rods (smooth surface after machining) and polishing rods (with an extremely high surface finish for precision applications).

Preparation process of tungsten rod

Tungsten rods are usually prepared using powder metallurgy technology, and the basic process includes:

Tungsten powder preparation: high-purity tungsten powder is purified from tungsten ore (such as wolframite or scheelite).
Powder pressing and sintering: tungsten powder is pressed into a blank and sintered at high temperature (2000-3000°C) to form a dense sintered tungsten rod.

Deformation processing: further processing by hot forging, rotary swaging, rolling or drawing to improve the density and mechanical properties of the material.
Post-processing: including heat treatment, surface polishing, or cleaning to meet specific application needs.

Unique properties of tungsten rods
Tungsten rods are preferred for their unique combination of properties:

High melting point: Tungsten has the highest melting point of any metal and is suitable for extremely high temperature environments such as quartz furnaces and sapphire crystal furnaces.
High density: The proximity to gold density gives it an advantage in areas that require high-quality counterweights, such as aerospace balances.
Corrosion resistance: Tungsten has excellent corrosion resistance to most acids and bases at room temperature, and will only react slowly in high-temperature and strong oxidizing environments (such as nitric acid).
Mechanical strength: Tungsten rod still maintains high strength and creep resistance at high temperatures, and is suitable for long-term stressed parts.
Electrical and thermal conductivity: Although less conductive than metals such as copper, its stability at high temperatures makes it excellent in electrodes and filaments.

Classification and nomenclature of tungsten rods
Tungsten rods are often named based on their composition, use, or international standards. For example:

International standards: such as ASTM B760 (pure tungsten rod).
Doped tungsten rod grades: such as WT20 (2% thorium-doped tungsten rod), WL15 (1.5% lanthanum-doped tungsten rod), in line with AWS A5.12 standard.
Domestic standards, such as GB/T 4187-2017, specify the chemical composition, dimensional tolerances and performance requirements of tungsten rods. These nomenclature systems facilitate global trade and application, ensuring uniformity and traceability of material specifications.

Global tungsten rod market overview
As a high-performance material, tungsten rod is widely used in global industrial systems. China is the world's largest tungsten resource and tungsten product producer, accounting for more than 80% of global tungsten production, mainly exported to the United States, Europe and Japan. The production of tungsten rods is concentrated in a small number of specialized enterprises, and the market demand is mainly driven by semiconductor manufacturing, new energy, aerospace and defense industries.

Tungsten rod is environmentally friendly and sustainable
The production of tungsten rods involves tungsten ore mining and high-temperature processing, which is energy-intensive and can produce exhaust gases and residues. In recent years, green manufacturing technologies (e.g. low-energy sintering, waste recycling) have been adopted to

reduce environmental impact. In addition, the high durability and recyclability of tungsten rods make them sustainable throughout their life cycle.

1.2 The importance of tungsten rods in industry

Tungsten rods play a key role in global industries due to their excellent performance and are widely used in high-tech, demanding fields such as semiconductor manufacturing, aerospace, defense, energy, medical and lighting industries. Its importance is reflected in its unique properties that meet the material needs of extreme environments, driving technological progress and industrial efficiency. The importance of tungsten rods in industry is discussed in detail from multiple perspectives.

Core applications in high-temperature environments

The high melting point of tungsten rod (3410°C) makes it an irreplaceable material in high-temperature environments. In the quartz continuous melting furnace, the tungsten rod is used as a core rod to withstand extreme temperatures of more than 2000°C for the production of high-purity quartz glass, which is widely used in the optical fiber and semiconductor industries. Similarly, in a sapphire crystal furnace, tungsten rods are processed into crucibles or supports for the production of artificial sapphire crystals, which are used in LED substrates and optical windows. The creep resistance of tungsten rods ensures structural stability even under long-term high temperature stress, which is unmatched by other metal materials such as nickel and molybdenum.

The backbone of the semiconductor and electronics industries

Semiconductor manufacturing requires extremely high material purity and performance, and tungsten rods play an important role in this. For example, in the production of monocrystalline silicon, tungsten rods are used as heating elements or support structures for high-temperature furnaces to ensure the stability and uniformity of crystal growth. In addition, doped tungsten rods (such as cerium-doped or lanthanum-doped tungsten rods) are widely used as argon arc welding electrodes for precision welding of semiconductor equipment, and their excellent arc stability and wear resistance improve welding quality and efficiency. Tungsten rods are also processed into sputtering targets for use in physical vapor deposition (PVD) processes to manufacture thin film layers for integrated circuits and displays.

Strategic materials in the field of defense and military

The high density and hardness of tungsten rods make it a strategic material for the military industry. Tungsten alloy rods (e.g. tungsten nickel-iron alloy, with a density of up to 18.5 g/cm³) are processed into armor-piercing cores for striking anti-tank and armored targets, with high kinetic energy and penetration far exceeding those of conventional steels. In addition, tungsten rods were conceived in the concept of "kinetic weapons" as high-density kinetic warheads, and although they have not yet been actually deployed, their potential shows the importance of tungsten rods in future military technology. The high temperature and corrosion resistance of tungsten rods also make them suitable for missile nozzles and armor parts.

A reliable choice for the aerospace industry

Tungsten rods are widely used in the aerospace industry, where materials are extremely demanding in terms of weight, strength and high temperature resistance. Tungsten alloy rods are used as counterweights for aircraft and satellites due to their high density, ensuring precise weight distribution and flight stability. For example, in helicopter rotors and spacecraft attitude control systems, tungsten rod counterweights significantly reduce volume requirements. In addition, tungsten rods are machined into high-temperature components, such as rocket engine nozzle linings and thermal protection components for re-entry vehicles, whose anti-ablative properties extend component life.

Critical components in the lighting and energy industry

In the lighting industry, tungsten rods are the core material of traditional incandescent and halogen lamps. Tungsten rods are drawn into filaments (which can be as small as a few microns in diameter) and are used as filaments that emit light for long periods of time at high temperatures due to their high melting point and low vapor pressure. Although LED technology is gradually replacing traditional lighting, tungsten filament is still indispensable in specialty lighting such as photographic lights and stage lights. In the field of new energy, tungsten rods are used in the control rods and high-temperature experimental devices of nuclear reactors to ensure safety and experimental accuracy.

A unique contribution to the medical and scientific fields

The high density and radiation shielding ability of tungsten rods make them shine in the medical field. Tungsten alloy rods are processed into collimators and shields for radiotherapy equipment that are used to precisely direct X-rays or gamma rays to protect patients and medical staff from unwanted radiation. In the field of scientific research, tungsten rods are used as heating elements or electrodes in high-temperature experimental furnaces, supporting cutting-edge research in materials science, physics and chemistry. For example, in high-temperature superconductivity experiments, the stability of tungsten rods ensures the reliability of the experimental environment.

Drive industrial efficiency and innovation

The diverse applications of tungsten rods not only meet the existing industrial needs, but also promote technological innovation. For example, in the automotive industry, tungsten rods are used to manufacture wear-resistant tools and molds for automated production lines, improving production efficiency and product consistency. In the sporting goods (e.g., golf clubs, darts) and jewelry industries, tungsten alloy rods are machined into precision components due to their high density and wear resistance to meet consumer demand for high-performance products. These emerging applications demonstrate the wide adaptability of tungsten rods in both traditional and modern industries.

The importance of the economy and the supply chain

As a rare metal product, tungsten rod has an important position in the global economy. China is the world's largest producer of tungsten, controlling about 80% of the tungsten resources and products market, and the export of tungsten rods is critical to the international supply chain. The high added value and irreplaceability of tungsten rod make it a strategic reserve material for the industrial system of many countries. For example, the United States and the European Union classify tungsten as a critical mineral, ensuring their supply chain security to support defense and high-end manufacturing.

Challenges and Continued Importance

Although tungsten rods are indispensable in industry, their production faces challenges such as high energy consumption, environmental pollution and resource scarcity. The development of green manufacturing technology and tungsten waste recycling technology has become the focus of the industry. However, these challenges have not diminished the importance of tungsten rods, but have led to technological advancements that will allow it to continue to play a central role in the industry of the future.

1.3 Historical Background and Development

As an important material in modern industry, the development process of tungsten rod is closely related to the discovery, purification technology and industrial application of tungsten. From the discovery of tungsten in the late 18th century to the widespread use of tungsten rod in the 21st century, the history of tungsten rod reflects the evolution of materials science, metallurgical technology, and industrial needs. The following is a detailed trace of the historical background of tungsten rod and the development trajectory of its technology and application.

Tungsten discovery and early research

The discovery of tungsten dates back to 1781, when the Swedish chemist Carl Wilhelm Scheele discovered the presence of tungsten acid by analyzing wolframite. In 1783, Spanish brothers Juan José and Fausto Elhuyar first isolated tungsten from tungsten acid and named it "tungsten" (Swedish for "heavy stone"), so named for its high density. Early tungsten research was mainly focused on chemical properties, limited to laboratory scale, and industrial applications of tungsten have not yet been carried out due to its high melting point and difficult to process.

In the mid-19th century, with the advancement of metallurgical technology, the potential industrial value of tungsten gradually emerged. In the 1850s, tungsten began to be tried in the production of alloy steels to enhance the hardness and wear resistance of the steel. However, the purification and molding technology of pure tungsten is still immature, which limits its wide application.

Initial industrialization of tungsten rods

The industrialization of tungsten rods began at the beginning of the 20th century and is closely related to the needs of the lighting industry. In 1904, Hungarian engineers Sandor Just and Franz Hanaman developed tungsten incandescent lamps to replace inefficient carbon filament lamps. Tungsten's high melting point and low vapor pressure make it an ideal filament material, but early tungsten filaments are easily embrittlement, making it difficult to process into rods or filaments.

In 1909, William D. Coolidge of General Electric invented the preparation process of ductile tungsten to produce tungsten rods and tungsten wires with better toughness through powder metallurgy and high-temperature forging technology. This breakthrough enabled the mass production of tungsten rods, significantly reducing the cost of incandescent lamps and driving a revolution in the lighting industry. Kulich's process forms the basis for modern tungsten rod production, including the core steps of powder pressing, sintering and texturing processing.

The application of tungsten rods in the 20th century expanded

In the first half of the 20th century, the application of tungsten rods expanded from lighting to several industrial fields.

Electronics: In the 1920s, tungsten rods were used in cathodes and electrodes for vacuum and X-ray tubes, and performed well in high-temperature electronics due to their high melting point and electrical conductivity.

Military industry: During World War I, tungsten was used to make high-strength alloy steels to enhance the performance of tank armor and artillery shells. During World War II, tungsten alloy rods began to be machined into armor-piercing cores, significantly increasing the effectiveness of anti-tank weapons.

Welding technology: In the 1940s, tungsten rods were developed as argon arc welding (TIG welding) electrodes, and thorium-doped tungsten rods (containing 2% thorium oxide) became the standard material in the welding industry due to their excellent arc stability.

During this period, the production technology of tungsten rods continued to improve. The optimization of powder metallurgy process improves the density and mechanical properties of tungsten rods, while the introduction of deformation processing technologies such as rotary forging and drawing greatly improves the dimensional accuracy and surface quality of tungsten rods.

The strategic position of the Cold War and tungsten rods

During the Cold War, tungsten rods became a strategic material for their applications in the defense and aerospace sectors. In the 1950s-1970s, tungsten alloy rods were widely used in jet engine turbine blades, missile components, and spacecraft counterweights. Both the U.S. and the Soviet Union listed tungsten as a critical resource, building stockpiles to ensure supply chain security. China's tungsten industry also developed rapidly during this period, relying on rich tungsten ore resources, becoming the world's major tungsten rod supplier.

In the 1960s, a breakthrough was made in the research and development of doped tungsten rods. Potassium-doped tungsten rod (WK) improves creep resistance at high temperature by adding trace amounts of potassium and is suitable for high-temperature furnace elements. Rare-earth tungsten rods (e.g., cerium-doped, lanthanum-doped) improve the durability and arc stability of the electrode, gradually replacing thorium-doped tungsten rods, which are slightly radioactive.

Modern tungsten rod technology and globalization

In the 21st century, the application and production technology of tungsten rod has entered a new stage.

Semiconductors and new energy: The use of tungsten rods in the manufacture of monocrystalline silicon, sapphire crystals and thin-film solar cells has proliferated. For example, tungsten rods are used as high-temperature furnace core rods and sputtering targets, supporting the rapid development of the semiconductor and photovoltaic industries.

Green manufacturing: With the improvement of environmental protection requirements, tungsten rod production began to adopt low-energy sintering technology and waste recycling process. For example, waste tungsten rods can be chemically purified to be remade into tungsten powder, reducing resource consumption.

New alloys and doping: Tungsten-nickel-copper alloy rods are used in medical devices due to their non-magnetic and high density, and lanthanum-doped tungsten rods (WL20) have become the mainstream choice for welding electrodes due to their environmental friendliness.

The global tungsten rod market is centered on China, accounting for more than 80% of global production. Some international companies have a presence in the high-end tungsten rod market, focusing on the production of high-precision and special tungsten rods. The formulation of international standards (e.g., ASTM B777, ISO 24370) and domestic standards (e.g., GB/T 4187-2017) has facilitated the standardized trade of tungsten rods.

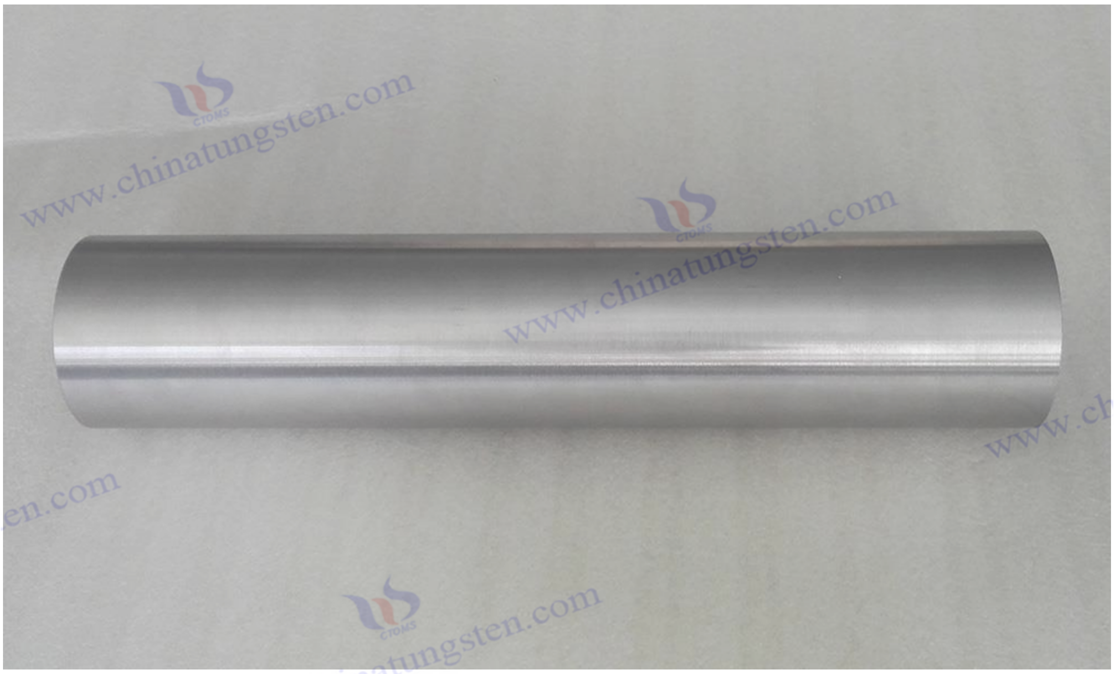
Challenges and future of tungsten rod development

The development of tungsten rods faces challenges such as resource scarcity, environmental pressure and high cost. The environmental damage caused by tungsten mining has prompted countries to strengthen regulation, and the high melting point and high hardness of tungsten have increased the difficulty of processing and energy consumption. In the future, the development direction of tungsten rod industry includes:

New processes, such as plasma sintering and additive manufacturing (3D printing) for the production of tungsten rod parts with complex shapes.

New materials: develop low-toxicity doped tungsten rods to completely replace thorium-doped tungsten rods.

Circular economy: Increase tungsten recovery and reduce dependence on raw ore.



CTIA GROUP LTD tungsten rods

Chapter 2 Types of Tungsten Rods

As a high-performance metal material, tungsten rod is widely used in industrial, electronic, military, medical and scientific research fields due to its excellent physical, chemical and mechanical properties. There are many types of them, which can be classified according to composition, manufacturing process, use, specification, surface condition, special type and international standards. This chapter aims to provide a systematic and comprehensive classification framework that provides an in-depth discussion of the definition, characteristics, production process, application scenarios, industry challenges, and development trends of each tungsten rod.

2.1 Tungsten rods are classified by composition

The composition of tungsten rods is a key factor in determining its performance and application. According to the differences in the main components and added elements, tungsten rods can be divided into three categories: pure tungsten rods, high-purity tungsten rods and doped tungsten rods. Let's break down each of them in detail.

2.1.1 Pure tungsten rods

Definitions and Overview

Pure tungsten rod is a rod-shaped material made of tungsten (purity usually ≥ 99.9%) as the main ingredient through powder metallurgy and deformation processing technology. Tungsten (chemical symbol W, atomic number 74) is known for its extremely high melting point (3410°C), high density (19.25 g/cm³) and excellent corrosion resistance, making pure tungsten rods ideal for high-temperature, high-strength and corrosion-resistant environments. Pure tungsten rods usually contain trace impurities (e.g. iron, nickel, carbon), but are strictly controlled in the ppm level to ensure chemical stability and high-temperature performance.

characteristic

Physical properties: The melting point of tungsten is the highest of all metals, second only to the sublimation point of carbon (about 3550°C). Pure tungsten rods have a density close to the theoretical value of 19.25 g/cm³, which is comparable to gold, making them suitable for high-quality counterweight applications. The extremely low coefficient of thermal expansion (4.5×10^{-6}/°C) ensures dimensional stability at high temperatures. The thermal conductivity is about 173 W/m·K and the electrical conductivity is 18% IACS (International Annealed Copper Standard), which is suitable for high-temperature conductive applications.

Chemical characteristics: Pure tungsten rod has excellent corrosion resistance to acids, alkalis and most oxidants at room temperature. For example, hydrochloric acid, sulfuric acid and hydrofluoric acid have little effect at room temperature and only react slowly in concentrated nitric acid or molten alkali at high temperatures. The low vapor pressure ($<10^{-4}$ Pa at 3000°C) makes it excellent in vacuum, high temperature environments.

Mechanical characteristics: high hardness (Vickers hardness 350–450 HV), tensile strength 700–1000 MPa, but low toughness, easy to produce micro-cracks during processing. Excellent creep resistance, long-term stress at 2500°C, suitable for high-temperature stressed parts.

Microstructure: The grain size is 10–50 μm after sintering, and can be refined to 5–20 μm after deformation, reducing porosity and improving strength.

Production process

The production of pure tungsten rod mainly adopts powder metallurgy process, and the process is as follows:

Preparation of tungsten powder: tungsate is extracted from wolframite ($FeMnWO_4$) or scheelite ($CaWO_4$), and high-purity tungsten powder (particle size 0.5–5 μm, purity ≥ 99.9%) is prepared by hydrogen reduction. The reduction process requires controlled temperature (600–900°C) and atmosphere to avoid oxidation or carbon contamination.

Pressing: Tungsten powder is formed into rod-like blanks by cold isostatic pressing or molding at 100–200 MPa, with a density of about 50–60% theoretical density.

Sintering: Sintering at 2000–2800°C for 1–3 hours in a hydrogen protected or vacuum furnace with a billet density of 90–95%. The sintering temperature and holding time need to be precisely controlled to balance grain growth and porosity elimination.

Deformation: Improved mechanical properties by hot forging (rotary or hammer swaging, 1200–1500°C) or hot rolling to increase the density (close to 19.25 g/cm³). Rotary swaging achieves multiple passes with small deformation (10–20%), reducing the risk of cracking.

Post-treatment: annealing (1000–1200°C) to relieve internal stresses, turning or polishing to improve surface quality, surface roughness is typically Ra 1.6–3.2 μm, meeting industrial precision requirements.

apply

Pure tungsten rods are widely used in high-temperature and high-purity scenarios:

Electronics industry: used as vacuum tube cathode, X-ray tube target and electrical discharge processing (EDM) electrode.

Lighting industry: Drawn into tungsten filaments (0.01–0.1 mm diameter) for the manufacture of

incandescent lamps, halogen lamps and special light sources (e.g. photographic lamps).
High-temperature furnace: used as the core rod of quartz continuous melting furnace, which can withstand high temperatures above 2000 °C to produce quartz glass for optical fibers; Or as a sapphire crystal furnace support, growing crystals for LED substrates.
Scientific research: Used as a heating element or electrode in high-temperature experimental equipment, such as a heat source in high-temperature superconductivity research.
Aerospace: Processed into small counterweights for use in satellite attitude control systems.
Others: Used for high-temperature molds and wear-resistant tools, such as glass forming molds.

Challenges and trends

Challenge: Low toughness, easy cracking during processing, especially in small diameter drawing, which requires multiple annealing, which increases costs. High-temperature processing equipment, such as vacuum sintering furnaces, consumes energy and is complex to maintain. Impurities can be difficult to control, and trace amounts of oxygen or carbon can lead to reduced performance.
Trend:
Plasma sintering (SPS) technology is used to reduce the sintering temperature to 1800°C, save energy by 30%, and reduce oversized grains.
Nano-scale tungsten powder (particle size < 100 nm) is used to increase the sintering density to 98% and enhance the mechanical properties.
Development of an automated sintering control system to monitor temperature and atmosphere through sensors to improve product consistency.
The preparation technology of low-oxygen tungsten powder (such as plasma reduction) was studied to reduce the oxygen content to less than 10 ppm.

Pros and cons:

Advantages: Extremely high melting point and chemical stability, suitable for extreme environments; High density is suitable for counterweights; Non-radioactive and environmentally friendly.
Disadvantages: low toughness, difficult processing; High production costs, especially in high-precision applications.
Markets & Standards
Pure tungsten rods account for about 30% of the global tungsten products market. Compliance with standards includes ASTM B760, GB/T 4187-2017 and ISO 24370. The global pure tungsten rod market size was approximately $1 billion in 2023 and is expected to grow to $1.5 billion by 2030, driven by semiconductor and aerospace demand.

2.1.2 High purity tungsten rods (≥99.95%)

Definitions and Overview

High-purity tungsten rod refers to tungsten rod with tungsten purity of 99.95% or more, and the impurity content (such as Fe, Ni, C, O) is controlled below 50 ppm, which is prepared by multiple purification and special processes. High-purity tungsten rods are designed for semiconductor, medical, and high-end electronic devices that meet stringent requirements for purity and cleanliness. Its properties are close to the theoretical limits of tungsten and are widely used in cleanroom and high-precision applications.

characteristic

Physical properties: density 19.2–19.3 g/cm³, close to the theoretical value; The melting point is 3410 °C, and the coefficient of thermal expansion is 4.5×10^{-6}/°C. Due to the extremely low impurities, the crystal structure is more homogeneous and the surface quality is excellent.

Chemical properties: Extremely chemically stable, almost non-reactive with ambient chemicals. At high temperatures, it reacts slowly only with fluorine gas or strong oxidizing agents such as molten sodium nitrate. Low vapor pressure ensures stability in a vacuum environment.

Mechanical properties: fine grain (5–15 μm), Vickers hardness 400–500 HV, tensile strength 800–1100 MPa. The toughness is still low, and micro-cracks need to be avoided in processing.

Electrical and thermal conductivity: the resistivity is about 5.3 μΩ·cm, which is slightly better than that of pure tungsten rod (5.5 μΩ·cm), because of the reduction of impurities. The thermal conductivity is 173 W/m·K, which is suitable for high-temperature heat conduction.

Production process

The production of high-purity tungsten rod adds purification and cleaning control on the basis of pure tungsten rod:

Preparation of high-purity tungsten powder: chemical vapor deposition (CVD) or multiple hydrogen reduction, the impurity content is reduced to less than 50 ppm. The reduction furnace uses high-purity hydrogen (99.999%) to avoid nitrogen and oxygen pollution.

Vacuum sintering: sintering at 2600–2800°C for 2–4 hours in an ultra-high vacuum (10^{-5} Pa) furnace with a porosity of <1%. The vacuum environment prevents the formation of oxides.

Precision machining: multi-pass rotary swaging or rolling, processing temperature 1200–1400°C, deformation 10–15%. Surface turned or polished with a roughness of Ra 1.6–3.2 μm.

Quality control: Impurities were detected using ICP-MS (Inductively Coupled Plasma Mass Spectrometry) and trace elements were analyzed by GD-MS (Glow Discharge Mass Spectrometry). Cleanroom (ISO Class 5) packaging to avoid surface contamination.

apply

High-purity tungsten rods are used in areas where purity and cleanliness are critical:

Semiconductor industry: components used in ion implantation devices (e.g. ion source electrodes) with a diameter of 5–20 mm to ensure wafer cleanliness.

Sputtering targets: processed into targets (50–100 mm diameter) for physical vapor deposition (PVD) for the production of thin film layers for integrated circuits, OLED displays and solar cells.

Medical devices: for X-ray and CT scanning equipment targets to reduce radiation interference caused by impurities, 10–30 mm diameter.

Aerospace: Precision components used as high-temperature test equipment, such as thermocouple protective sleeves or high-temperature wind tunnel test elements.

Scientific research: used as a high-purity electrode in particle accelerators and plasma research, withstanding high-energy environments.

Emerging applications: Used in EUV (extreme ultraviolet lithography) equipment components to meet the needs of chip manufacturing below 7nm.

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Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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Challenges and trends

Challenge: High cost of preparation of high-purity tungsten powder, large investment in CVD equipment; Ultra-high vacuum sintering has extremely high requirements for equipment tightness and stability; Cleanroom processing increases operating costs.

Trend:

Electrolytic purification technology was developed to replace CVD and reduce costs, with a target impurity < 20 ppm.

Laser surface treatment is used to improve surface quality and reduce the dependence on mechanical polishing.

Research on ultra-high purity tungsten (99.9999%) for use in next-generation semiconductor devices such as 3nm lithography machines.

Introduce AI quality control system to monitor impurities and crystal defects in real time to improve yield.

Pros and cons:

Advantages: Extremely high purity ensures stable performance and is suitable for clean environment; The crystals are homogeneous, reducing defects.

Disadvantages: high production cost, difficult processing; Strict requirements for equipment and environment.

Markets & Standards

The high-purity tungsten rod market is concentrated in high-end manufacturing. Complies with ASTM B760 high purity requirements, SEMI standard (semiconductor industry) and GB/T 4187-2017. The global high-purity tungsten rod market is approximately $300 million in 2023, mainly driven by the semiconductor and photovoltaic industries.

2.1.3 Doped tungsten rods (rare earth doping, oxide doping)

Definitions and Overview

Doped tungsten rods are special tungsten rods made by adding small amounts of rare earth elements (e.g., cerium, lanthanum, yttrium) or oxides (e.g., thorium oxide, zirconia) to the tungsten matrix, and the doping amount is usually 0.5–2 wt%. Doping improves the arc stability, creep resistance, machinability, and electrode life of tungsten, and is widely used in welding electrodes, high-temperature furnace components, and electronic devices. Doped tungsten rod has become a key material in modern industry because of its customized properties.

characteristic

Physical properties: The melting point and density are close to those of pure tungsten (3410°C, 19.0–19.2 g/cm³), and the doped elements refine the grain (5–15 μm) to improve uniformity.

Chemical properties: Maintains tungsten's corrosion resistance, but in high-temperature oxidizing environments, certain doped elements (such as thorium) may slightly reduce stability. Thorium oxide doping introduces slight radioactivity and requires special treatment.

Mechanical properties: Grain refinement and dopant strengthening improve tensile strength (1000–1200 MPa) and toughness, and reduce processing cracks. Improved creep resistance, suitable for

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long-term use at high temperatures.

Electrical and thermal conductivity: doping reduces the resistivity (e.g., about 5.0 μΩ·cm of thorium-doped tungsten rod) and improves arc stability. The thermal conductivity is slightly lower than that of pure tungsten (about 160 W/m·K).

Main types

Rare earth doped tungsten rod: Cerium oxide (CeO_2), lanthanum oxide (La_2O_3) or yttrium oxide (Y_2O_3) are added to improve arc performance and durability, non-radioactive, and meet environmental protection requirements.

Oxide-doped tungsten rods: thorium oxide (ThO_2) and zirconia (ZrO_2) are added to enhance high-temperature performance and electrode life, and some types (such as thorium-doped) are gradually eliminated.

Composite doped tungsten rods: Combine a variety of dopants (such as La_2O_3+CeO_2) to optimize arc stability, life and burn resistance.

Potassium-doped tungsten rods: Added trace amounts of potassium (50–100 ppm) for improved creep resistance, designed for high-temperature furnaces.

Production process

Dopant addition: Tungsten powder is evenly mixed with rare earth oxides or metal salts (such as lanthanum nitrate), and ball milling or spray drying is used to ensure uniform distribution.

Pressing and sintering: sintering at 2300–2600°C in a hydrogen protection furnace, lower than the sintering temperature of pure tungsten to prevent the dopant from volatilizing. After sintering, the density is 95–98%.

Deformation: Rotary swaging (1200–1400°C) or drawing (800–1000°C) to form a rod, dopant to reduce processing cracks.

Surface treatment: Turned or polished, surface roughness Ra 1.6–3.2 μm, for electrodes or high-temperature components.

Quality control: XRF (X-ray fluorescence spectroscopy) to detect the dopant content, SEM (scanning electron microscopy) to analyze the grain distribution.

apply

Welding electrode: thorium-doped (WT20), cerium-doped (WC20), lanthanum-doped (WL20) tungsten rods are used for argon arc welding (TIG) and plasma welding, with fast arc start and low burn-out rate.

High-temperature furnace element: potassium-doped or rare earth-doped tungsten rod is used for heating elements of vacuum furnace and hydrogen furnace, which can withstand more than 2500 °C.

Electronics: Doped tungsten rods are used in the emitters of cathode ray tubes, microwave devices, and lasers.

Aerospace: Rare earth tungsten rods are used in high-temperature experimental equipment, such as plasma propeller electrodes.

Emerging application: High-temperature nozzles for 3D printing metal devices, resistant to high-temperature metal melts.

Challenges and trends

Challenge: The homogeneity of the dopant is difficult to control, and high-temperature sintering may lead to volatilization; The radioactivity of thorium-doped tungsten rods limits its application, and environmentally friendly alternatives need to be developed.

Trend:

Research and development of new composite rare earth doping (such as $La_2O_3+Y_2O_3$) to improve the comprehensive performance and increase the target life by 20%.

Nano doping technology was used to reduce the doping amount (<0.5 wt%) and improve the effect.

Development of non-radioactive, high-performance electrodes that meet global environmental standards, such as the EU RoHS directive.

Use AI to optimize doping formulations and predict arc performance and lifetime.

Pros and cons:

Advantages: customized performance, arc stability and life better than pure tungsten; Suitable for demanding applications.

Disadvantages: the production process is complex and the cost is high; Some doping (e.g. thorium) has environmental restrictions.

Markets & Standards

Doped tungsten rods account for more than 70% of the welding electrode market. Compliant with AWS A5.12, YS/T 695-2009, and ISO 24370. The global doped tungsten rod market is approximately USD 500 million in 2023, mainly driven by the welding and aerospace industries.

2.2 Tungsten rods are classified according to the manufacturing process

The manufacturing process of tungsten rods has a significant impact on its performance, accuracy and application. The following is a detailed discussion of the characteristics of sintering, forging, rolling, drawing, and extruding tungsten rods according to the classification of major processing processes.

2.2.1 Sintered tungsten rods

Definitions and Overview

Sintered tungsten rod is a tungsten rod directly formed by pressing and high-temperature sintering in powder metallurgy, with a density of 90–95% theoretical density and a rough surface with an oxide layer (black skin). As a semi-finished product, sintered tungsten rods are the basis for subsequent forging, rolling or drawing and are suitable for roughing or high-temperature applications.

characteristic

Physical properties: density 17.5–18.5 g/cm³, surface roughness Ra 3.2–6.4 μm, with black oxide layer.

Mechanical characteristics: Vickers hardness 300–400 HV, tensile strength 500–800 MPa, poor toughness, easy to produce microcracks.

Microstructure: Large grains (10–50 μm) and porosity of 5–10%, affecting strength and conductivity.

Production process

Tungsten powder pressing: high-purity tungsten powder or doped tungsten powder is coldly isostatically pressed into rod blanks at 100–200 MPa.

High-temperature sintering: sintering at 2000–2800°C for 1–3 hours in a hydrogen protected or vacuum furnace to form a dense structure of particles.

Cooling & Inspection: Slow cooling (10–20°C/min) reduces internal stress, and ultrasonic porosity and crack detection.

apply

Semi-finished products: forging, rolling or drawing processing to produce high-precision tungsten rods.

High temperature furnace: directly used as a quartz furnace support, withstand high temperature of 2000°C.

EDM: Used as a low-precision EDM electrode after roughing.

Other: Temporary parts for high-temperature experimental furnaces, such as crucible supports.

Challenges and trends

Challenge: High porosity limits mechanical properties; The energy consumption of sintering is large, and hydrogen protection needs to be strictly controlled; Large-size sintered rods are prone to internal defects.

Trend:

Microwave sintering technology is used to reduce the temperature to 1800°C and save energy by 30%.

Developed a hot isostatic pressing (HIP) sintering process to increase the density to 97%.

Simulate the sintering process using digital twin technology to optimize temperature and atmosphere control.

Pros and cons:

Advantages: simple process, low cost; Suitable for large size tungsten rods.

Disadvantages: low density and performance, poor surface quality, further processing required.

2.2.2 Forged tungsten rods

Definition and OverviewForged tungsten rods are deformed by hot forging (hammer forging or rotary swaging), resulting in a density close to the theoretical value (19.0–19.25 g/cm³) and a significant improvement in mechanical properties. Forged fine grains for enhanced strength and creep resistance, suitable for high-precision and high-strength applications.

characteristic

Physical properties: density 19.0–19.25 g/cm³, surface roughness Ra 1.6–3.2 μm (after turning light).

Mechanical properties: grain size 5–20 μm, tensile strength 1000–1400 MPa, toughness slightly better than sintered tungsten rod.

Microstructure: strong grain orientation, <1% porosity, and improved creep resistance.

Production process

Preheating: The sintered tungsten rod is heated to 1200–1500°C under the protection of hydrogen or argon to prevent oxidation.

Hot forging: Use an air hammer or rotary swaging machine to perform multi-pass forging with a controlled deformation of 10–20% each time to reduce the risk of cracking.

Annealing: Stress relief annealing at 1000–1200°C to prevent crack propagation.

Surface treatment: Turned or polished to a surface roughness of Ra 1.6–3.2 μm to meet the required precision requirements.

apply

Industrial parts: for quartz furnace cores or sapphire crystal furnace crucibles.

Aerospace: Machined into counterweights or high-temperature components such as thruster nozzles.

Electrode: High-precision forged tungsten rod is used for plasma cutting and welding.

Others: used for high-temperature molds, such as ceramic sintering molds.

Challenges and trends

Challenge: High-temperature forging requires special equipment; Large-diameter rods (>50 mm) are prone to cracking; Forging has high energy consumption.

Trend:

Use finite element simulation to optimize forging parameters and reduce defects.

Develop a hybrid forging-rolling process to improve efficiency and reduce costs.

Induction heating technology is used to accurately control the forging temperature and save 20% energy.

Pros and cons:

Advantages: high density and mechanical strength; Suitable for demanding applications; Grain refinement improves performance.

Disadvantages: high processing cost; Strict equipment requirements; It is difficult to process large specifications.

2.2.3 Rolled tungsten rods

Definitions and Overview

Rolled tungsten rods are further processed by hot rolling or cold rolling process, with high dimensional accuracy and good surface quality, suitable for mass production of small and medium-diameter (5–20 mm) tungsten rods.

characteristic

Physical properties: density close to theoretical (19.0–19.25 g/cm³), surface roughness Ra 1.6–3.2 μm.

Mechanical characteristics: rolling-induced grain orientation, tensile strength 1200–1500 MPa, toughness slightly better than wrought tungsten rod.

Microstructure: fine and uniform grain size (5–15 μm), porosity <1%, excellent strength and conductivity.

Production process

Preheating: Sintered or forged tungsten rods are heated to 1000–1300°C to improve ductility.

Hot rolling: Through multi-pass rolling, the diameter is gradually reduced and the deformation is 15–25%.

Cold rolling (optional): Cold rolling of small diameter tungsten rods to improve dimensional accuracy.

Annealing: Annealing at 900–1100°C eliminates work hardening.

apply

Electronics industry: rolled tungsten rod drawn into tungsten wire, manufacturing filament and electrode.

Medical devices: processed into X-ray targets or radiation shields.

Precision components: used for high-precision mechanical parts, such as molds and tools.

Other: Used in high-temperature experimental equipment, such as thermocouple support.

Challenges and trends

Challenge: Expensive rolling equipment; Poor rolling uniformity of large diameter (>20 mm); Cold rolling increases costs.

Trend:

The continuous rolling line is used to improve the production efficiency by 30%.

An automated rolling control system is used to ensure dimensional consistency.

Development of high-temperature alloy rolls to extend the life of equipment.

Pros and cons:

Advantages: high dimensional accuracy, good surface quality, suitable for mass production.

Disadvantages: high cost of equipment; Limited to small and medium-sized diameters; Cold rolling consumes a lot of energy.

2.2.4 Draw tungsten rods

Definitions and Overview

Drawing tungsten rod is a drawing process to gradually reduce the diameter of the sintered or forged tungsten rod through a diamond die, usually < 5 mm, with high surface quality and excellent dimensional accuracy, suitable for tungsten wire and precision electrodes.

characteristic

Physical properties: density close to theoretical (19.2–19.25 g/cm³), surface roughness Ra 1.6–3.2 μm.

Mechanical properties: fibrous crystal structure, tensile strength 1500–2000 MPa, low toughness.

Microstructure: The grains are highly oriented along the drawing direction, and the porosity is close to 0%.

Production process

Blank preparation: Use forged or rolled tungsten rods (diameter 5–10 mm).

Drawing: Drawing through the diamond die at 800–1000°C with a diameter reduction of 5–10%.
Lubrication and annealing: Lubrication with graphite or molybdenum disulfide and periodic annealing (900–1100°C) to relieve stress.
Cleaning & Polishing: Chemical cleaning removes lubricants and polishes to Ra 1.6–3.2 μm.

apply

Tungsten filament production: tungsten rod drawn to make incandescent lamps, halogen lamps and tungsten filaments for special light sources.
Welding electrode: used for argon arc welding and plasma welding electrode, with high dimensional accuracy.
Microelectronics: Processed into miniature electrodes or probes for semiconductor testing.
Other: High-precision components for laser equipment.

Challenges and trends

Challenge: Diamond dies wear out quickly and are costly; Multiple annealing increases energy consumption; Small diameter drawing is easy to break.
Trend:
Polycrystalline diamond (PCD) molds are used to extend the life by 50%.
Development of a continuous drawing process to increase production by 20%.
Laser heating and drawing are used to precisely control the temperature and reduce breakage.

Pros and cons:

Advantages: Extreme precision and surface quality; High intensity; Suitable for microfabrication.
Disadvantages: complex process; Large wear and tear of the mold; Limited to small diameters.

2.2.5 Extrude tungsten rods

Definitions and Overview

Extruded tungsten rod is formed by hot extrusion process, which is suitable for large diameter (>20 mm) or complex cross-section tungsten rod, with excellent density and strength.

characteristic

Physical properties: density 19.0–19.2 g/cm³, surface roughness Ra 1.6–3.2 μm (after processing).
Mechanical characteristics: tensile strength 1000–1300 MPa, strong grain orientation, good impact resistance.
Microstructure: Uniform grain (10–20 μm) and <2% porosity, suitable for high-intensity applications.

Production process

Billet preheating: The sintered billet is heated to 1300–1600°C and protected by hydrogen or argon.
Hot extrusion: Extrusion by hydraulic extruder (500–1000 MPa).
Cooling & Straightening: Control the cooling rate (10–20°C/min) to correct deformation.
Surface treatment: Turned or polished to Ra 1.6–3.2 μm.

apply

Aerospace: Large diameter extruded tungsten rods are used for aircraft and satellite counterweights.
Military: Processed into armor-piercing cores or high-density kinetic energy components.
Industrial: used for high-temperature furnace supports and large molds.
Other: used as a base material for nuclear reactor control rods.

Challenges and trends

Challenge: High-pressure extrusion requires large equipment; Severe wear and tear of the mold; Process control is complex.
Trend:
Developed ceramic coating molds to reduce wear by 30%.
Use simulation software to optimize extrusion parameters and improve yield.
Research on the combination of additive manufacturing and extrusion to produce complex shapes of tungsten rods.

Pros and cons:

Advantages: suitable for large specifications and complex cross-sections; High density and strength.
Disadvantages: large investment in equipment; The surface quality is inferior to that of drawn tungsten rods; The process is complex.

2.3 Tungsten rods are classified according to their use

Tungsten rods are used in a variety of applications, including industrial, electronic, military and other special fields. The following is a detailed breakdown.

2.3.1 Tungsten rods for industrial use

Definitions and Overview

Industrial tungsten rods are used in high-temperature, high-strength or high-wear-resistant environments, such as quartz furnaces, sapphire crystal furnaces and rare earth purification equipment, including pure tungsten rods, tungsten alloy rods and doped tungsten rods.

Features & Applications

Quartz furnace: forging or extruding pure tungsten rods (diameter 20–50 mm) as core rods, withstanding high temperatures above 2000°C, to produce quartz glass for optical fibers.
Sapphire Crystal Furnace: Tungsten rods are processed into crucibles or supports for growing sapphire crystals for LED substrates.
Rare earth purification: tungsten rod is used as a high-temperature container or electrode for rare earth element smelting and refining.
Dies & Tools: Tungsten alloy rods (W-Ni-Fe) are used in stamping dies and cutting tools due to their high hardness and wear resistance.
Others: used for high-temperature ceramic sintering furnace supports.

Production & Requirements

Forging or extrusion ensures high density, surface roughness Ra 1.6–3.2 μm, and dimensional tolerances ± 0.1 mm.

2.3.2 Tungsten rods for electronics

Definitions and Overview

Tungsten rods for electronics are used in the manufacture of filaments, electrodes and sputtering targets, including pure tungsten rods, high-purity tungsten rods and doped tungsten rods.

Features & Applications

Filament: Tungsten filament is made by drawing pure tungsten rods, which are used in incandescent lamps, halogen lamps and special light sources.
Electrode: Doped tungsten rod (such as WT20, WC20) is used for argon arc welding and plasma welding electrode.
Sputtering target: High-purity tungsten rod is processed into a target for semiconductor and display film deposition.
Vacuum tubes and X-ray tubes: high-purity tungsten rods are used for cathodes and targets.
Other: for laser emitters.

Production & Requirements

Drawing and polishing to Ra 1.6–3.2 μm, high purity according to ASTM B760 and SEMI standards.

2.3.3 Tungsten rod for military use

Definitions and Overview

Tungsten rods for military use are mainly tungsten alloy rods, which are used for high-density and high-strength military components, such as armor-piercing bullet cores and kinetic weapons.

Features & Applications

Armor-piercing core: Tungsten-nickel-iron alloy rod (density 18.0–18.5 g/cm³) for anti-tank ammunition with high penetrating power.
Kinetic weapons: Large-diameter tungsten alloy rods are used in high-kinetic warheads, theoretically for weapons of the "Scepter of God" concept.
Armor parts: tungsten rods are machined into missile nozzle linings or armor protection.
Other: Radiation shielding for nuclear weapons components.

Production & Requirements

Extrusion or forging ensures high density, according to ASTM B777, and a surface roughness of Ra 1.6–3.2 μm.

2.3.4 Other special purpose tungsten rods

Definitions and Overview

Other special-purpose tungsten rods include medical, scientific and consumer goods such as radiation shielding, laboratory equipment and sporting goods.

Features & Applications

Medical: tungsten alloy rods are used in shielding and collimators for X-ray and CT equipment.

Scientific research: doped tungsten rod is used in the heating element of the high-temperature experimental furnace.

Consumer goods: tungsten alloy rods are processed into darts, golf club weights and tungsten steel jewelry.

Other: Wear-resistant parts for geological drilling tools.

Production & Requirements

Depending on the application, the drawing, extrusion or forging process is selected with a surface roughness of Ra 1.6–3.2 μm.

2.4 Tungsten rods are classified according to specifications

The specifications of tungsten rods are mainly based on diameter, and are divided into three categories: small diameter, medium diameter and large diameter.

2.4.1 Small diameter tungsten rods (<5mm)

Definitions and Overview

Tungsten rods with small diameters (<5 mm diameter) are prepared by drawing process with high dimensional accuracy and good surface quality.

Features & Applications

Characteristics: diameter 0.1–5 mm, surface roughness Ra 1.6–3.2 μm, tensile strength 1500–2000 MPa.

Applications: tungsten filament raw materials, welding electrodes, microelectronic probes, laser components.

The production of drawing process is the mainstay, which requires high-precision molds and multiple annealing.

2.4.2 Medium diameter tungsten rods (5-20mm)

Definitions and Overview

Medium-diameter tungsten rods (5–20 mm) are prepared by forging or rolling to provide both strength and processability.

Features & Applications

Characteristics: density 19.0–19.25 g/cm³, surface roughness Ra 1.6–3.2 μm.

Applications: high-temperature furnace components, counterweights, welding electrodes, medical targets.

Production of forging or rolling processes, suitable for mass production.

2.4.3 Large diameter tungsten rods (>20mm)

Definitions and Overview

Large-diameter tungsten rods (>20 mm) are prepared by extrusion or forging and are suitable for large format parts.

Features & Applications

Characteristics: density 19.0–19.2 g/cm³, high impact resistance, surface roughness Ra 1.6–3.2 μm.
Application: military bullet core, aviation counterweight, large mold, nuclear components.

The production of extrusion process is mainly based on large-tonnage equipment.

2.5 Tungsten rods are classified according to their surface state

The surface condition affects the application and processability of tungsten rods, which are divided into black leather rods, polishing rods and polishing rods.

2.5.1 Black Leather Sticks

Definitions and Overview

Black skin rod is a sintered or preliminarily machined tungsten rod with an oxide layer on the surface and has not been finished.

Features & Applications

Characteristics: Surface roughness Ra 3.2–6.4 μm, density 17.5–18.5 g/cm³.
Application: semi-finished products for subsequent forging or rolling; High-temperature furnace roughing components.

Production is cooled directly after sintering to retain the oxide layer.

2.5.2 Cartlight sticks

Definitions and Overview

The turning rod removes the black skin by turning or grinding, and the surface is smooth and the dimensional accuracy is high.

Features & Applications

Characteristics: Surface roughness Ra 1.6–3.2 μm, dimensional tolerance ± 0.05 mm.
Applications: welding electrodes, high-temperature furnace elements, precision counterweights.

The production of turning or grinding processes requires high-precision machine tools.

2.5.3 Polishing rods

Definitions and Overview

The polishing rod achieves a high surface quality through fine polishing, making it suitable for high precision and clean environments.

Features & Applications

Characteristics: Surface roughness Ra 1.6–3.2 μm, dimensional tolerance ± 0.02 mm.

Applications: Semiconductor equipment electrodes, sputtering targets, medical components.

Production of multi-pass polishing, using diamond grinding wheels or chemical polishing.

2.6 Special tungsten rods

Specialty tungsten rods can be doped or optimized to meet specific application needs.

2.6.1 Potassium tungsten rods

Definitions and Overview

Potassium-tungsten rods (WK) are used in high-temperature furnace elements to improve creep resistance at high temperatures by adding trace amounts of potassium (50–100 ppm).

Features & Applications

Characteristics: fine grains, strong creep resistance, 20–30% longer life.

Application: High temperature furnace heating element, vacuum furnace support.

The production is produced by adding potassium salts to tungsten powder, sintering and then drawing or forging.

2.6.2 Thorium-doped tungsten rods

Definitions and Overview

Thorium-doped tungsten rod (WT20, containing 2% ThO_2) was once a standard material for welding electrodes due to its good arc stability.

Features & Applications

Characteristics: fast arc start-up, long life, surface roughness Ra 1.6–3.2 μm, but slightly radioactive.

Application: TIG welding electrodes are gradually being replaced by environmentally friendly electrodes.

Thorium oxide is added to the production, and after sintering, drawing and molding.

2.6.3 Cerium-doped tungsten rods

Definitions and Overview

Cerium-doped tungsten rod (WC20, with 2% CeO_2) is non-radioactive and has excellent arc performance.

Features & Applications

Characteristics: arc stability, low burn-out rate, surface roughness Ra 1.6–3.2 μm, suitable for low-current welding.

Application: TIG welding, plasma welding electrode.

Cerium oxide is added to the production, sintered and then drawn.

2.6.4 Lanthanum-doped tungsten rods

Definitions and Overview

Lanthanum-doped tungsten rods (WL15/WL20 with 1.5–2% La_2O_3) are the first choice for environmentally friendly welding electrodes.

Features & Applications

Characteristics: high arc stability, long life, non-radioactivity, surface roughness Ra 1.6–3.2 μm.
Application: high-precision welding, semiconductor equipment electrodes.

Lanthanum oxide is added to production, sintered and then drawn or polished.

2.6.5 Zirconium-doped tungsten rod

Definitions and Overview

Zirconium-doped tungsten rod (WZ8, containing 0.8% ZrO_2) is suitable for AC welding and has strong resistance to pollution.

Features & Applications

Characteristics: resistant to electrode contamination, suitable for aluminum and magnesium welding, surface roughness Ra 1.6–3.2 μm.
Application: AC TIG welding electrode.

Zirconia is added to production, sintered and then drawn.

2.6.6 Yttrium-doped tungsten rod

Definitions and Overview

Yttrium-doped tungsten rods (WY20 with 2% Y_2O_3) are used for special welding due to their high electron emissivity.

Features & Applications

Characteristics: High electron emissivity, suitable for high-frequency welding, surface roughness Ra 1.6–3.2 μm.
Application: plasma cutting, special electrode.

Yttrium oxide is added to the production, sintered and then drawn.

2.6.7 Composite rare earth tungsten rod

Definitions and Overview

Composite rare earth tungsten rods combine a variety of rare earth oxides (such as La_2O_3+CeO_2) to optimize the comprehensive performance.

Features & Applications

Characteristics: Excellent arc stability, lifetime and burn resistance, surface roughness Ra 1.6–3.2 µm.

Applications: demanding welding, aerospace electrodes, 3D printing nozzles.

Composite rare earths are added to the production, drawn or polished after sintering.

2.7 Comparison of international models and grades

The types and grades of tungsten rods are based on international and domestic standards, which are easy to trade and apply.

2.7.1 Pure tungsten rod grade

overview

Pure tungsten rod grades include WP (AWS A5.12), W1 (GB/T 4187-2017) and ASTM B760 specified pure tungsten rod.

Grades & Requirements

WP: ≥ 99.9% purity, used for welding electrodes and filaments.

W1: Purity ≥ 99.95%, impurities are strictly controlled.

ASTM B760: Specifies purity and mechanical properties.

2.7.2 Doped tungsten rod grades

Doped tungsten rod grades are based on AWS A5.12 and YS/T 695-2009, common models include:

WT20: 2% thorium-doped, red marked, welded electrode.

WC20: 2% cerium-doped, gray logo, environmentally friendly electrode.

WL15/WL20: 1.5–2% lanthanum-doped, gold or blue logo, high performance electrode.

WZ8: 0.8% zirconium-doped, white logo, AC welding.

WY20: 2% yttrium-doped, cyan logo, special welding.

2.7.3 Comparison table of domestic and foreign grades (GB/T, ASTM, ISO)

type	GB/T standard	ASTM Standards	ISO standard	AWS A5.12
Pure tungsten rod	W1	ASTM B760	ISO 24370	WP
Thorium-doped tungsten rod	WT	ASTM B776	ISO 24370	WT20
Cerium-doped tungsten rod	WC	ASTM B776	ISO 24370	WC20
Lanthanum-doped tungsten rod	WL	ASTM B776	ISO 24370	WL15/WL20
Zirconium-	WZ	ASTM B776	ISO 24370	WZ8

doped tungsten rod				
Tungsten alloy rods	W-Ni-Fe/Cu	ASTM B777	ISO 24370	-

Illustrate

GB/T 4187-2017 and YS/T 695-2009 stipulate the chemical composition and properties of tungsten rods in China.

ASTM B760 and B777 are international standards for pure tungsten and tungsten alloys.

ISO 24370 specifies the general requirements for tungsten and tungsten alloys.

AWS A5.12 specifies the grade and color scale of doped tungsten rods for welding electrodes.

CTIA GROUP LTD tungsten rods

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2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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Chapter 3 Characteristics of Tungsten Rods

As a high-performance refractory metal material, tungsten rod has a wide range of applications in industry, electronics, aerospace, medical and scientific research fields due to its excellent physical, chemical and mechanical properties. This chapter discusses in detail the physical properties of tungsten rods (including high melting point, high density, low coefficient of thermal expansion, thermal conductivity and low vapor pressure), chemical properties (corrosion resistance, chemical stability and reactivity with elements), mechanical properties (high strength hardness, creep resistance, toughness and machinability), and compares the characteristics of different types of tungsten rods (pure tungsten rods, high-purity tungsten rods, doped tungsten rods), and finally provides the MSDS (Material Safety Data Sheet) information of tungsten rods.

3.1 Physical properties of tungsten rods

The physical properties of tungsten rods are the basis for a wide range of applications in extreme environments, including high melting point, high density, low coefficient of thermal expansion, good thermal conductivity and low vapor pressure. These properties make tungsten rods perform well at high temperatures, high loads, and vacuums.

3.1.1 High melting point of tungsten rods

Tungsten has a melting point of 3410°C, which is the highest of all metals, second only to the sublimation point of carbon (about 3550°C). This property makes tungsten rods an irreplaceable material in high-temperature environments, suitable for applications that withstand extreme heat loads. The high melting point of tungsten stems from its body-centered cubic (BCC) lattice structure, high interatomic metal bond energy and strong binding force, which enables tungsten rods to maintain structural stability at temperatures close to the melting point.

Application Scenarios:

High-temperature furnace elements: Tungsten rods are used as the core rods of quartz furnaces, which withstand high temperatures of 2000–2500°C to produce quartz glass for optical fibers.
Sapphire Crystal Furnace: Tungsten rod is used as a crucible or support for the growth of sapphire crystals for LED substrates with an operating temperature of up to 2200°C.
Aerospace: Tungsten rods are used in nozzle linings for high-temperature thrusters, such as plasma thrusters, to withstand high-temperature plasma impacts.
Lighting industry: tungsten rod drawn into tungsten filament, used in incandescent lamps, halogen lamps and special light sources, the working temperature can reach 2800°C.

Technical Challenges:

At high temperatures, tungsten rods may react in small amounts with furnace atmospheres (e.g. oxygen or nitrogen) and need to be protected by hydrogen or vacuum.
High melting point requires special high-temperature equipment (such as vacuum sintering furnaces), which consumes high energy and increases production costs.
Long-term operation at high temperatures can lead to grain growth and affect mechanical properties.

Development Trends:

Develop advanced high-temperature furnace designs that combine induction heating and inert atmospheres to reduce energy consumption and increase efficiency.

Tungsten matrix composites were studied, and the high-temperature stability was further improved by adding high-temperature resistant phases (such as zirconia), and the target temperature resistance was up to 3000°C.

Plasma sintering (SPS) technology is used to reduce the sintering temperature to 1800°C, reducing grain oversize and energy consumption.

3.1.2 High density of tungsten rods

The density of tungsten rods is close to the theoretical value of 19.25 g/cm³, which is comparable to gold and only lower than osmium and iridium. The high density is due to the tight packing of tungsten atoms and the high atomic weight (183.84 u), which gives it a large mass in a small volume, making it suitable for high-quality counterweights and radiation shielding applications.

Application Scenarios:

Aerospace counterweights: Tungsten rods are machined into satellite or drone counterweights to optimize space utilization and center of gravity adjustment.

Military: tungsten alloy rods (W-Ni-Fe or W-Ni-Cu) are used in armor-piercing bullet cores or kinetic weapons to enhance penetration and kinetic energy.

Medical: Tungsten rods are used in shielding X-ray and CT equipment to absorb high-energy radiation and protect operators.

Consumer goods: Tungsten alloy rods are used in golf club weights, darts or high-end tungsten steel jewelry to enhance stability and feel.

Technical Challenges:

High density increases the difficulty of machining, requiring high-precision equipment to control dimensional tolerances, especially in small diameter drawing.

Large-format tungsten rods (> 50 mm diameter) are susceptible to internal defects such as porosity or cracks during extrusion or forging.

The addition of nickel, iron and other elements to tungsten alloy rod may reduce the corrosion resistance, and the alloy ratio needs to be optimized.

Development Trends:

Development of high-density tungsten matrix composites (e.g., W-Ni-Cu) to optimize the balance between density and toughness and improve processability.

Additive manufacturing techniques, such as 3D printing, are used to produce complex-shaped counterweights, reducing material waste and processing costs.

Finite element simulation is used to optimize the forging and extrusion process of large tungsten rods, reducing internal defects and improving yield.

3.1.3 Low coefficient of thermal expansion of tungsten rods

Tungsten rods have a very low coefficient of thermal expansion of 4.5×10^{-6}/°C (20–1000°C), which is much lower than steel (11–13×10⁻⁶/°C) and copper (16–18×10⁻⁶/°C). The low coefficient of thermal expansion enables the tungsten rod to maintain excellent dimensional stability at high temperatures, reduce thermal stress and deformation, and is suitable for high-precision and high-temperature environments.

Application Scenarios:

Semiconductor equipment: High-purity tungsten rods are used for ion implantation equipment electrodes, and dimensional stability ensures wafer processing accuracy.

High-temperature furnace: Tungsten rod is used as a quartz furnace core rod or sapphire furnace support, which can withstand high temperatures above 2000°C without deformation.

Optical industry: Tungsten rods are used in laser equipment components to keep the optical system aligned and prevent thermal deformation from affecting the optical path.

Aerospace: Tungsten rods are used in high-temperature wind tunnel test components to resist thermal deformation and maintain experimental accuracy.

Technical Challenges:

The combination of low coefficient of thermal expansion and low toughness makes tungsten rods sensitive to thermal shock, and rapid temperature changes may cause microcracks.

Thermal expansion mismatch with other materials at high temperatures can lead to interfacial stresses that affect the performance of composite parts.

Precision machining needs to take into account the difference in thermal expansion to ensure tolerance control.

Development Trends:

Investigate tungsten matrix composites to adjust the coefficient of thermal expansion to match other materials (e.g., ceramics or alloys) and reduce interfacial stresses.

Finite element simulation is used to optimize component design, predict thermal stress distribution, and reduce the risk of thermal deformation.

Development of high-temperature coating technologies (e.g. zirconia coatings) to enhance the thermal shock resistance of tungsten rods.

3.1.4 Thermal and electrical conductivity of tungsten rods

Tungsten rod has good thermal conductivity and moderate electrical conductivity, with a thermal conductivity of about 173 W/m·K (20°C) and an electrical conductivity of 18% IACS (International Standard for Annealed Copper, about 9.8 MS/m). These properties stem from tungsten's metallic bond structure and electron mobility, making it suitable for high-temperature conductive and thermally conductive applications. Although the conductivity is lower than that of copper (100% IACS), the stability of tungsten rods at high temperatures and the low rate of change of resistance give them an advantage in specific scenarios.

Application Scenarios:

Electronics: Tungsten rods are used in vacuum tube cathodes, X-ray tube targets and electrical discharge machining (EDM) electrodes, combining conductivity and high temperature stability.

Welding electrodes: Doped tungsten rods (such as cerium-doped or lanthanum-doped) are used for argon arc welding (TIG) and plasma welding, and the arc stability depends on its conductivity.
High-temperature furnace: Tungsten rod is used as a heating element, using thermal conductivity to quickly transfer heat, and the working temperature can reach 2500°C.
Scientific research: Tungsten rod is used as an electrode for high-temperature superconductivity experiments, and its conductivity and high temperature resistance ensure the reliability of the experiment.

Technical Challenges:
Conductivity is lower than copper and silver, limiting the competitiveness of tungsten rods in low-resistance applications.
The resistivity increases slightly at high temperatures (about 0.004/°C), and the circuit design needs to be optimized to compensate.
Thermal conductivity decreases slightly at very high temperatures (>2000°C) and thermal management design needs to be considered.

Development Trends:
Development of doped tungsten rods (e.g. lanthanum-doped or cerium-doped) to reduce resistivity and improve arc stability.
STUDY OF NANOSTRUCTURED TUNGSTEN MATERIALS TO OPTIMIZE CONDUCTIVITY THROUGH GRAIN BOUNDARY ENGINEERING SNOWFLAKE.
A conductive coating (e.g. graphene coating) is used to improve the conductivity of the surface of tungsten rods for special electrodes.

3.1.5 Low vapor pressure of tungsten rods
Tungsten rods have a very low vapor pressure ($<10^{-4}$ Pa at 3000°C) at high temperatures, making them stable in vacuum or high temperature environments, and not easy to volatilize or pollute the environment. This property is due to the high melting point and strong metallic bonds of tungsten, which reduce the evaporation of atoms at high temperatures.

Application Scenarios:
Vacuum furnace: tungsten rod is used as a heating element or support for vacuum high temperature furnace to prevent material volatilization and polluting the furnace environment.
Semiconductor manufacturing: high-purity tungsten rods are used in ion implantation equipment and sputtering targets, and the low vapor pressure ensures a pollution-free clean room environment.
Aerospace: Tungsten rods are used in high-temperature vacuum experimental equipment, such as plasma research devices, to maintain long-term stability.
Electronics: Tungsten rods are used in vacuum electron tubes (e.g. X-ray tubes) to prevent material volatilization at high temperatures from affecting performance.

Technical Challenges:
Trace impurities such as oxygen or carbon can increase vapor pressure, and raw material purity needs to be tightly controlled.

The vacuum system requires ultra-high vacuum (less than 10^{-5} Pa), which requires high tightness of the equipment.
Long-term operation at high temperatures may lead to oxidation of the surface, requiring a protective atmosphere or coating.

Development Trends:
Developed ultra-high-purity tungsten (99.9999%) to further reduce vapor pressure and meet the needs of next-generation semiconductors.
Research high-temperature anti-oxidation coatings (e.g. SiC or Al_2O_3) to reduce surface evaporation.
Optimize the vacuum furnace design, combined with low-temperature plasma sintering, to reduce the operating temperature.

3.2 Chemical properties of tungsten rods

The chemical properties of tungsten rods include excellent corrosion resistance, chemical stability, and limited elemental reactivity, making them excellent in harsh chemical environments and suitable for a wide range of industrial and scientific applications.

3.2.1 Corrosion resistance of tungsten rods

Tungsten rods have excellent corrosion resistance to acids, alkalis and most oxidizing agents (such as hydrochloric acid, sulfuric acid, hydrofluoric acid) at room temperature, and only react slowly in high-temperature concentrated nitric acid or molten alkali (such as sodium hydroxide). Corrosion resistance results from a dense oxide layer (WO_3) formed on the surface of tungsten, which effectively isolates external chemicals.

Application Scenarios:
Chemical industry: Tungsten rods are used in corrosion-resistant electrodes or containers, such as electrochemical processing equipment.
High-temperature furnace: Tungsten rod is used as a heating element in hydrogen or an inert atmosphere and is resistant to corrosive gases.
Medical equipment: Tungsten rod is used as a target for X-ray equipment to resist high-temperature oxidation environments.
Marine: tungsten alloy rod is used as a counterweight in seawater environment, resistant to salt spray corrosion.

Technical Challenges:
The oxide layer may thicken or peel off at high temperatures, requiring a protective atmosphere (e.g. hydrogen or argon).
Certain strong oxidizing agents, such as aqua regia, can corrode tungsten rods at high temperatures, limiting the range of applications.
The addition of nickel or iron to tungsten alloy rods may reduce corrosion resistance, and the alloy ratio needs to be optimized.

Development Trends:

Development of corrosion-resistant coatings (e.g. zirconia or silicon nitride) to enhance high temperature corrosion resistance.

Research on tungsten matrix composites with the addition of corrosion-resistant elements such as chromium to improve performance.

Optimize surface treatment processes (e.g. plasma spraying) to create a denser protective layer.

3.2.2 Chemical stability of tungsten rods

Tungsten rods are chemically stable at ambient and moderate temperatures (<500°C) and virtually do not react with oxygen, nitrogen or other common gases. At high temperatures (>1000°C), tungsten rods may slowly form WO_3 with oxygen, or hard compounds (e.g., WC, WN) with carbon and nitrogen, but the reaction rate is low and needs to be triggered by specific conditions.

Application Scenarios:

Vacuum environment: Tungsten rod is used in the heating element of the vacuum furnace, and the chemical stability ensures long-term operation without pollution.

Semiconductor manufacturing: High-purity tungsten rods are used in ion implantation devices to prevent chemical reactions from contaminating wafers.

High-temperature experiments: Tungsten rods are used in high-temperature superconductivity or plasma research to remain chemically inert.

Electronics: Tungsten rods are used in the cathode of vacuum tubes to prevent chemical reactions from affecting performance.

Technical Challenges:

Trace reactions with oxygen or carbon at high temperatures can lead to surface deterioration, requiring strict atmosphere control.

Doping with additives in tungsten rods, such as thorium oxide, may reduce chemical stability and require optimization of the formulation.

Long-term operation at high temperatures can trigger the accumulation of surface compounds, which can affect conductivity.

Development Trends:

Ultra-high purity tungsten (99.999%) was developed to reduce chemical reactions caused by impurities.

Chemical vapor deposition (CVD) coating is used to form a stable protective layer and extend the life.

Research on self-healing coating technology to automatically repair surface damage at high temperatures.

3.2.3 Reactivity of tungsten rods with other elements

Tungsten rods have very low reactivity with other elements at room temperature, and only have limited reactions with oxygen, carbon, nitrogen, fluorine and other elements under specific high temperature conditions. For example, WO_3 is formed with oxygen at > 1000°C, tungsten carbide

(WC) with carbon at >1500°C, and tungsten nitride (WN) with nitrogen at >2000°C. These reactions require high energy activation, and the reaction products are usually high hardness compounds, some of which can be used to enhance the properties of tungsten rods.

Application Scenarios:

Hard coating: Using the reactivity of tungsten and carbon, a WC coating is formed on the surface of the tungsten rod to enhance wear resistance.

High temperature experiment: Tungsten rod is used in a high temperature reactor in an inert atmosphere to control the reaction with carbon or nitrogen.

Welding electrode: The doped tungsten rod reacts with oxygen in the high-temperature arc to maintain the stability of the arc.

Chemical industry: tungsten rods are used in special chemical reaction vessels to resist corrosion by specific gases.

Technical Challenges:

The high temperature reaction may change the surface properties of the tungsten rod and affect the electrical or thermal conductivity.

Reaction products (e.g., WO_3) may degrade surface quality and need to be cleaned or protected regularly.

Doping elements can cause complex reactions that require precise control of doping amounts and process conditions.

Development Trends:

Research selective reaction technology to control the reaction of tungsten with specific elements at high temperature to form functional coatings.

Development of multi-layer composite coatings (e.g. WC/Al_2O_3) that balance corrosion resistance and functionality.

Optimize the atmosphere control technology, reduce unnecessary high temperature reactions, and improve the life of tungsten rods.

3.3 Mechanical properties of tungsten rods

The mechanical properties of tungsten rods include high strength and hardness, excellent creep resistance, and limited toughness and machinability, which make it excellent in high load and high temperature stress environments, but it is difficult to process.

3.3.1 High strength and hardness of tungsten rods

Tungsten rods have extremely high strength and hardness, with a Vickers hardness (HV) range of 350–500 and a tensile strength between 700–2000 MPa (depending on the processing process and doping). The high strength is due to the strong metallic bonds and body-centered cubic lattice of tungsten, and the high hardness makes it wear-resistant and suitable for high-load applications.

Application Scenarios:

High Temperature Molds: Tungsten rods are used in glass forming or ceramic sintering molds to

resist high pressure and wear.
Military: tungsten alloy rods are used for armor-piercing bullet cores, combined with high hardness and density, to enhance penetration.
Industrial tools: Tungsten rods are machined into cutting tools or stamping dies and are resistant to high stresses.
Aerospace: Tungsten rods are used in high-temperature thruster components to withstand mechanical loads.

Technical Challenges:
High hardness increases the difficulty of cutting and grinding, requiring diamond tools or laser machining.
High strength but high brittleness, easy to produce microcracks during processing.
Large-format tungsten rods (>50 mm) are forged or extruded with internal stress concentration, and the process needs to be optimized.

Development Trends:
Nanocrystalline tungsten material is used to refine the grain to <100 nm to improve strength and hardness.
Development of plasma-assisted processing technology to reduce processing cracks and improve accuracy.
Tungsten matrix composites are studied, with the addition of toughness-enhancing phases (e.g., nickel) to balance strength and toughness.

3.3.2 Creep resistance of tungsten rods
Tungsten rods have excellent creep resistance at high temperatures (>2000°C) and can withstand stress for a long time without significant deformation. Creep resistance stems from the high melting point and stable crystal structure of tungsten, and doped tungsten rods (e.g. potassium or rare earth) are further enhanced by grain boundary strengthening.

Application Scenarios:
High-temperature furnace: Tungsten rod is used as a support for a quartz furnace or sapphire furnace and is subjected to long-term high-temperature stress.
Aerospace: Tungsten rods are used in high-temperature wind tunnel test components to resist creep deformation.
Scientific research: Tungsten rods are used in high-temperature experimental equipment to maintain long-term dimensional stability.
Industrial: Tungsten rods are used in high-temperature molds to resist deformation under long-term stress.

Technical Challenges:
Grain growth at very high temperatures (>2500°C) may reduce creep resistance, and microstructure needs to be controlled.
Long-term operation may result in surface oxidation or dopant volatilization, affecting performance.

Doped tungsten rods need to optimize the distribution of dopant to avoid local uneven performance.

Development Trends:

Development of doping technologies (e.g., composite rare earth doping) to further improve creep resistance and extend the target life by 30%.

Hot Isostatic Pressing (HIP) process is used to reduce grain boundary defects and improve high-temperature stability.

Research on high-temperature in-situ monitoring technology to evaluate creep behavior in real time and optimize design.

3.3.3 Toughness and machinability of tungsten rods

Tungsten rods have low toughness and are brittle, especially at room temperature. The body-centered cubic lattice structure and high hardness result in poor ductility and are processed at high temperatures (800–1500°C) or multiple annealing times to improve plasticity. Doped tungsten rods can slightly improve toughness by adding rare earths or oxides (such as cerium oxide, lanthanum oxide), but it is still difficult to process.

Application Scenarios:

Drawing: Tungsten rods are drawn into tungsten filaments (0.01–0.1 mm diameter), which require high temperature and multiple annealings for filament production.

Precision parts: Tungsten rods are processed into semiconductor probes or electrodes, which require high-precision machining technology.

Welding electrode: Doped tungsten rod (WC20, WL20) is processed into electrode, and the toughness is optimized to improve the service life.

Mold making: tungsten rods are processed into complex shape molds, which require laser or EDM processing.

Technical Challenges:

The brittleness is high at room temperature, and the processing is easy to produce micro-cracks, which reduces the yield rate.

High-temperature processing requires specialized equipment, such as vacuum furnaces or induction heaters, which increases costs.

Small-diameter tungsten rods (<1 mm) have a high risk of pull-out fracture and require precise control of deformation.

Development Trends:

Developed nanoscale tungsten powder sintering technology to refine grains and improve toughness and processability.

Laser processing or EDM machining is used to reduce mechanical stress and improve machining accuracy.

Research on new dopants (such as composite rare earths) to improve the toughness at room temperature and reduce the difficulty of processing.

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CTIA GROUP LTD
Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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3.4 Comparison of characteristics of different types of tungsten rods

There are significant differences in the physical, chemical and mechanical properties of different types of tungsten rods (pure tungsten rods, high-purity tungsten rods, doped tungsten rods), which affect their application fields and performance.

3.4.1 Pure tungsten rod and high purity tungsten rods

Comparison of physical properties:

Pure tungsten rod (purity≥99.9%): density 19.0–19.25 g/cm³, melting point 3410°C, coefficient of thermal expansion 4.5×10^{-6}/°C, thermal conductivity 173 W/m·K, electrical conductivity 18% IACS. Grain sizes of 10–50 μm and trace impurities (100–500 ppm) can affect high-temperature performance.

High-purity tungsten rod (purity≥99.95%): density close to the theoretical value of 19.25 g/cm³, finer grain (5–15 μm), impurity content < 50 ppm, slightly better conductivity (resistivity about 5.3 μΩ·cm vs. 5.5 μΩ·cm), lower vapor pressure, suitable for clean environments.

Comparison of chemical properties:

Pure tungsten rod: strong corrosion resistance, but the trace reaction to oxygen or carbon is more obvious at high temperatures, and the atmosphere needs to be protected.

High-purity tungsten rods: higher chemical stability, almost no reaction with chemicals at room temperature, lower WO_3 formation rate at high temperatures, suitable for vacuum or cleanroom applications.

Comparison of mechanical characteristics:

Pure tungsten rod: Vickers hardness 350–450 HV, tensile strength 700–1000 MPa, low toughness, high temperature annealing is required for processing.

High-purity tungsten rod: the hardness is slightly higher (400–500 HV), the tensile strength is 800–1100 MPa, and the grain refinement improves the strength, but the toughness is still limited and requires precision machining.

Application Differences:

Pure tungsten rod: suitable for general high-temperature applications, such as quartz furnace core rods, filament raw materials, counterweights.

High-purity tungsten rods: Specially designed for high-precision and clean environments, such as electrodes for semiconductor ion implantation equipment, sputtering targets, and EUV lithography machine components.

Technical Challenges:

Pure tungsten rods are less costly, but impurities can affect performance consistency.

The production of high-purity tungsten rods requires CVD purification and clean room processing, which has high cost and strict equipment requirements.

Development Trends:

Pure tungsten rod: optimize the sintering process, reduce impurities, and improve performance

stability.
High-purity tungsten rod: develop ultra-high-purity tungsten (99.9999%) to meet the needs of chip manufacturing below 3nm.

3.4.2 Special properties of doped tungsten rods

Physical properties: Doped tungsten rods (containing 0.5–2 wt% rare earths or oxides, such as cerium oxide, lanthanum oxide, thorium oxide) are slightly less dense than pure tungsten rods (19.0–19.2 g/cm³) due to the lower density of dopants. The grain refinement is 5–15 μm, and the coefficient of thermal expansion and thermal conductivity (about 160 W/m·K) is slightly lower than that of pure tungsten rod, but the electrical conductivity is slightly higher (about 5.0 μΩ·cm), due to the improved electron mobility of the dopant.
Chemical properties: Doped tungsten rods maintain the corrosion resistance and chemical stability of tungsten, but at high temperatures, some dopants (such as thorium oxide) may cause a slight reaction that reduces stability. Rare earth doping (such as cerium-doped, lanthanum-doped) is non-radioactive, meets environmental protection requirements, and has better chemical stability.
Mechanical characteristics: The doped tungsten rod is strengthened by grain boundaries to improve the tensile strength (1000–1200 MPa) and toughness, and the creep resistance is significantly improved, which is suitable for long-term stress at high temperature. With a Vickers hardness of 400–500 HV, the processability is better than that of pure tungsten rods, but it still needs to be processed at high temperatures.

Application Scenarios:
Welding electrode: Doped tungsten rod (such as WC20, WL20) is used for argon arc welding and plasma welding, with high arc stability and low burnout rate.
High-temperature furnace: potassium-doped or rare-earth tungsten rod is used for vacuum furnace heating element, which can withstand more than 2500 °C.
Electronics: Doped tungsten rods are used in cathode ray tubes, microwave devices, and laser emitters.
Emerging application: High-temperature nozzles for 3D printing metal devices, resistant to high-temperature metal melts.

Technical Challenges:
The uniformity of the dopant is difficult to control, and high-temperature sintering may lead to volatilization and affect performance.
The application of thorium-doped tungsten rods is slightly radioactive, and environmentally friendly alternatives need to be developed.
The doping process increases production complexity and cost, requiring optimization of recipes and processes.

Development Trends:
Research and development of composite rare earth doping (such as $La_2O_3+Y_2O_3$) to improve arc stability, life and burn resistance.
Nano doping technology is used to reduce the doping amount (<0.5 wt%) and improve performance

efficiency.
Development of non-radioactive, high-performance electrodes that meet global environmental standards (e.g. EU RoHS Directive).

3.5 Tungsten Rod MSDS from CITA GROUP LTD

The following is a summary of the MSDS (Material Safety Data Sheet) of Chinatungsten Tungsten Rods, which covers safety, health and environmental information based on the general characteristics and industry standards of tungsten rods. Since tungsten rod is a solid metal material, its MSDS content is relatively concise, mainly focusing on the potential risks in processing and use.

Material Safety Data Sheets (MSDS)

Product Name: Tungsten rod (pure tungsten rod, high purity tungsten rod, doped tungsten rod)
Chemical composition:
Pure tungsten rod: tungsten (W) ≥ 99.9%, trace impurities (Fe, Ni, C, O, etc., 100–500 ppm).
High purity tungsten rod: tungsten (W) ≥ 99.95%, impurities < 50 ppm.
Doped tungsten rod: tungsten (W) 97–99.5%, dopant (such as CeO_2, La_2O_3, ThO_2, K) 0.5–2 wt%.

Physical form: Solid metal rod with density 19.0–19.25 g/cm³ and surface roughness Ra 1.6–3.2 μm.
Hazard Overview:
There is no significant danger at room temperature, high chemical stability, and it is not easy to burn or explode.
Processing (e.g., cutting, grinding, welding) may produce metal dust or fumes, which may cause respiratory irritation if inhaled.
Thorium-doped tungsten rod (WT20) contains thorium oxide, which is slightly radioactive and requires special protection.

Health Hazards:
Inhalation: Tungsten dust may irritate the respiratory tract, and long-term exposure may cause lung discomfort.
Skin contact: Solid tungsten rods are non-toxic, but processing dust may cause minor skin irritation.
Eye contact: Dust may cause mechanical irritation and should be rinsed with eyes.
Ingestion: The likelihood of accidental ingestion is low, and small amounts of ingestion are not significantly toxic, but should be avoided.
Thorium-doped tungsten rods: Long-term exposure to thorium oxide dust may increase the risk of radiation and exposure needs to be controlled.

Safety precautions:
Personal protection: Wear a dust mask (N95 or higher), protective eyewear and gloves during processing.
Ventilation: The processing area needs to be equipped with a local exhaust or dust removal system to control the dust concentration.

Radioactive protection (thorium-doped tungsten rods): use a special fume hood, monitor radiation levels regularly, and comply with local regulations (e.g. China GB 18871-2002).

Handling & Storage:
Store in a dry, well-ventilated warehouse away from contact with strong oxidizing agents (e.g. concentrated nitric acid).
The processing equipment needs to be grounded to prevent dust explosions caused by static electricity accumulation.
Waste tungsten rods are recycled as metal waste, and thorium-doped tungsten rods need to be disposed of in accordance with radioactive waste regulations.

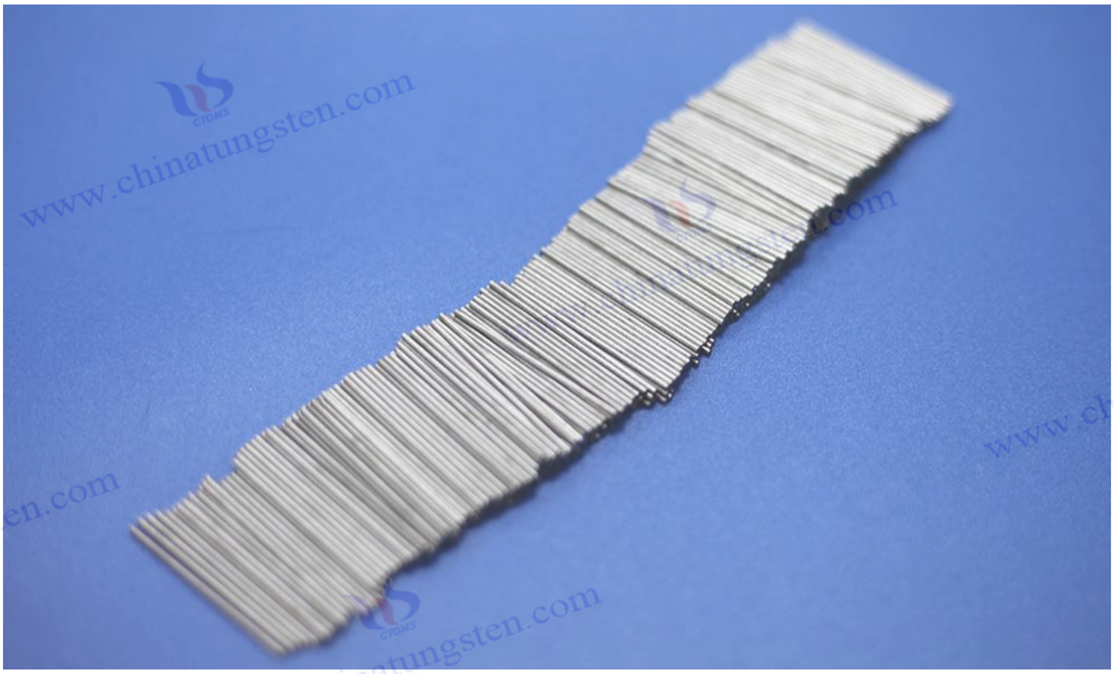
First Aid Measures:
Inhalation: Move the person to fresh air and seek medical attention if necessary.
Skin contact: Wash your skin with soap and water and seek medical attention if necessary.
Eye contact: Rinse with plenty of water for at least 15 minutes and seek medical attention if necessary.
Intake: Rinse your mouth immediately, dilute with water, and seek medical attention if necessary.

Environmental impact:
Tungsten rods themselves are not toxic to the environment, but processing dust can pollute air or water bodies and needs to be collected properly.
Waste doped with thorium-tungsten rod should be disposed of in accordance with radioactive waste regulations to avoid environmental pollution.

Regulatory Information:
It conforms to China GB/T 4187-2017 (tungsten rod standard) and YS/T 695-2009 (tungsten electrode standard).
Thorium-doped tungsten rods are subject to the International Atomic Energy Agency (IAEA) Safety Code for Radioactive Materials and the Chinese GB 18871-2002 (Standard for Protection against Ionizing Radiation).

Shipping Information:
Transportation of non-dangerous goods, in line with the requirements of the International Maritime Organization (IMO) and the International Air Transport Association (IATA).
Thorium-doped tungsten rods shall be marked with radioactive warnings, and shall be packaged and transported in accordance with regulations.

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



CTIA GROUP LTD tungsten rods

Chapter 4 Preparation and Production Technology of Tungsten Rods

As a high-performance refractory metal material, the preparation process of tungsten rod involves complex raw material treatment, powder metallurgy, deformation processing, post-treatment and customized technology for different types of tungsten rod. Tungsten's high melting point (3410°C), high density (19.25 g/cm³) and unique mechanochemical properties place stringent demands on production equipment and process control. This chapter will discuss in detail the preparation and production process of tungsten rods, including raw material preparation, powder metallurgy technology, deformation processing technology, preparation of large-scale tungsten rods, post-treatment technology and the process characteristics of different types of tungsten rods (pure tungsten rods, high-purity tungsten rods, doped tungsten rods).

4.1 Preparation of raw materials for tungsten rods

The preparation of tungsten rods begins with the acquisition and processing of high-quality raw materials, involving the mining and purification of tungsten ore, the preparation of tungsten powder, and the addition of alloying elements or dopants. These steps have a direct impact on the purity, performance and production efficiency of tungsten rods.

4.1.1 Mining and purification of tungsten ore

The raw material of tungsten rod is mainly derived from tungsten ore, and the common types include wolframite ($FeMnWO_4$) and scheelite ($CaWO_4$). Mining is usually carried out using open-pit or underground mining methods, depending on the geological conditions of the deposit. The mined ore undergoes multiple stages of purification to obtain a high-purity tungsten compound.

Process:
Ore crushing and grinding: The raw ore is crushed to small particles (<10 mm) and further refined to the micron level (10–100 μm) by ball milling or rod milling to improve the efficiency of subsequent beneficiation.
Beneficiation: Gravity beneficiation (e.g., jig, shaker), flotation or magnetic separation techniques are used to separate tungsten ore from gangue to obtain high-grade tungsten concentrate (WO_3 content 60–70%).
Chemical purification: Tungsten concentrate is roasted (500–800°C) to remove impurities such as sulfur and arsenic, followed by alkali (sodium hydroxide) or acid (hydrochloric acid) leaching to produce sodium tungstate (Na_2WO_4) or tungstic acid (H_2WO_4).
Crystallization and refining: further purification by solvent extraction or ion exchange to generate high-purity ammonium tungstate (APT, $(NH_4)_2WO_4$) with a purity of more than 99.9%, which is suitable for subsequent tungsten powder preparation.

Key points:
The beneficiation process needs to be precisely controlled to reduce impurities (e.g. silicon, phosphorus, iron).
The alkali leaching method is suitable for wolframite, and the acid leaching method is suitable for scheelite, and the process needs to be optimized according to the ore type.
High-purity APT is the key raw material for the preparation of high-purity tungsten rods, and impurities such as carbon and oxygen need to be strictly controlled.

4.1.2 Preparation of tungsten powder

Tungsten powder is the core raw material for the preparation of tungsten rods, which is obtained by reducing ammonium tungstate or tungsten oxide (WO_3) by hydrogen, and the particle size and purity directly affect the properties of tungsten rods.

Process:
Oxide preparation: Ammonium tungstate is calcined in air (400–600°C) and decomposed into tungsten oxide (WO_3) or WO_{29}, the color is yellow or blue-green.
Hydrogen reduction: Tungsten oxide is reduced to high-purity hydrogen (99.999%) at 600–900°C in a multi-tube furnace or rotary furnace in two stages: first to WO_2 (brown) and then further to tungsten metal powder (grey). The reducing atmosphere needs to be strictly controlled to avoid oxygen or nitrogen pollution.
Sieving and classification: Tungsten powder (0.5–5 μm) with uniform particle size can be obtained by vibrating screen or air flow classification, which is suitable for different types of tungsten rods (e.g., pure tungsten rods require larger particle sizes, and high-purity tungsten rods require finer particle sizes).
Quality Control: Impurities are detected using X-ray fluorescence spectroscopy (XRF) or inductively coupled plasma mass spectrometry (ICP-MS) to ensure a purity of ≥ 99.9% (high-purity tungsten powder ≥ 99.95%).

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Key points:
The reduction temperature and hydrogen flow rate need to be precisely adjusted to control the particle size and morphology of tungsten powder.
High-purity tungsten powder needs to be produced in a clean environment to avoid dust pollution.
Tungsten powder should be sealed for storage to prevent oxidation or moisture absorption.

4.1.3 Addition of alloying elements and dopants

In order to prepare doped tungsten rods or tungsten alloy rods, alloying elements or dopants need to be added to tungsten powder to improve arc stability, creep resistance or processability.

Craft:
Dopant selection: Common dopant options include rare earth oxides (e.g., cerium oxide CeO_2, lanthanum oxide La_2O_3, yttrium Y_2O_3, 0.5–2 wt%), oxides (e.g., thorium ThO_2, zirconia ZrO).₂) or trace amounts of potassium (50–100 ppm). The alloying elements include nickel, iron, and copper, which are used to prepare high-density tungsten alloy rods.
Mixing method: The dopant is evenly mixed with tungsten powder by high-energy ball milling or spray drying to ensure that the dopant is evenly distributed. The ball milling time is controlled at 4–8 hours to avoid powder over-fineness or contamination.
Solution doping: The dopant is dissolved in water in the form of nitrate (such as lanthanum nitrate), sprayed on the surface of tungsten powder, and formed a uniform doping after drying.
Quality control: Scanning electron microscopy (SEM) was used to analyze the dopant distribution, and XRF was used to detect the doping amount to ensure compliance with the design requirements (e.g., CeO_2 content of 2% ± 0.1%).

Key points:
The particle size of the dopant should be matched to that of tungsten powder (typically < 1 μm) to avoid agglomeration.
Thorium-doped tungsten rods require special protection because thorium oxide is slightly radioactive.
The proportion of alloying elements should be controlled to prevent the melting point or corrosion resistance of tungsten from being reduced.

4.2 Powder metallurgy technology of tungsten rods

Powder metallurgy is the core technology of tungsten rod preparation, which converts tungsten powder into dense rod-shaped blanks through powder mixing, pressing and high-temperature sintering, which provides the basis for subsequent deformation processing.

4.2.1 Powder mixing and pressing

Powder mixing: Tungsten powder (or doped tungsten powder) is mixed with a binder (e.g. polyvinyl alcohol PVA) by mechanical mixing or spray drying to ensure flow and formability. Mixing equipment includes planetary mills or V-mixers with a mixing time of 2–4 hours to avoid powder oxidation or contamination.

Pressing process:
Cold isostatic pressing (CIP): The mixed tungsten powder is loaded into a flexible mold and pressed into a rod-like blank at a pressure of 100–200 MPa with a density of about 50–60% theoretical density. CIP is suitable for large size blanks and has good uniformity.
Moulding: Pressing on a hydraulic press using a steel die, suitable for small batches or small diameter blanks at pressures of 50–150 MPa.
Process control: The pressing speed needs to be slow (0.5–1 mm/s) to prevent cracking of the blank. The blank is degreased in a vacuum or inert atmosphere to remove the binder.

Key points:
The surface of the mold needs to be smooth to reduce the surface defects of the blank.
The pressing pressure needs to be adjusted according to the powder particle size and the type of dopants.
Clean environment (e.g. ISO class 7) to avoid dust contamination.

4.2.2 High temperature sintering
High-temperature sintering is a key step in powder metallurgy, in which tungsten powder particles are combined at high temperatures to form high-density blanks.

Process:
Sintering equipment: hydrogen protection furnace or vacuum sintering furnace is adopted, the temperature is 2000–2800 °C, and the temperature is kept for 1–3 hours.
Sintering process: Tungsten powder blanks are subjected to particle diffusion and binding at high temperatures, with a porosity of 5–10% and a density of 90–95% theoretical density. The sintering is divided into pre-sintering (1000–1500°C, removal of volatile impurities) and main sintering (2000–2800°C, densification).
Atmosphere control: hydrogen protection against oxidation, flow rate 0.5–2 m^3/h; Vacuum sintering (10^{-3}–10^{-5} Pa) is suitable for high-purity tungsten rods to reduce gas adsorption.
Cooling: Slow cooling (10–20°C/min) to prevent cracks caused by thermal stress.

Key points:
The sintering temperature needs to be optimized according to the particle size of the tungsten powder and the type of dopants, too high may lead to too large grains.
The atmosphere inside the furnace needs to be of high purity (99.999%) to avoid carbon or oxygen pollution.
The sintered blank needs to be ultrasonically inspected to check for internal porosity and cracks.

4.2.3 Performance optimization of sintered tungsten rods
Sintered tungsten rods (black rods) need to be further optimized to meet the application requirements.

Optimization method:
Secondary sintering: Short-term secondary sintering (0.5–1 hour) at 2200–2600°C in a vacuum

furnace further reduces the porosity to <2% and increases the density to more than 19.0 g/cm³.
Hot isostatic pressing (HIP): Processed at 2000°C, 100–200 MPa, micropores were eliminated, and the density was close to the theoretical value of 19.25 g/cm³.
Surface cleaning: The surface oxide layer is removed with chemical cleaning (hydrochloric acid or hydrofluoric acid) to achieve a roughness of Ra 3.2–6.4 μm.
Microstructure adjustment: Optimize grain size (10–50 μm) and increase strength by controlling the sintering time and cooling rate.

Key points:
The HIP process requires special equipment for high-performance tungsten rods.
Surface cleaning should be carried out in a ventilated environment to avoid acid hazards.
Performance optimization requires balancing grain size and porosity to prevent loss of strength.

4.3 Tungsten rod deformation processing technology
Deformation processing further improves the density, strength and dimensional accuracy of tungsten rods through hot forging, hot extrusion, rolling and drawing to meet the needs of different applications.

4.3.1 Hot forging (hammer forging, rotary forging)
Hot forging processes sintered tungsten rods into high-density bars through high-temperature mechanical deformation, which is divided into hammer forging and rotary forging.

Hammer forging process:
Equipment: Air hammer or hydraulic forging machine, forging temperature 1200–1500°C, hydrogen or argon protection.
Process: The sintered tungsten rod is preheated to 1200°C and forged in multiple passes with a deformation of 10–20% each time, gradually reducing the diameter and increasing the density (19.0–19.25 g/cm³).
Post-treatment: Annealing after forging (1000–1200°C) for stress relief and surface turning to a roughness of Ra 1.6–3.2 μm.

Rotary swaging process:
Equipment: Rotary swaging machine with high-frequency induction heater at 1200–1400°C.
Process: Tungsten rods are subjected to multi-directional pressure in a rotating die and are uniformly deformed, suitable for small and medium-diameter rods (5–50 mm).
Advantages: Rotary swaging is more uniform than hammer swaging, has a lower risk of cracking, and is suitable for high-precision applications.

Key points:
The forging temperature needs to be precisely controlled to avoid overheating and over-graining.
The amount of deformation needs to be controlled step by step to prevent internal stress concentration.
Protective atmospheres (e.g., argon) prevent oxidation of the surface.

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Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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4.3.2 Hot extrusion

Hot extrusion is used for the forming of tungsten rods with large specifications or complex cross-sections, with high density and strength.

Process:

Preheating: Sintered tungsten rods are heated to 1300–1600°C and protected by hydrogen or argon.

Extrusion: Tungsten rods are extruded by a hydraulic extruder (500–1000 MPa) with a diameter of 20–100 mm and a density of 19.0–19.2 g/cm³.

Straightening and cooling: Cool slowly (10–20°C/min) after extrusion and adjust the shape using a straightener.

Surface treatment: Turning or grinding to a roughness of Ra 1.6–3.2 μm.

Key points:

Molds need to be made of high-temperature resistant materials (such as molybdenum or ceramic) to reduce wear.

The extrusion speed (0.1–0.5 mm/s) needs to be slow to prevent cracking.

Large-diameter extrusion requires high-tonnage equipment to control costs.

4.3.3 Rolling

Tungsten rods are processed into small and medium-sized diameters (5–20 mm) by hot or cold rolling with high dimensional accuracy and good surface quality.

Process:

Hot rolling: sintered or forged tungsten rods are heated to 1000–1300°C and gradually reduced in diameter by rolling in multiple passes (15–25% deformation).

Cold rolling (optional): Small diameter tungsten rods (<10 mm) are rolled at room temperature or low temperature (<500°C) for improved accuracy.

Annealing: Annealing at 900–1100°C eliminates work hardening and prevents cracking.

Surface treatment: Polished to roughness Ra 1.6–3.2 μm.

Key points:

Hot rolling requires high-temperature rolls (e.g. molybdenum alloys) to withstand the hardness of tungsten.

Cold rolling is limited to small diameters and requires high-precision equipment.

The annealing atmosphere should be pure to prevent surface contamination.

4.3.4 Pulling

Drawing is used to produce small diameter tungsten rods (<5 mm) and is a key process for the manufacture of tungsten wires and precision electrodes.

Process:

Blank preparation: Use forged or rolled tungsten rods (diameter 5–10 mm).

Drawing: Drawing through a diamond die at 800–1000°C in multiple passes with a diameter

reduction of 5–10% each time to a final diameter of 0.01 mm (tungsten wire).
Lubrication and annealing: Lubrication with graphite or molybdenum disulfide and periodic annealing (900–1100°C) to relieve stress.
Cleaning & Polishing: Chemical cleaning removes lubricants and polishes to a roughness of Ra 1.6–3.2 μm.

Key points:
The diamond die needs to be replaced regularly to maintain accuracy.
The drawing speed (1–5 m/min) needs to be controlled to avoid breakage.
An inert atmosphere is required for high-temperature drawing to prevent oxidation.

4.4 Preparation of large-scale tungsten rods

Large-size tungsten rods (diameter > 20 mm) are widely used in aerospace, military and industrial fields due to their high density and high strength.

4.4.1 Technical difficulties and challenges

The preparation of large-scale tungsten rods faces the following technical difficulties:

High density requirements: close to the theoretical density (19.25 g/cm³), sintering and deformation processing need to strictly control the porosity.
Internal defects: Large-diameter blanks are prone to porosity, cracks or stress concentrations, which affect strength.
Equipment limitations: Extrusion or forging requires large-tonnage equipment (> 1000 tons), which has high requirements for die materials and heating systems.
Uniformity: Large-size bars are prone to uneven grains or compositional segregation during sintering and processing.
Cost control: high energy consumption for high-temperature and high-tonnage processing, fast mold wear, and increased production costs.

4.4.2 Preparation method of high-density tungsten rods

Process:

Large-format billet pressing: Large-diameter billets (50–100 mm diameter) are prepared by cold isostatic pressing (200–300 MPa) with a density of 50–60% theoretical density.
High-temperature sintering: sintering at 2200–2800°C for 2–4 hours in a vacuum or hydrogen furnace with a density of 90–95%.
Hot isostatic pressing (HIP): 1–2 hours at 2000°C, 150–200 MPa, microporosity eliminated, density approaching 19.25 g/cm³.
Hot extrusion: extruded at 1300–1600 °C, 800–1200 MPa, diameter 20–100 mm, surface roughness Ra 3.2–6.4 μm.
Post-treatment: annealing (1000–1200°C) for stress relief and turning to roughness Ra 1.6–3.2 μm.

Key points:
The HIP process is the key to high density and requires ultra-high pressure equipment.
Extrusion dies need to be made of high-temperature resistant materials (e.g., molybdenum alloys) to reduce wear.
Sintering and extrusion are heated in sections to ensure a uniform temperature.

4.4.3 Process optimization and innovation

Optimization measures:

Graded sintering: multi-stage heating (1000°C pre-sintering, 2500°C main sintering) is used to reduce the excessive grain size.
Composite molds: Use molybdenum-based or ceramic-coated molds to extend mold life.
Automated control: Sensors monitor temperature, pressure, and atmosphere to improve process consistency.
Continuous extrusion: Develop a continuous hot extrusion line to reduce intercooling and reheating and improve efficiency.
Grain control: Optimize grain size (10–30 μm) and increase strength by adding trace amounts of dopants such as potassium or rare earths.

Key points:
Automated control requires integrated temperature and pressure sensors to ensure real-time monitoring.
Composite molds need regular maintenance to prevent deformation or wear.
The dopant should be added precisely to prevent the performance at high temperatures.

4.5 Post-treatment technology of tungsten rods

Post-treatment techniques include heat treatment, surface treatment, and precision machining to optimize the performance, surface quality, and dimensional accuracy of tungsten rods.

4.5.1 Heat treatment

Heat treatment relieves machining stress, optimizes microstructure, and improves the mechanical properties of tungsten rods through annealing or aging treatment.

Process:
Stress Relief Annealing: Hold at 1000–1200°C for 1–2 hours in a vacuum or hydrogen furnace with a cooling rate of 10–20°C/min to reduce internal stress.
Recrystallization annealing: Incubate at 1400–1600°C for 0.5–1 hour to adjust grain size (10–30 μm) to improve toughness.
Aging treatment (doped tungsten rod): keep warm at 800–1000°C for 2–4 hours to stabilize the dopant distribution and enhance arc performance.

Key points:
The annealing atmosphere needs to be of high purity (99.999% hydrogen or 10^{-5} Pa vacuum) to

prevent oxidation.

The temperature and holding time need to be adjusted according to the type of tungsten rod (pure tungsten or doped).

Cooling needs to be slow to avoid cracks caused by thermal stress.

4.5.2 Surface treatment (polishing, cleaning)

Surface treatment improves the surface quality and cleanliness of tungsten rods to meet the needs of high-precision applications.

Polishing process:

Mechanical polishing: Polishing to a roughness of Ra 1.6–3.2 μm using a diamond grinding wheel or alumina abrasive, suitable for welding electrodes or semiconductor components.

Chemical polishing: A mixture of hydrofluoric acid and nitric acid (ratio 1:3) is used to soak for 10–30 seconds to remove the surface oxide layer and achieve a mirror effect.

Electrolytic polishing: tungsten rod is used as anode, phosphate-based electrolyte treatment, and the surface roughness can reach Ra 1.6 μm or less.

Cleaning process:

Chemical cleaning: Cleaning with dilute hydrochloric acid or lye (sodium hydroxide) to remove oil and oxides on the surface.

Ultrasonic cleaning: Add cleaning agent to deionized water and ultrasonic cleaning for 5–10 minutes to ensure cleanliness.

Plasma cleaning: Removal of trace contaminants in vacuum plasma equipment, suitable for high-purity tungsten rods.

Key points:

Polishing should be carried out in a clean environment (ISO class 5) to prevent secondary contamination.

Chemical cleaning needs to control the acid and alkali concentration to avoid corrosion of tungsten rods.

Plasma cleaning is suitable for high-precision applications and requires special equipment.

4.5.3 Precision machining and cutting

Precision machining and cutting are used to produce tungsten rods of specific shapes and sizes to meet the high precision requirements.

Process:

Turning: CNC lathes with diamond tools for machining diameter tolerances ± 0.05 mm and surface roughness Ra 1.6–3.2 μm.

Grinding: Machining of small diameter tungsten rods (<5 mm) with a tolerance of ± 0.02 mm using a center grinder or a centerless grinder.

Electrical Discharge Cutting (EDM): For cutting complex shapes or large sizes of tungsten rods with an accuracy of ±0.01 mm, suitable for military parts.

Laser cutting: using high-power lasers, cutting small diameter tungsten rods or micro parts, small heat affected zone, high precision.

Key points:
Diamond tools need to be replaced regularly to maintain cutting accuracy.
EDM needs to control the discharge parameters to prevent surface burns.
Laser cutting requires inert gas protection to reduce oxidation.

4.6 Process characteristics of different types of tungsten rods

Different types of tungsten rods (pure tungsten rods, high-purity tungsten rods, doped tungsten rods) have different preparation processes due to differences in composition and application.

4.6.1 Pure tungsten rod process

Process characteristics:
Raw materials: Tungsten powder with a purity of ≥ 99.9%, particle size of 0.5–5 μm, and impurities (such as Fe, C, O) are controlled at 100–500 ppm.
Powder metallurgy: cold isostatic pressing (100–200 MPa) billet, hydrogen protected sintering (2000–2800°C), density 90–95%.
Deformation: hot forging or rolling (1200–1500°C), multi-pass deformation, density up to 19.0–19.25 g/cm³.
Post-treatment: annealed (1000–1200°C) for stress relief, turned or polished to a roughness of Ra 1.6–3.2 μm.
Application-oriented: The process focuses on cost control and is suitable for general high-temperature applications (such as quartz furnace core rods, filament raw materials).

Key points:
The sintering temperature needs to balance grain growth and pore elimination.
The processing technology is simple, and the equipment requirements are relatively low.
The surface treatment is mainly mechanical polishing to meet the industrial precision.

4.6.2 High-purity tungsten rod process

Process characteristics:
Raw materials: Tungsten powder with a purity of ≥ 99.95%, particle size of 0.1–1 μm, impurity < 50 ppm, purified by chemical vapor deposition (CVD).
Powder metallurgy: sintering (2600–2800°C) in ultra-high vacuum (10^{-5} Pa) with a density of more than 98% and a porosity of <1%.
Deformation: rotary swaging or rolling (1200–1400°C) with a deformation of 10–15% to ensure fine grains (5–15 μm).
Post-processing: electropolishing or plasma cleaning, roughness Ra 1.6–3.2 μm, cleanroom (ISO class 5) packaging.
Application-oriented: The process emphasizes high purity and cleanliness, and is suitable for semiconductor, medical, and EUV lithography machine components.

Key points:
Purification and sintering require ultra-high purity equipment to prevent contamination.
Processing requires a clean environment to control dust and impurities.
Post-processing is mainly chemical or electrolytic polishing to ensure surface quality.

4.6.3 Doped tungsten rod process

Process characteristics:
Raw materials: 0.5–2 wt% dopants (e.g., CeO_2, La_2O_3, ThO_2, K) are added to tungsten powder and mixed evenly by ball milling or solution doping.
Powder metallurgy: sintering temperature 2300–2600°C (lower than pure tungsten rod) to prevent dopant volatilization, density 95–98%.
Deformation: Drawing or rotary swaging (800–1400°C), dopant to improve toughness and reduce the risk of cracking.
Post-treatment: annealed (800–1000°C) stabilized dopant, polished to roughness Ra 1.6–3.2 μm, thorium-doped tungsten rod for radioactive protection.
Application-oriented: Process-optimized arc stability and creep resistance for welding electrodes and high-temperature furnace components.

Key points:
The dopant needs to be evenly distributed to avoid uneven performance.
Thorium-doped tungsten rods require special protection to comply with radioactivity regulations.
The drawing process requires multiple annealing to improve the success rate of machining.

CTIA GROUP LTD tungsten rods

Chapter 5 Uses of Tungsten Rods

With its high melting point (3410°C), high density (19.25 g/cm³), excellent mechanical strength, corrosion resistance and chemical stability, tungsten rod has shown irreplaceable application value in many fields. From industrial production to military defense, from electronic lighting to aerospace, to medical research and daily life, tungsten rods and their derivatives are widely used in high-performance scenarios. This chapter will discuss in detail the specific uses of tungsten rods in industry, military and defense, electronics and lighting, automotive and aerospace, medical and scientific research, and other fields, including quartz furnace core rods, armor-piercing bullet cores, tungsten wire electrodes, aerospace high-temperature components, radiation shielding, sporting goods, and more.

5.1 Industrial applications of tungsten rods

The industrial applications of tungsten rods are mainly concentrated in high-temperature, high-load and precision manufacturing environments, and its high melting point and dimensional stability make it an ideal material under extreme working conditions.

5.1.1 Tungsten core rod for quartz furnace

Quartz furnaces are used to produce high-purity quartz glass, mainly serving the optical fiber, semiconductor and photovoltaic industries. The tungsten rod is used as the core rod in the furnace, which withstands high temperatures of 2000–2500°C to maintain structural stability and ensure uniform flow of quartz melt.

App Features:
Material requirements: pure tungsten rod (purity ≥99.9%) or high purity tungsten rod (≥99.95%), diameter 10–50 mm, to prevent the adhesion of quartz.
Function: The core rod is fixed in the center of the furnace body, guiding the quartz blank to melt into a tube or rod shape, which can withstand high temperature and slight oxidation atmosphere.
Advantages: Tungsten's high melting point and low coefficient of thermal expansion (4.5×10^{-6}/°C) ensure that it does not soften or deform during long-term operation; Low vapor pressure reduces contamination in the furnace.
Typical scenario: Production of fiber optic preforms or quartz tubes for 5G communication base stations or solar cell substrates.

Key points:
The core rod needs to be cleaned regularly to avoid quartz residue affecting the surface quality.
Hydrogen or inert atmosphere protection for long service life.
Precision machining ensures the roundness and straightness of the core rod and meets the requirements of high-precision quartz products.

5.1.2 Preparation of monocrystalline silicon wafers

Monocrystalline silicon wafers are the core material for semiconductor chip manufacturing, and tungsten rods are used as heating elements, supports, or seed clamping rods in Czochralski monocrystalline furnaces.

App Features:
Material requirements: high-purity tungsten rod (purity≥99.95%), diameter 5–20 mm, to prevent contamination of silicon melt.
Function: As a seed crystal clamping rod, it can fix the silicon seed crystal and guide the growth of single crystal; As a heating element, it withstands a high temperature of 2300°C and provides a stable thermal field.
Advantages: high chemical stability ensures no contamination of high-purity silicon; High strength and creep resistance support long periods of high-temperature operation; Low vapor pressure is suitable for vacuum environments.
Typical scenario: Production of 8–12-inch monocrystalline silicon wafers for 5nm chip manufacturing.

Key points:
Tungsten rods need to be processed and stored in a clean room to avoid the introduction of impurities.
The clamping rod needs to be machined with high precision to ensure perfect alignment with the seed crystal.
Replace the heating element regularly to prevent grain growth from affecting performance.

5.1.3 Rare earth element purification

Rare earth elements (e.g. lanthanum, cerium, neodymium) are essential in the field of new energy, magnetic materials and catalysts, and tungsten rods are used as electrodes or crucible supports in electrolytic furnaces or high-temperature melting furnaces for rare earth purification.

App Features:
Material requirements: pure tungsten rod or doped tungsten rod (cerium or lanthanum-doped, 0.5–2 wt%), diameter 10–30 mm.
Function: As an electrode, tungsten rod provides stable current in electrolytic purification; As a support, it withstands high temperatures of 1600–2000°C and keeps the structure intact.
Advantages: strong corrosion resistance, resistance to rare earth melt erosion; Doped tungsten rod improves arc stability and prolongs electrode life; High density ensures mechanical stability.
Typical scenario: Production of high-purity lanthanum (La) or cerium (Ce) for permanent magnets for wind power or automotive exhaust catalysts.

Key points:
Doped tungsten rods need to be evenly doped to ensure consistent arc performance.
The surface of the electrode needs to be polished to reduce rare earth residues.
The electrolytic furnace needs an inert atmosphere to prevent oxidation of tungsten rods.

5.1.4 Tungsten crucible for sapphire crystal furnace

Sapphire crystals (Al_2O_3) are key materials for LED substrates and optical windows, and tungsten rods are processed into crucibles or supports in sapphire crystal growth furnaces that withstand temperatures of 2200–2400°C.

App Features:
Material requirements: high-purity tungsten rod (purity ≥ 99.95%), diameter 20–100 mm, surface roughness Ra 1.6–3.2 μm after processing into crucible.
Function: The tungsten crucible contains molten alumina, and the support fixes the crucible or seed crystal, keeps the thermal field stable, and promotes the growth of single crystal.
Advantages: high melting point and creep resistance ensure that the crucible does not deform; Low coefficient of thermal expansion reduces thermal stress; High density provides mechanical support.
Typical scenario: Production of 4–6 inch sapphire crystals for LED lighting or smartphone screens.

Key points:
The crucible needs to be precision machined to ensure a smooth inner wall and reduce crystal defects.
Vacuum or hydrogen protection prevents oxidation of tungsten crucibles.
The crucible needs to be inspected regularly to prevent cracks from affecting the quality of the crystal.

5.2 Tungsten rods are used in military and national defense

The high density and strength of tungsten rods make them important applications in the military and defense fields, especially in armor-piercing cores and high-explosive tungsten rods.

5.2.1 Armor-piercing cores

Armor-piercing cores are used in tank guns or anti-armor weapons, and tungsten alloy rods are an ideal material due to their high density and hardness.

App Features:
Material requirements: tungsten alloy rod (W-Ni-Fe or W-Ni-Cu, tungsten content 90–95 wt%), density 18.0–18.5 g/cm³, diameter 10–30 mm.
Function: The core penetrates the armor under high-speed impact (>1500 m/s), relies on high density to provide kinetic energy, and high hardness ensures that it does not fragment.
Advantages: more environmentally friendly than depleted uranium cores, with a density close to uranium (19.1 g/cm³); Excellent tensile strength (800–1200 MPa) ensures impact stability; It has good processing performance and is easy to form.
Typical scenario: for 120 mm tank shells or anti-tank missile warheads.

Key points:
The alloy ratio needs to be optimized to ensure a balance between density and toughness.
The core needs to be machined with high precision, and the diameter tolerance ± 0.05 mm.
Surface polishing reduces air resistance and increases range.

5.2.2 High-explosive tungsten rods

The high-explosive tungsten rod (also known as the "kinetic rod" or "scepter of God" concept) is a hypothetical high-velocity kinetic weapon that uses tungsten rods to be thrown from space or high altitudes, relying on gravitational acceleration and density to produce massive destructive power.

App Features:
Material requirements: pure tungsten rod or tungsten alloy rod, density 19.0–19.25 g/cm³, diameter 50–100 mm.
Function: Tungsten rod hits the target at supersonic speed (>Mach 100) from a high altitude (> 10 km), releasing kinetic energy equivalent to a small nuclear bomb to destroy underground fortresses or military facilities.
Advantages: High density provides huge kinetic energy; High melting point withstands frictional heat during re-entry (>2000°C); Non-radioactive and in line with international regulations.
Typical scenario: Theoretically used for precision strikes against high-value targets, such as command centers or nuclear facilities.

Key points:
Tungsten rods need to be coated with a high temperature resistance to prevent re-entry ablation.
The dimensions and weights need to be precisely designed to ensure a stable trajectory.
The throwing system requires high-precision guidance to control the landing point error.

5.3 Tungsten rods are used in electronics and lighting

Tungsten rods are widely used in tungsten filaments, electrodes and sputtering targets based on their high melting point, electrical conductivity and low vapor pressure.

5.3.1 Tungsten filament (filament, support wire)

Tungsten filament is the core component of incandescent lamps, halogen lamps and special light sources, and is made of tungsten rod drawing.

App Features:
Material requirements: pure tungsten rod (purity≥99.9%), drawn into 0.01–0.1 mm diameter tungsten wire.
Function: The filament emits light at a high temperature of 2500–2800°C, providing a high-efficiency light source; The support wire fixes the filament to keep the structure stable.
Advantages: high melting point ensures that the filament does not melt; Low vapor pressure reduces evaporation and prolongs life; Good electrical conductivity (18% IACS) supports efficient luminescence.
Typical scenes: automotive halogen headlights, projector bulbs, stage lighting.

Key points:
Tungsten filament needs to be annealed several times to improve ductility.
The filament needs to be evenly drawn to prevent local overheating and breakage.
Inert gases (e.g. argon) fill the bulb and reduce tungsten evaporation.

5.3.2 Electrodes (tungsten electrodes, rare earth tungsten electrodes)

Tungsten rods are processed into electrodes and are widely used in argon arc welding (TIG), plasma welding and electronic equipment.

App Features:
Material requirements: doped tungsten rods (e.g. cerium-doped WC20, lanthanum-doped WL20, thorium-doped WT20), diameter 1–5 mm.
Function: The electrode provides a stable current in a high temperature arc (>6000°C), igniting and maintaining the arc, suitable for welding or plasma cutting.
Advantages: Doped tungsten rod to improve arc stability and reduce burning loss; High melting point to withstand high arc temperatures; Rare earth doping (e.g., CeO_2) is non-radioactive and environmentally friendly compared to thorium-doped electrodes.
Typical scenarios: welding of stainless steel or aluminum alloys, plasma processing in semiconductor equipment manufacturing.

Key points:
The electrode tip needs to be ground into a tapered shape to optimize the arc concentration.
The dopant needs to be evenly distributed to ensure consistent performance.
Thorium-doped electrodes need to be protected and comply with radioactivity regulations.

5.3.3 Sputtering targets
Tungsten rods are processed into sputtering targets for physical vapor deposition (PVD) coatings to produce semiconductors and optical devices.

App Features:
Material requirements: high-purity tungsten rod (purity ≥99.95%), diameter 50–100 mm.
Function: The target is bombarded with high-energy ions in a vacuum chamber, releasing tungsten atoms that are deposited on the substrate to form a conductive or protective coating.
Advantages: High purity ensures that the coating is free of impurities; Low vapor pressure suitable for vacuum environment; High density increases target life.
Typical scenario: Production of interconnect layers for 3–5nm chips and fabrication of anti-reflective optical coatings.

Key points:
The target material needs to be of ultra-high purity to prevent contamination of the chip.
The surface needs to be electropolished to reduce particle defects.
The target material needs to be replaced regularly to recover the residual tungsten.

5.4 Tungsten rods are used in automotive and aerospace
The application of tungsten rod in the automotive and aerospace fields mainly uses its high density, high strength and high temperature resistance to meet the needs of complex working conditions.

5.4.1 Automotive automation components
Tungsten rods are used in automotive manufacturing for counterweights, welding electrodes, and automation components to improve efficiency and performance.

App Features:
Material requirements: tungsten alloy rod (W-Ni-Fe, density 18.0–18.5 g/cm³) or doped tungsten rod (WC20), diameter 5–20 mm.
Function: Counterweights (e.g. crankshaft counterweights) optimize engine vibration; Tungsten electrodes are used for resistance spot welding, connecting body steel plates; High-density components are used in automatic transmissions to enhance wear resistance.
Advantages: high density reduces component volume; High hardness (350–500 HV) withstands abrasion; Doped tungsten electrode improves welding stability.
Typical scenario: New energy vehicle battery pack welding, engine counterweight optimization.

Key points:
The counterweight needs to be precision machined to a controlled weight tolerance of ± 0.1 g.
Welding electrodes need to be ground regularly to maintain the tip shape.
Components need to be coated with a corrosion-resistant coating to resist moisture and salt spray.

5.4.2 Aerospace high-temperature components

Tungsten rods are used in the aerospace industry for high-temperature thrusters, wind tunnel test components and counterweights to meet the requirements of extreme environments.

App Features:
Material requirements: pure tungsten rod or tungsten alloy rod, density 19.0–19.25 g/cm³, diameter 10–50 mm.
Function: Nozzle lining withstands high temperature of plasma thruster (>2000°C); Optimization of the center of gravity by counterweights (e.g. satellite balance weights); Wind tunnel test components are resistant to thermal deformation.
Advantages: High melting point and creep resistance ensure high temperature stability; High density provides efficient counterweights; Low coefficient of thermal expansion reduces thermal stress.
Typical scenario: ion thruster nozzles, spacecraft attitude control counterweights.

Key points:
The components need to be coated with a high-temperature resistant coating to prevent oxidation.
The counterweight needs to be machined with high precision to ensure a precise center of gravity.
Wind tunnel components need to be polished to reduce airflow disturbances.

5.5 Tungsten rod is used in medical and scientific research

The application of tungsten rod in the medical and scientific research fields is mainly based on its high density, high temperature resistance and chemical stability to meet the needs of high precision and special environments.

5.5.1 Medical devices (radiation shielding)

Tungsten rods are processed into radiation shields that are widely used in X-ray, CT and radiotherapy equipment to protect healthcare workers and patients.

App Features:
Material requirements: tungsten alloy rod (W-Ni-Cu, density 18.0–18.5 g/cm³), diameter 10–50 mm.
Function: The shielding absorbs high-energy X-rays or gamma rays, replacing the lead shielding and providing higher protection efficiency.
Advantages: High density provides excellent shielding performance, 30% smaller volume than lead; Non-toxic, in line with medical and environmental protection requirements; High strength withstands long-term use.
Typical scenes: CT machine collimator, tumor radiotherapy equipment shield.

Key points:
The shielding needs to be precision machined to ensure that gaps are minimized.
The surface needs to be polished to prevent dust from polluting the medical environment.
The alloy needs to be lead-free and RoHS compliant.

5.5.2 Experimental equipment (high temperature experiments)

Tungsten rods are used in scientific research for high-temperature experimental equipment such as vacuum furnaces, superconductivity experiments and plasma research.

App Features:
Material requirements: high-purity tungsten rod (purity≥99.95%) or doped tungsten rod, diameter 5–20 mm.
Function: As a heating element, withstand high temperature above 2500°C; As an electrode, it provides a stable current; As a support, keep the experimental setup stable.
Advantages: low vapor pressure ensures a clean vacuum environment; High melting point supports extreme temperatures; Chemical stability prevents experimental contamination.
Typical scenarios: high-temperature superconducting material testing, nuclear fusion plasma experiments.

Key points:
Tungsten rods need to be of ultra-high purity to prevent impurities from interfering with the experiment.
The electrodes need to be polished to reduce arc instability.
The vacuum furnace needs regular maintenance to prevent oxidation of tungsten rods.

5.6 Tungsten rods are used in other fields

Tungsten rods also have unique applications in sporting goods, jewelry, and special tools, reflecting their versatility.

5.6.1 Sporting goods (tungsten carbide darts)

Tungsten alloy rods are used to make high-end darts to improve competitive performance.

App Features:
Material requirements: tungsten alloy rod (W-Ni-Cu, density 18.0–18.5 g/cm³), diameter 5–10 mm.

Function: The body of the dart uses high density to achieve small volume and high weight, optimizing the stability and accuracy of the throw.
Advantages: High density, smaller than traditional brass darts, suitable for dense target areas; High hardness to withstand repeated impacts; It can be customized to meet individual needs.
Typical scenes: professional darts competitions, high-end entertainment equipment.

Key points:
Darts need to be precision turned to control the weight distribution.
The surface needs to be polished or plated to improve the aesthetics and feel.
The alloy ratio needs to be optimized to ensure toughness and prevent breakage.

5.6.2 Jewellery (tungsten carbide jewellery)
Tungsten alloy rods are processed into rings, bracelets and other jewelry, which are both beautiful and durable.

App Features:
Material requirements: tungsten alloy rod (W-Ni-Cu or W-C, density 18.0–18.5 g/cm^3), diameter 5–20 mm.
Function: Jewelry utilizes high hardness and corrosion resistance, providing scratch resistance and durability; The high density gives a calm feel.
Advantages: more wear-resistant than stainless steel or titanium; Can be polished to a mirror effect; It is non-toxic and suitable for people with sensitive skin.
Typical scenes: wedding rings, commemorative bracelets, high-end fashion jewelry.

Key points:
Jewelry needs to be machined with high precision and dimensional tolerances ± 0.05 mm.
The surface needs to be electroplating or CVD coating to enhance oxidation resistance.
The design needs to be weight-sensitive to prevent excessive weight from affecting wearing comfort.

5.6.3 Special tools and molds
Tungsten rods are machined into cutting tools, stamping dies or wear-resistant parts for high-intensity industrial machining.

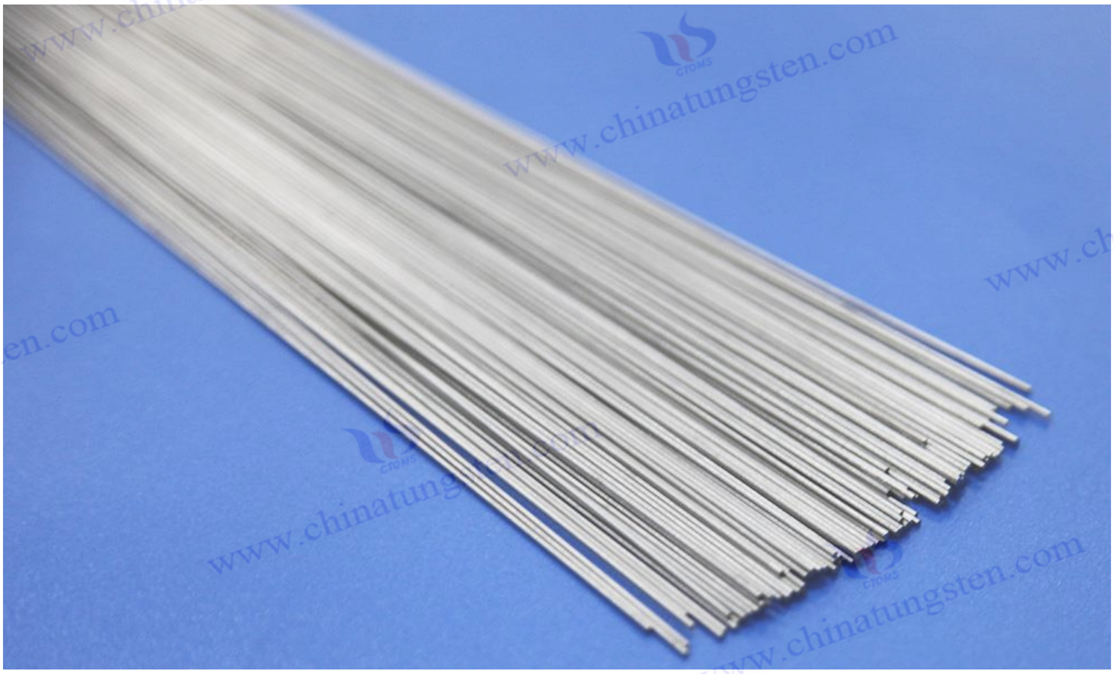
App Features:
Material requirements: pure tungsten rod or tungsten alloy rod, density 19.0–19.25 g/cm^3, diameter 5–30 mm.
Function: cutting hard materials (such as ceramics, alloy steel); die stamping of automotive parts or electronic components; Wear-resistant parts are used in mining equipment.
Advantages: High hardness (350–500 HV) resistance to wear; High strength supports high loads; Corrosion resistance and extended life.
Typical scenario: aviation parts processing, electronic chip mold manufacturing.

Key points:

The cutter needs to be diamond ground to ensure that the cutting edge is sharp.

The mold needs to be heat treated to relieve the processing stress.

The surface needs to be polished or coated to reduce material adhesion.



CTIA GROUP LTD tungsten rods

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Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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Chapter 6 Tungsten Rod Production Equipment

The production of tungsten rods involves a complex process chain from raw material processing to finished product processing, which requires extremely high equipment performance, as tungsten's high melting point (3410°C), high density (19.25 g/cm³) and hardness (350–500 HV) require specialized equipment to achieve high precision, high efficiency and high quality production. This chapter focuses on the key equipment required for tungsten rod production, including powder metallurgy equipment (mixers, presses, high-temperature sintering furnaces), deformation processing equipment (air hammers, electro-hydraulic hammers, rotary swaging machines, hot extrusion machines, rolling mills, drawing machines), post-processing equipment (heat treatment furnaces, polishing and cleaning equipment, precision machining equipment), advanced production equipment (plasma sintering equipment, vacuum melting furnaces, automatic control systems), and practical guides for equipment selection and maintenance.

6.1 Powder metallurgy equipment for tungsten rods

Powder metallurgy is the basic process of tungsten rod production, which involves the mixing, pressing and high-temperature sintering of tungsten powder, and the equipment used needs to ensure powder uniformity, billet compactness and high temperature stability.

6.1.1 Mixers

The mixer is used to homogeneously mix tungsten powder with dopants (such as cerium oxide, lanthanum oxide) or binders (such as polyvinyl alcohol) to provide high-quality raw materials for subsequent pressing.

Equipment features:
Type: V-mixer, planetary ball mill or three-dimensional mixer with a volume of 50–500 L and suitable for small to medium batch production.
Principle of operation: The powder is tumbled in the container by rotation or vibration, and the planetary ball mill achieves micron-level mixing by high-speed grinding with a mixing time of 2–8 hours.
Process adaptation: V-type mixer is suitable for pure tungsten powder or low doping amount (<1 wt%); Ball mills are suitable for highly doped (e.g. 2 wt% CeO_2) or nanoscale powders, where the grinding medium (tungsten or zirconia balls) needs to be controlled to avoid contamination.
Key parameters: 50–300 rpm, cleanliness (ISO 7 environment), protection against oxidation by inert gases (e.g. nitrogen).

Industrial Practice:
The inner wall of the mixer should be lined with stainless steel or tungsten alloy to reduce iron pollution.
Equipped with a dust collection system to prevent tungsten powder from flying.
Mix homogeneity (e.g., SEM analysis) is checked regularly to ensure consistent dopant distribution.

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6.1.2 Presses

The press presses the mixed tungsten powder into a rod-shaped blank, which provides the initial shape and density for sintering.

Equipment features:

Type: Cold isostatic press (CIP) as the main press, supplemented by hydraulic molding press, pressure range 100–300 MPa.

Principle of operation: CIP presses blanks with a diameter of 20–100 mm by applying uniform pressure in a liquid medium (water or oil) via a flexible mould (rubber or polyurethane); The moulding machine is pressed directly by means of a steel die and is suitable for small diameters (<20 mm).

Process adaptation: CIP is suitable for large-size or complex-shaped blanks, with a density of 50–60% theoretical density; The molding machine is suitable for high-precision low-volume production with a tolerance of ± 0.1 mm.

Key parameters: pressure control accuracy ± 1 MPa, pressing speed 0.5–1 mm/s, smooth mold surface to reduce defects.

Industrial Practice:

CIP molds need to be replaced regularly to prevent deformation from affecting the quality of the blank.

The molding machine needs to be equipped with a vacuum degassing device to remove the air between the powders.

After pressing, the blank needs to be X-rayed to check for internal cracks or pores.

6.1.3 High temperature sintering furnace

The high-temperature sintering furnace heats the pressed blank to 2000–2800°C to bind the tungsten powder particles to form a high-density bar.

Equipment features:

Type: Hydrogen shield, vacuum sintering or induction furnace with a furnace volume of 0.1–1 m^3.

Principle of operation: By means of resistance or induction heating, high-purity hydrogen (99.999%) is introduced into the furnace or a vacuum (10^{-3}–10^{-5} Pa) and the billet is dispersed at high temperatures with a density of 90–95%.

Process adaptation: the hydrogen furnace is suitable for pure tungsten rods, and the cost is low; The vacuum furnace is suitable for high-purity tungsten rods to reduce the adsorption of impurities; Induction furnaces are suitable for rapid sintering with a holding time of 1–3 hours.

Key parameters: temperature control accuracy ± 10°C, cooling rate 10–20°C/min, furnace material molybdenum or graphite.

Industrial Practice:

The furnace chamber needs to be cleaned regularly to remove tungsten vapor deposits.

Equipped with an atmosphere monitoring system to detect oxygen content (<10 ppm) in real time.

After sintering, the bars are ultrasonically inspected to ensure that there are no internal defects.

6.2 Tungsten rod deformation processing equipment

Deformation processing equipment improves the density and strength of tungsten rods through high-temperature mechanical deformation, involving forging, extrusion, rolling and drawing.

6.2.1 Air hammers and electro-hydraulic hammers

Air hammers and electro-hydraulic hammers are used for hot forging tungsten bar blanks, preliminary forming and increasing density.

Equipment features:

Type: Air hammer (0.5–5 tonnes), electro-hydraulic hammer (1–10 tonnes), suitable for bars with a diameter of 20–100 mm.

Principle of operation: The air hammer drives the hammer head by compressed air, and the electro-hydraulic hammer provides higher precision and force (50–200 kN) through the hydraulic system, forging in multiple passes at 1200–1500°C with a deformation of 10–20% per pass.

Process adaptation: air hammer is suitable for small and medium-scale production, low cost; The electro-hydraulic hammer is suitable for large size bars, with high control accuracy and reduced cracks.

Key parameters: forging frequency 10–30 times/min, heating with hydrogen protection, mold material is molybdenum alloy.

Industrial Practice:

Equipped with an induction heater to maintain a constant forging temperature.

The hammer head needs to be smoothed regularly to prevent dents on the surface of the bar.

Annealing after forging (1000–1200°C) relieves stress.

6.2.2 Rotary swaging machines

The rotary swaging machine realizes high-precision forging of tungsten rods by rotating dies, which is suitable for small and medium-diameter bars.

Equipment features:

Type: CNC rotary swaging machine, machining diameter 5–50 mm, equipped with high-frequency induction heating.

Operating principle: The tungsten rod rotates at 1200–1400°C, and the mold applies multi-directional pressure, gradually reducing the diameter, and the deformation is uniform, and the density reaches 19.0–19.25 g/cm³.

Process adaptation: suitable for high-purity tungsten rod or doped tungsten rod with a tolerance of ± 0.05 mm.

Key parameters: rotation speed 100–500 rpm, pressure 10–50 kN, mold life approx. 1000 cycles.

Industrial Practice:

The mold needs to be molybdenum-based or ceramic-coated to withstand high-temperature wear.

Equipped with a cooling system to prevent the equipment from overheating.

After rotary swaging, the bar needs to be straightened to maintain straightness.

6.2.3 Hot extruders

The hot extrusion machine is used for the forming of tungsten rods with large specifications or complex cross-sections, with high density and strength.

Equipment features:
Type: Hydraulic extruder, pressure 500–1200 MPa, suitable for diameters 20–100 mm.
Operating principle: Tungsten bar blank is preheated at 1300–1600°C and extruded by a die with an extrusion ratio of 5:1–10:1.
Process adaptation: suitable for tungsten alloy rod or large-size pure tungsten rod, hydrogen or argon protection is required to prevent oxidation.
Key parameters: extrusion speed 0.1–0.5 mm/s, mould material molybdenum or ceramic, temperature control accuracy ± 20°C.

Industrial Practice:
The mold needs to be lubricated regularly (graphite or molybdenum disulfide) to reduce wear.
Equipped with automatic feeding system to improve production efficiency.
After extrusion, the bar needs to be cooled slowly to prevent cracking.

6.2.4 Rolling mills and drawing machines

Rolling mills and drawing mills are used to produce small and medium-diameter tungsten rods or tungsten wires with high precision and excellent surface quality.

Rolling mill features:
Type: Hot rolling mill (1000–1300°C) or cold rolling mill (<500°C) with a processing diameter of 5–20 mm.
Principle of operation: The tungsten rod is reduced by multiple passes of rolls (molybdenum alloy or cemented carbide) with a deformation of 15–25% each time.
Process adaptation: hot rolling is suitable for pure tungsten rod, cold rolling is suitable for high-precision doped tungsten rod, with a tolerance of ± 0.02 mm.
Key parameters: roll speed 50–200 rpm, annealing temperature 900–1100°C.

Features of the drawing machine:
Type: Multi-die drawing machine, machining diameter 0.01–5 mm, equipped with diamond dies.
Principle of operation: Tungsten rod is drawn by a die at 800–1000°C with a diameter reduction of 5–10%, and the lubricant is graphite or molybdenum disulfide.
Process adaptation: suitable for tungsten wire or small diameter electrode.
Key parameters: Drawing speed 1–5 m/min, tool life approx. 500 kg tungsten rod.

Industrial Practice:
Rolls and dies need to be replaced regularly to maintain accuracy.
Equipped with an in-line inspection system to monitor diameter and surface quality.
Drawing requires multiple annealing to prevent breakage.

6.3 Post-processing equipment for tungsten rods

Post-processing equipment optimizes the performance, surface quality, and dimensional accuracy of tungsten rods and involves heat treatment, polishing, cleaning, and precision machining.

6.3.1 Heat treatment furnaces

Heat treatment furnaces are used for annealing or aging treatment, relieving machining stresses and optimizing microstructures.

Equipment features:
Type: Vacuum heat treatment furnace or hydrogen protection furnace with furnace volume 0.05–0.5 m^3.
Principle of operation: heating by resistance or induction, temperature 800–1600°C, heat preservation 0.5–4 hours, cooling rate 10–20°C/min.
Process adaptation: stress relief annealing (1000–1200°C) suitable for forging or extruding rods; Recrystallization annealing (1400–1600°C) is suitable for drawing rods; Aging treatment (800–1000°C) is suitable for doped tungsten rods.
Key parameters: temperature accuracy ±5°C, vacuum 10^{-5} Pa or hydrogen purity 99.999%.

Industrial Practice:
The furnace is made of molybdenum or graphite, which is resistant to high temperature corrosion.
Equipped with an atmosphere control system to prevent oxidation.
After heat treatment, the bar needs to be hardness tested to verify the performance.

6.3.2 Polishing and cleaning equipment

Polishing and cleaning equipment improves the surface quality of tungsten rods and meets the needs of high-precision applications.

Polishing Equipment:
Type: Mechanical polishing machine (diamond grinding wheel), chemical polishing tank, electrolytic polishing equipment.
Principle of operation: mechanical polishing removes surface defects through abrasives; Chemical polishing uses a hydrofluoric acid/nitric acid mixture (1:3) soaked for 10–30 seconds; Electrolytic polishing uses tungsten rod as anode and phosphate-based electrolyte treatment to achieve mirror effect.
Process adaptation: mechanical polishing is suitable for industrial-grade bars; Chemical and electrolytic polishing is suitable for high-purity tungsten rods or electrodes.

Cleaning equipment:
Type: Ultrasonic cleaning machine, plasma cleaning equipment.
Operating principle: Ultrasonic cleaning removes oil stains by 40 kHz ultrasonic wave and deionized water (including cleaning agent) for 5–10 minutes; Plasma cleaning uses argon plasma in a vacuum chamber to remove trace contaminants.
Process adaptation: ultrasonic cleaning is suitable for conventional bars; Plasma cleaning is suitable

for high-purity tungsten rods for semiconductors.

Industrial Practice:
Polishing is done in an ISO Class 5 cleanroom to prevent dust contamination.
The chemical polishing bath requires a ventilation system to treat the waste liquid.
After cleaning, the rod should be dry and sealed to prevent moisture absorption.

6.3.3 Precision machining equipment (lathes, grinding machines)

Lathe features:
Type: CNC lathe (CNC machine) suitable for high-precision machining, equipped with diamond tools.
Principle of operation: Tungsten rods are machined by rotary cutting with a diameter tolerance of ± 0.05 mm.
Process adaptation: suitable for large-size bars or complex shape processing, such as aviation counterweights.
Key parameters: 500–1500 rpm, feed 0.1 mm/rev.

Grinding machine features:
Type: Centerless grinder, center grinder, suitable for small diameter bars.
Operating principle: grinding by grinding wheels (diamond or ceramic) with a diameter tolerance of ± 0.02 mm.
Process adaptation: Centerless grinding machine is suitable for electrode or tungsten wire blank, and center grinding machine is suitable for high-precision mold parts.
Key parameters: grinding wheel speed 2000–3000 rpm, coolant oil or water based.

Industrial Practice:
Tools and grinding wheels need to be replaced regularly to prevent wear and tear affecting accuracy.
Equipped with a cooling system to reduce thermal distortion.
After processing, ultrasonic cleaning is required to remove debris.

6.4 Advanced production equipment for tungsten rods

State-of-the-art production equipment improves the quality and efficiency of tungsten rods and represents the industry's technological frontier, including plasma sintering, vacuum melting, and automated control.

6.4.1 Plasma sintering equipment

Equipment features:
Type: Spark plasma sintering furnace (SPS) with a furnace volume of 0.01–0.1 m³.
Principle of operation: Plasma is generated by direct current pulses (1000–5000 A), combined with a high temperature of 1800–2200 °C and a pressure of 50–100 MPa, and sintered rapidly (5–15 minutes) with a density of more than 98%.
Process adaptation: suitable for high-purity tungsten rods or nano-doped tungsten rods, with fine grains (5–10 μm) and reduced energy consumption.

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Key parameters: current pulse frequency 50–100 Hz, vacuum 10^{-4} Pa, mold graphite or tungsten.

Industrial Practice:
Equipped with online monitoring, real-time control of current and temperature.
The mold needs to be resistant to high temperature and high pressure, and checked regularly.
After SPS, the porosity of the bar needs to be tested to ensure compactness.

6.4.2 Vacuum melting furnaces

Equipment features:
Type: Vacuum electric arc furnace (VAR) or electron beam melting furnace (EBM) with a volume of 0.05–0.5 m³.
Operating principle: VAR melts tungsten ingots in vacuum (10^{-5} Pa) by means of an electric arc (10–30 kV); EBM is melted using a high-energy electron beam (50–100 kW) and is suitable for ultra-high-purity tungsten.
Process adaptation: VAR is suitable for tungsten alloy rods, EBM is suitable for high-purity tungsten rods (purity ≥ 99.999%), reducing gas inclusion.
Key parameters: melting power 20–100 kW, cooling water flow 10–50 L/min.

Industrial Practice:
Equipped with a vacuum pump to maintain an ultra-high vacuum.
The smelt billet needs to be X-ray inspected to eliminate inclusions.
Maintain the electrodes or electron gun regularly to prolong the life.

6.4.3 Automatic control and monitoring systems

Equipment features:
Type: PLC control system, SCADA monitoring platform, integrated sensors (temperature, pressure, atmosphere).
Operating principle: Real-time collection of sintering, forging or processing data through sensors, PLC adjusts parameters, and SCADA provides remote monitoring and data analysis.
Process adaptation: It is suitable for the whole process automation, covering sintering, extrusion, polishing and other processes to improve consistency and efficiency.
Key parameters: temperature accuracy ± 1°C, pressure accuracy ± 0.1 MPa, data sampling rate 1 Hz.

Industrial Practice:
The system needs to be dustproof and waterproof and adapt to high temperature environments.
Calibrate the sensor regularly to ensure that the data is accurate.
Data storage needs to be encrypted to protect process parameters.

6.5 Equipment selection and maintenance of tungsten rods

The equipment selection needs to be optimized according to the type of tungsten rod and production demand, and the maintenance management should extend the life of the equipment.

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Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

Email: sales@chinatungsten.com; Phone: +86 592 5129595; 592 5129696
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6.5.1 Equipment requirements for different types of tungsten rods

Pure tungsten rod:
Requirements: Standard hydrogen sintering furnace (2000–2800°C), air hammer or hot rolling mill, low cost, suitable for high volume production.
Equipment features: CIP press (150 MPa), mechanical polishing machine, emphasizing durability and high output.
Applicable scene: quartz furnace core rod, counterweight.

High purity tungsten rod:
Requirements: Vacuum sintering furnace (10^{-5} Pa), SPS or EBM, rotary swaging machine or CNC lathe to ensure high cleanliness and precision.
Equipment features: clean room (ISO class 5) operation, electrolytic polishing and plasma cleaning equipment.
Applicable scenarios: semiconductor electrodes, sputtering targets.

Doped tungsten rods:
Requirements: planetary mill (homogeneous doping), vacuum heat treatment furnace (800–1200°C), drawing machine (0.01–5 mm).
Equipment features: thorium-doped tungsten rods need to be equipped with radioactive management facilities, emphasizing the optimization of arc performance.
Applicable scenarios: welding electrodes, high-temperature furnace components.

Industrial Practice:
Choose the size of the equipment according to the production volume (e.g. small furnace for R&D, large furnace for mass production).
High-purity tungsten rod equipment needs to be isolated in a clean room.
Doped tungsten rods need to be compatible with a variety of dopant mixing equipment.

6.5.2 Equipment maintenance and life management

Maintenance measures:
Regular inspection: check the wear and tear of molds, grinding wheels and tools every month; Calibrate temperature and pressure sensors quarterly.
Cleaning and maintenance: The sintering furnace needs to be cleaned every six months to remove tungsten vapor deposits; The polishing equipment needs to be cleaned weekly to prevent abrasive residues.
Lubrication management: extruders and drawing machines need to be replenished with high-temperature lubricants (such as molybdenum disulfide) every month; Regularly check the oil quality of the hydraulic system.
Preventive maintenance: Predict bearing failures through vibration monitoring; Use an infrared thermometer to detect overheating hotspots in the equipment and prevent overheating damage.
Spare parts management: stock critical components (e.g. diamond dies, molybdenum electrodes) to reduce downtime.

Life Management:

Mold life: Tungsten or extrusion die about 1000–5000 times, need to be regularly applied with a high-temperature resistant coating (e.g., ZrO_2).

Furnace life: Molybdenum or graphite furnace is sintered about 2000–3000 times, and the lining needs to be changed regularly.

Equipment upgrades: Older equipment (such as traditional air hammers) can be upgraded to CNC systems to improve accuracy and efficiency.

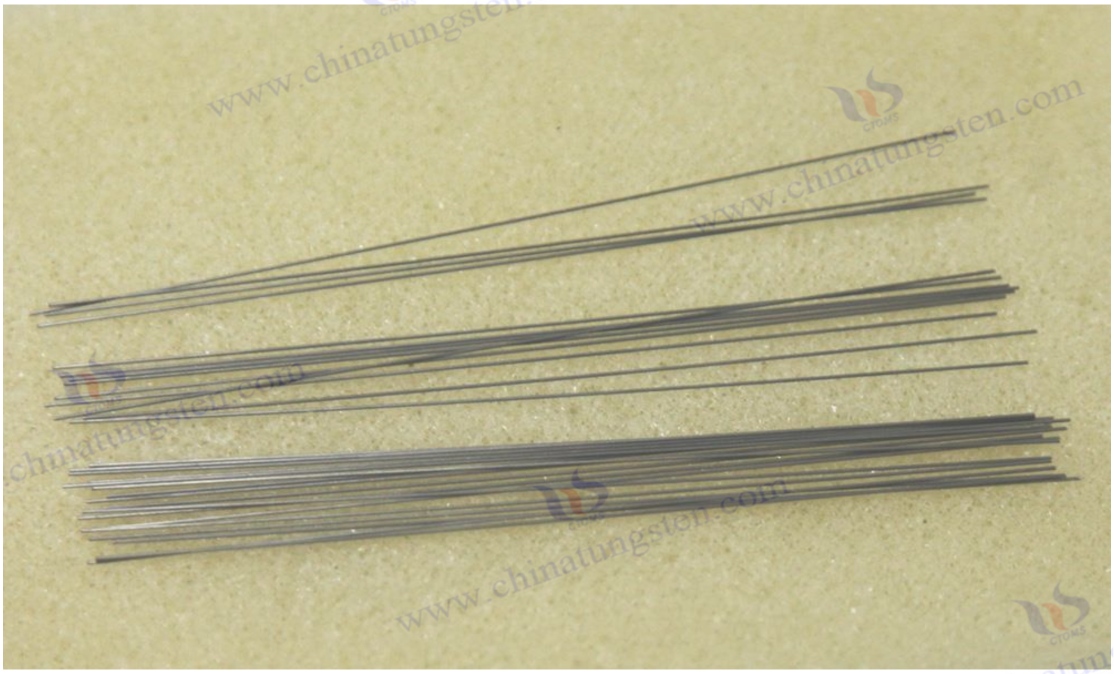
Data analysis: Analyze equipment operation data through SCADA system to optimize maintenance intervals and extend life by 20–30%.

Industrial Practice:

Establish a maintenance log to record every maintenance and failure.

Train operators to recognize early signs of failure, such as abnormal vibrations or temperature fluctuations.

Work with vendors to regularly update device firmware to optimize performance.



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Chapter 7 Domestic and Foreign Standards for Tungsten Rods

As a high-performance refractory metal material, the production, testing and application of tungsten rod need to follow strict domestic and foreign standards to ensure quality consistency, performance reliability and market competitiveness. These standards cover the chemical composition, physical properties, dimensional tolerances, surface quality and testing methods of tungsten rods, and are applicable to pure tungsten rods, high-purity tungsten rods, doped tungsten rods and tungsten alloy rods. This chapter systematically introduces the international standards (ISO, ASTM, RWMA, etc.) and Chinese standards (GB/T, YS/T, etc.) for tungsten rods, and compares and analyzes their differences, applicability and guiding significance for production testing.

7.1 International standards for tungsten rods

International standards provide unified specifications for the global trade and application of tungsten rods, mainly formulated by the International Organization for Standardization (ISO), the American Society for Testing and Materials (ASTM) and the Resistance Welding Manufacturing Association (RWMA), covering the composition, properties and uses of tungsten and tungsten alloys.

7.1.1 ISO Standard (ISO 24370: Tungsten and tungsten alloys)

Standard Overview: ISO 24370:2005 "Fine Ceramics and Refractory Metal Materials" is a standard for refractory metals developed by the International Organization for Standardization, including specifications for tungsten and tungsten alloy rods, suitable for high-temperature, high-strength applications.

Core Provisions:
Scope: Specify the chemical composition, mechanical properties and dimensional requirements of pure tungsten and tungsten alloy rods, which are suitable for aerospace, electronics and industrial fields.
Chemical composition: Pure tungsten rod tungsten content ≥ 99.9%, impurities (such as Fe, C, O) need to be controlled at trace levels; Tungsten alloy rods (e.g. W-Ni-Fe) need to be clear about the proportion of alloying elements.
Physical properties: specified density (pure tungsten ≥ 19.0 g/cm³), tensile strength and hardness, emphasizing creep resistance at high temperatures.
Dimensions and tolerances: Diameters range from 1–100 mm, tolerances are divided into common and high precision classes depending on the application.
Testing methods: X-ray fluorescence spectroscopy (XRF) is recommended to analyze the composition, ultrasonic to detect internal defects, and hardness tester to test mechanical properties.

Applicable Scenarios:
It is mainly used for aerospace high-temperature components (such as nozzle linings), electronic sputtering targets and welding electrodes.
Emphasizing international consistency, it is suitable for cross-border supply chains and export trade.

Key points:

The standard has strict requirements for the control of impurities in high-purity tungsten rods, and a clean production environment is required.
The testing method is in line with international standards and is convenient for global certification.
It needs to be updated regularly to accommodate new material technologies.

7.1.2 ASTM Standard (ASTM B777: High Density Tungsten Alloy)

Standard Overview: ASTM B777-15 Standard Specification for High Density Tungsten Based Alloys was developed by the American Society for Testing and Materials (ASTM) for the performance and application of tungsten alloy rods (e.g., W-Ni-Fe, W-Ni-Cu) and is widely used in military and medical fields.

Core Provisions:
Scope: Covers the classification of high-density tungsten alloy rods (Class 1–4), graded according to tungsten content (90–97 wt%) and performance.
Chemical composition: Specify the ratio of tungsten, nickel, iron or copper, and impurities (e.g. S, P) below the specified limits.
Physical properties: density range 17.0–18.5 g/cm³, tensile strength 600–1200 MPa, hardness 300–400 HV.
Dimensions and tolerances: 5–50 mm diameter, length can be customized, tolerances meet the requirements of precision machining.
Detection method: Inductively coupled plasma mass spectrometry (ICP-MS) was used to analyze the composition, magnetic particle testing was used to detect surface cracks, and tensile test was used to verify the strength.

Applicable Scenarios:
It is mainly used for armor-piercing cores, radiation shielding parts and aviation counterweights.
Suitable for the North American market and the military industry, with an emphasis on high density and mechanical properties.

Key points:
The standard is graded by density and strength, which is convenient for material selection.
There are clear requirements for the environmental friendliness of alloying elements (e.g., lead-free formulations).
Detection requires special equipment, which is costly.

7.1.3 RWMA Class 13

Standard Overview: The Resistance Welding Manufacturers Association (RWMA) has developed a Class 13 standard for pure tungsten rods and is designed for resistance welding electrodes and high-temperature electrode applications.

Core Provisions:
Scope: Specify the composition, conductivity and high temperature resistance of pure tungsten rod (tungsten content ≥ 99.9%).

Chemical composition: Strict control of carbon, oxygen, nitrogen and other impurities to prevent arc instability.
Physical properties: conductivity of about 18% IACS, hardness of 350–450 HV, resistance to burning at high temperatures.
Dimensions and tolerances: 1–10 mm diameter, ± 0.05 mm tolerance, suitable for electrode tip machining.
Detection method: conductivity tester verifies conductivity, microscope inspection of surface quality, high temperature resistance test simulates arc environment.

Applicable Scenarios:
It is used in resistance spot welding electrodes and electronic equipment assembly in automobile manufacturing.
It is suitable for high-frequency welding scenarios and emphasizes electrode life.

Key points:
Standard focused electrode performance, ignoring other applications.
It has high requirements for surface quality and requires precision polishing.
The detection method is simple and suitable for small and medium-sized businesses.

7.1.4 Other international standards
Overview: In addition to ISO, ASTM and RWMA, other international standards also cover tungsten rods, such as:

AWS A5.12: Tungsten and doped tungsten electrode standards (e.g., WT20, WC20) developed by the American Welding Institute that specify dopant content (e.g., 2% ThO_2 or CeO_2) and arc performance.
JIS Z 3211: Japanese Industrial Standard for the composition and size of tungsten electrodes for the Asian market.
DIN EN 26848: European standard specifying general requirements for tungsten rods, with an emphasis on high-temperature applications.

Core content:
AWS A5.12 focuses on the weldability of doped tungsten rods, including arc stability and burn-out rate.
JIS Z 3211 is similar to ISO 24370, but with tighter dimensional tolerances and is suitable for precision electronics.
DIN EN 26848 covers pure tungsten and alloy rods, with an emphasis on aerospace and defense applications.

Applicable Scenarios:
AWS A5.12 is used in the global welding industry, JIS Z 3211 serves the Japanese electronics market, and DIN EN 26848 is used for European aerospace companies.
These standards complement ISO and ASTM to meet the needs of regionalization.

Key points:
The applicable criteria need to be selected according to the target market.
Doped tungsten rod standards (e.g., AWS) have special management requirements for radiodopants (e.g., ThO_2).
Testing needs to be verified across standards, which increases the cost of certification.

7.2 Chinese standard for tungsten rods

The Chinese standard system includes national standards (GB/T) and industry standards (YS/T), covering the composition, performance, size and testing of tungsten rods, to meet the needs of domestic production and application.

7.2.1 GB/T 4187-2017 (National Standard for Tungsten Bar)

Standard overview: GB/T 4187-2017 "Tungsten Rod" is a Chinese national standard, which stipulates the performance and use of pure tungsten rod and high-purity tungsten rod, and is suitable for industrial, electronic and scientific research fields.

Core Provisions:
Range: Covers pure tungsten rods (≥ 99.9% tungsten content) and high purity tungsten rods (≥99.95%) with diameters of 1–100 mm.
Chemical composition: Strict limits for impurities (e.g., Fe, C, O) and oxygen content < 50 ppm for high-purity tungsten rods.
Physical properties: density ≥ 19.0 g/cm³, tensile strength varies according to diameter and processing state, hardness 300–450 HV.
Dimensions and tolerances: Tolerances are divided into ordinary grade (±0.1 mm) and precision grade (±0.05 mm), and the length can be customized.
Detection method: XRF or ICP-MS analysis of components, ultrasonic testing of internal quality, Vickers hardness tester testing hardness.

Applicable Scenarios:
It is used for quartz furnace core rod, monocrystalline silicon clamping rod, and semiconductor target.
Suitable for domestic market and export, emphasizing high purity and dimensional accuracy.

Key points:
The standard has high requirements for the clean production of high-purity tungsten rods, and a dust-free environment is required.
The testing methods are in line with international standards and are convenient for export certification.
Regular revisions to accommodate new processes.

7.2.2 GB/T 3459-2017 (tungsten and tungsten alloy products)

Standard Overview: GB/T 3459-2017 "Tungsten and Tungsten Alloy Products" is a Chinese national standard, covering tungsten rods, tungsten alloy rods and other tungsten products, suitable for aviation, military and industrial fields.

Core Provisions:
Range: including pure tungsten rods, doped tungsten rods and tungsten alloy rods (e.g. W-Ni-Fe) with a tungsten content of 90–99.9%.
Chemical composition: Specify the proportion of alloying elements (e.g., Ni, Fe), and impurity limits are related to the application.
Physical properties: density 17.0–19.25 g/cm³, tensile strength 600–1000 MPa, moderate elongation.
Dimensions & Tolerances: Diameter 5–50 mm, Tolerances ± 0.2 mm, special requirements can be customized.
Testing methods: ICP-AES analysis of components, magnetic particle flaw testing of surfaces, tensile testing to verify performance.

Applicable Scenarios:
It is used for armor-piercing bullet cores, aviation counterweights, and radiation shielding products.
Serving the domestic military industry and heavy industry, emphasizing high density and strength.

Key points:
The standard covers a variety of tungsten products, with high flexibility.
The environmental protection requirements for alloy rods are strict, and non-toxic formulations are required.
The detection needs to be supported by comprehensive equipment.

7.2.3 Industry standard (YS/T 695-2017: blunt electrode)
Standard Overview: YS/T 695-2017, "Blunt Electrode" is the industry standard for non-ferrous metals in China, aiming at the performance and production of pure blunt and doped blunt electrodes (such as WC20, WL20, WT20).

Core Provisions:
Range: Specify the composition, size, and arc properties of the blunt electrode, 0.5–10 mm diameter.
Chemical composition: pure blunt content≥99.9%, doped with blunt rare earth oxides (such as 2% CeO_2) or thorium oxide, low impurity limit.
Physical properties: excellent conductivity, high temperature burn resistance, high arc stability.
Dimensions & Tolerances: Tolerances ± 0.05 mm, tips need to meet welding requirements.
Detection method: arc testing machine to test ignition and stability, XRF analysis of dopant content, microscope inspection of surface.

Application Scenarios:
It is used for argon arc welding (TIG), plasma cutting, and serving automobile and shipbuilding.
It is suitable for the domestic welding industry, emphasizing the electrode performance.

Key points:
Thorium-doped blunt electrodes are subject to radioactivity regulations.

The test simulates the actual welding environment to verify the arc performance.
Standards are updated frequently, so keep an eye on the latest version.

7.3 Standard comparison and applicability of blunt rods

Standard comparison and applicability analysis: There are differences in the formulation objectives, requirements and application scenarios of domestic and foreign standards, and it is necessary to select appropriate specifications according to the type of blunt rod and the market.

7.3.1 Differences between domestic and foreign standards

Comparative Analysis:
Set goals:
International standards (such as ISO, ASTM) emphasize global universality and have broad terms, which are suitable for cross-border trade; Chinese standards (GB/T, YS/T) combine domestic technology and market demand, and the terms are more specific.
ASTM B777 focuses on high-density blunt alloy rods, suitable for military and medical; GB/T 3459 covers a wide range of blunt products and provides a wider range of flexibility.
RWMA Class 13 and YS/T 695 specialize in electrodes, and international standards focus more on conductivity and arc performance.

Technical Requirements:
International standard ingredients: international standards (such as ISO 24370) have stricter control of impurities (such as oxygen, carbon), which is suitable for high-purity blunt rods; Chinese standards (such as GB/T 4187) have slightly looser requirements for ordinary pure blunt rods to reduce production costs.
Physical properties: ASTM B777 requires higher strength and density tensile strength of blunt alloys (600–1200 MPa); GB/T 3459 emphasizes the density range (17.0–19.25 g/cm³).
Dimensional tolerance: ISO and JIS standard tolerances are tighter (±0.05 mm), suitable for high precision; GB/T tolerance grading (±0.1–0.2 mm) for a wide range of requirements.

Detection Method:
International standards recommend XRF, ICP-MS, and magnetic particle testing, consistent with Chinese standards, but ASTM requires more complex tensile testing.
The arc test of YS/T 695 is more industry-specific, and AWS A5.12 is similar but more stringent.

Key points:
International standards are more suitable for export and high-end markets, while Chinese standards are more in line with domestic production reality.
The testing equipment needs to be compatible with both standards, and the balance between cost and efficiency needs to be considered.
The radioactivity management of thorium-doped tungsten electrodes is more stringent in international standards.

7.3.2 Standard requirements for different types of tungsten rods

Pure blunt rod:
Applicable standards: ISO 24370, GB/T 4187, RWMA Class 13.
Requirements: blunt content ≥ 99.9%, low impurities (e.g. oxygen < 100 ppm), density ≥ 19.0 g/cm³, tolerance ± 0.1 mm.
Applicable scenarios: quartz furnace core samples, counterweights, emphasizing high temperature stability and cost control.

High purity tungsten rod:
Applicable standards: ISO 24370, GB/T 4187 (high purity grade), ASTM B760 (blunt plate extension reference).
Requirements: Blunt content≥ 99.95%, very low impurities (e.g. oxygen < 30 ppm), clean production, tolerance ± 0.05 mm.
Applicable scenarios: semiconductor targets, medical devices, emphasizing high density and purity.

Doped blunt rods:
Applicable standards: AWS A5.12, YS/T 695, GB/T 3459.
Requirements: Dopant (e.g., 2% CeO_2) is evenly distributed, arc stability is high, and thorium-doped rods need radioactive control.
Applicable scenarios: welding electrodes, high-temperature furnace components, emphasizing electrical performance.

Tungsten alloy rod:
Applicable standards: ASTM B777, GB/T 3459.
Requirements: blunt content 90–97%, density 17.0–18.5 g/cm³, tensile strength 600–800 MPa, non-toxic formulation.
Applicable scenarios: armor-piercing bullet core, radiation shielding, emphasizing high strength and environmental protection.

Key points:
The standard selection should be matched to the type of blunt rod and the field of application.
High-purity and doped blunt rods require higher precision equipment to support production and inspection.
Blunt alloy rods need to pay attention to environmental regulations.

7.3.3 The guiding significance of standards for production and testing

Production Instructions:
Ingredient control: Standards specify limits for impurities and dopants to guide raw material selection and purification processes (e.g., ISO requires oxygen < 50 ppm and hydrogen reduction needs to be optimized).
Process optimization: Tolerances and performance requirements (e.g., ±0.1 mm for GB/T) guide the precision of pressing, sintering, and processing equipment.
Quality management: The standard requires to promote ISO 9001 and other system certification,

standardize the production process, and reduce the defect rate.

Testing Guidance:
Compositional analysis: XRF, ICP-MS ensure that chemistry meets standards, and instruments need to be calibrated regularly.
Performance verification: Tensile tests, hardness tests, and arc tests verify mechanical and electrical properties with standardized sample preparation.
Defect Inspection: Ultrasonic and magnetic particle testing techniques detect internal and surface defects to ensure product safety.

Industrial Practice:
Enterprises need to establish standardized quality control laboratories equipped with multi-functional testing equipment.
Regularly train employees to familiarize themselves with the differences between domestic and foreign standards and improve compliance.
Export products need to meet the target market standards first, and prepare for certification in advance.

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Tungsten Rods Introduction

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✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
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Hardness (Vickers HV)	340–400 HV
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5. Procurement Information

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Chapter 8 Detection of Tungsten Rods

As a high-performance refractory metal material, the quality of tungsten rod directly affects the application performance, and the physical properties, chemical composition, microstructure and special properties need to be evaluated by comprehensive testing methods. The testing covers a variety of techniques from macro to micro, including physical property testing, chemical analysis, microscopic observation, non-destructive testing and performance verification, with different emphases for pure tungsten rods, high-purity tungsten rods and doped tungsten rods. This chapter will elaborate on the testing methods of tungsten rods, including density, hardness, tensile strength, thermal properties, chemical composition, microstructure, non-destructive testing, high temperature, corrosion resistance, conductivity and other performance tests, and analyze the testing priorities of different types of tungsten rods.

8.1 Physical properties of tungsten rod test

Physical property testing evaluates the density, hardness, strength, and thermal properties of tungsten rods to ensure they meet design requirements for aerospace, electronics, and industrial applications.

8.1.1 Density test of tungsten rods

Purpose: Density is the key indicator of tungsten rod quality, reflecting the compactness of sintering and processing, the theoretical density of pure tungsten rod is 19.25 g/cm³, and the tungsten alloy rod is 17.0–18.5 g/cm³.

Detection Method:
Archimedes method: Tungsten rods are immersed in deionized water, dry weight and weight in water are measured, and density is calculated. Use a high-precision electronic balance (accuracy ±0.001 g) and a thermostatic sink (25°C).
X-ray densitometer: Density measurement by X-ray absorption, suitable for fast non-contact inspection with an accuracy of ± 0.05 g/cm³.

Operational Points:
The surface of the sample should be cleaned to remove oil or oxide layers.
The Archimedes method requires calibration of the density of the liquid to exclude air bubbles.
The X-ray method requires periodic calibration of the instrument to verify the standard sample.

Interpretation of results:
Densities lower than theoretical values may indicate insufficient porosity or sintering.
The density of tungsten alloy rods needs to match the alloy ratio, and the deviation may be due to uneven composition.

8.1.2 Hardness test of tungsten rods (Vickers, Brinell)

Test purpose: The hardness reflects the mechanical strength and wear resistance of tungsten rod, and the hardness of pure tungsten rod is about 350–450 HV, and the hardness of tungsten alloy rod is about 300–400 HV.

Detection Method:
Vickers hardness (HV): A 10–50 kgf load is applied using a diamond indenter, the indentation diagonal length is measured, and the hardness is calculated. Suitable for small diameter rods or high-precision testing.
Brinell hardness (HB): 500–3000 kgf load is applied using a carbide ball indenter to measure the indentation diameter and is suitable for large rods.

Operational Points:
The sample needs to be polished to a mirror surface to avoid surface defects affecting the results.
Vickers testing requires the selection of appropriate loads to prevent the indentation from being too small or too large.
The Brinell test ensures that the indenter is perpendicular to the sample and averaged over multiple measurements.

Interpretation of results:
Too much hardness may indicate too fine grains or too much dopant.
Low hardness can be due to insufficient porosity or processing stress.

8.1.3 Tensile strength and toughness test of tungsten rods

Purpose: To evaluate the bearing capacity and fracture behavior of tungsten rod under tensile load with tensile strength and toughness, the tensile strength of pure tungsten rod is about 600–1000 MPa, and the tungsten alloy rod is higher.

Detection Method:
Tensile test: Using a universal materials testing machine, a tungsten rod sample (standard sizes such as 5 mm diameter and 50 mm length) is clamped and stretched at a rate of 0.5–1 mm/min, and the breaking load and elongation are recorded.
Impact test: The Charpy impact testing machine is used to test the impact toughness of tungsten rod at low temperature or room temperature and measure the absorbed energy.

Operational Points:
Samples should be processed according to standards (e.g., ASTM E8) to avoid surface scratches.
The tensile test requires the ambient temperature (23±5°C) to be controlled and the stress-strain curve recorded.
The impact test requires the selection of an appropriate notch type (e.g., V-shape) to ensure repeatability.

Interpretation of results:
Insufficient tensile strength may indicate internal defects or excessive grain size.
Low toughness can be due to improper doping or uneven sintering, and the process needs to be optimized.

8.1.4 Thermal expansion and thermal conductivity test of tungsten rods

Purpose: The coefficient of thermal expansion (about 4.5×10^{-6}/°C) and thermal conductivity (about 170 W/m·K) affect the dimensional stability and thermal conductivity of tungsten rod in high temperature environment.

Detection Method:
Thermal expansion test: The coefficient of thermal expansion is calculated by measuring the change in sample length in the range of 100–1000°C using a thermal dilatometer (e.g., dilatometer).
Thermal conductivity test: The laser flash method is used to heat one end of the tungsten rod to measure the thermal diffusion rate and calculate the thermal conductivity.

Operational Points:
Thermal expansion tests are performed in an inert atmosphere (e.g. argon) to prevent oxidation.
Thermal conductivity testing requires calibration of the instrument to verify accuracy using a standard sample such as copper.
The sample size should be uniform (e.g., 10 mm diameter, 2 mm thickness).

Interpretation of results:
A high coefficient of thermal expansion may indicate impurities or alloying elements.
Low thermal conductivity can be due to uneven porosity or microstructure.

8.2 Chemical composition analysis of tungsten rods

Chemical composition analysis ensures that tungsten rods meet standards for purity and dopant content, and detection of impurities is critical to performance.

8.2.1 Spectroscopic analysis (ICP-MS, XRF)

Purpose: To quantitatively analyze the contents of tungsten, dopant (such as Ce, La, Th) and impurities (such as Fe, C, O) in tungsten rods.

Detection Method:
Inductively Coupled Plasma Mass Spectrometry (ICP-MS): The sample is dissolved in an acid solution (e.g., nitric acid + hydrofluoric acid) and separated by plasma excitation and mass spectrometry to detect the elemental content with a sensitivity of ppb.
X-ray fluorescence spectroscopy (XRF): X-ray excitation of the sample surface, analysis of fluorescence spectra, rapid determination of elemental content, suitable for non-destructive analysis.

Operational Points:
ICP-MS requires high-purity reagents and a clean laboratory (ISO Class 5) to avoid contamination.
XRF polishes the surface of the sample to ensure it is flat, and calibrates the instrument to improve accuracy.
The two methods need to be used in combination, with ICP-MS for trace element verification and XRF for rapid screening.

Interpretation of results:
Tungsten content below the standard (e.g., 99.9%) may indicate insufficient purification.
Deviations in dopant content can affect arc performance or high temperature stability.

8.2.2 Detection of trace elements and impurities

Purpose: Trace elements (such as O, C, N) and impurities (such as Fe, Si) may reduce the performance of tungsten rods, which need to be strictly controlled.

Detection Method:
Inert gas melting method: the sample is melted in argon at a high temperature to release oxygen, nitrogen and carbon, and analyzed by infrared or thermal conductivity detector with a sensitivity of ppm.
Glow discharge mass spectrometry (GD-MS): The sample surface is excited by glow discharge and the trace impurities are analyzed by mass spectrometry, which is suitable for high-purity tungsten rods.

Operational Points:
Samples are ultrasonically cleaned to remove surface contaminants.
The inert gas melting method requires high-purity argon (99.999%), calibrating the standard gas.
GD-MS requires a vacuum environment (10^{-6} Pa) and regular maintenance and discharge power.

Interpretation of results:
High oxygen content can lead to high temperature brittleness, and the sintering atmosphere needs to be optimized.
Excessive impurities may be due to contamination of raw materials, and quality control needs to be strengthened.

8.3 Microstructure analysis of tungsten rods

Microstructure analysis reveals the grain size, microstructure uniformity, and defect distribution of tungsten rods, affecting mechanical and thermal properties.

8.3.1 Microscope observation (SEM, TEM)

Purpose: To observe the surface morphology, fracture characteristics and internal structure of tungsten rod, and to identify cracks, pores or dopant distribution.

Detection Method:
Scanning electron microscopy (SEM): Scanning the surface of a sample with an electron beam with nanometer resolution, equipped with an energy dispersive spectrometer (EDS) to analyze the elemental distribution.
Transmission electron microscopy (TEM): Electron beam penetrates ultra-thin samples (<100 nm) to observe crystal structure and dislocations, suitable for high-resolution analysis.

Operational Points:

SEM samples need to be polished or fractured, and carbon or gold plating to improve conductivity.
TEM samples need to be prepared with ionized thinning to keep them clean to avoid contamination.
The microscope needs to be calibrated, and the magnification and imaging conditions are recorded.

Interpretation of results:
SEM shows porosity or cracks, indicating sintering or machining defects.
TEM reveals dopant agglomeration or grain boundary anomalies that require optimization of the mixing process.

8.3.2 Grain size and microstructure uniformity
Purpose: Grain size (typically 10–50 μm) and microstructure homogeneity affect the strength, toughness, and high-temperature performance of tungsten rods.

Detection Method:
Light microscopy: The sample is polished and chemically etched (e.g., HNO_3 solution) to observe the grain boundaries and measure the average grain size.
X-ray diffraction (XRD): Analyzes crystal orientation and grain size, calculates grain size (via Scherrer's formula).

Operational Points:
The corrosion time needs to be precisely controlled (10–30 seconds) to avoid excessive corrosion.
XRD requires a high purity tungsten standard calibration with a scan angle of 10–80°.
Different areas are measured multiple times to ensure accurate tissue uniformity assessment.

Interpretation of results:
Grain size is too large and the strength may be reduced, so the sintering temperature needs to be adjusted.
Uneven tissue can be due to improper pressing or doping, and the process needs to be optimized.

8.4 Non-destructive testing of tungsten rods
Non-destructive testing (NDT) is used to evaluate tungsten rod internal and surface defects, maintain sample integrity, and is suitable for quality control.

8.4.1 Ultrasonic testing
Purpose: To detect the internal pores, cracks or inclusions of tungsten rods to ensure structural integrity.

Detection Method:
Using an ultrasonic flaw detector, 5–10 MHz ultrasound is emitted, the reflected signal is received, and the location and size of the defect are analyzed.
A longitudinal or shear wave probe combined with a water couplant scans the full length of the bar.

Operational Points:

The surface of the sample should be flat, clean and remove oil.
The probe needs to be calibrated to verify sensitivity using a standard defective sample.
The height and position of the defect echo are recorded, and the C-scan is plotted.

Interpretation of results:
Strong echoes indicate large defects (e.g., porosity > 0.5 mm) that require rework.
Continuous echoes can originate from lamellar cracks and need to be sliced for verification.

8.4.2 X-ray inspection
Purpose: To identify the internal pores, inclusions or cracks of tungsten rods, which are suitable for large-size bars.

Detection Method:
Using an industrial X-ray machine (100–300 kV), a tungsten rod is penetrated, a transmission image is recorded, and the defect characteristics are analyzed.
Cooperate with digital imaging (DR) or computed tomography (CT) to improve resolution.

Operational Points:
It needs to be protected from radiation, and professional qualifications are required for operation.
Adjust the X-ray energy to ensure penetration of thick samples (>20 mm).
Calibrated with standard defect samples, the grayscale values of the images were recorded.

Interpretation of results:
Dark areas indicate porosity or inclusions and need to be verified in conjunction with ultrasound.
CT reconstruction quantifies defect volume and guides quality assessment.

8.4.3 Magnetic particle testing
Test purpose: to detect tungsten alloy rod (such as W-Ni-Fe) surface and near-surface cracks, pure tungsten rod is not suitable due to non-magnetism.

Detection Method:
A magnetic field (AC or DC) is applied to a magnetizing device, fluorescent magnetic particles are sprayed, and magnetic traces are observed under a UV lamp.
Longitudinal or transverse magnetization to detect cracks in different directions.

Operational Points:
The surface of the sample needs to be cleaned, and the magnetizing current needs to be adjusted according to the diameter (500–2000 A).
The magnetic particle should be sprayed evenly, and the observation time should be controlled to 1–2 minutes.
The length and distribution of magnetic marks are recorded, and photos are taken for archiving.

Interpretation of results:

Linear magnetic marks indicate surface cracks that require polishing or rework.
Dense magnetic marks may be due to machining stresses and need to be eliminated by heat treatment.

8.5 Performance verification of tungsten rods

Performance verification tests simulate real-world operating conditions to evaluate the performance of tungsten rods in high-temperature, corrosive, and electrical environments.

8.5.1 High temperature performance test

Purpose: To evaluate the oxidation, creep and strength of tungsten rods at high temperatures (1000–2500°C) for aerospace and furnace applications.

Detection Method:
High-temperature tensile test: The tensile strength is tested using a high-temperature testing machine by heating the sample to a specified temperature in a vacuum or argon furnace.
Creep test: A constant load (e.g. 100 MPa) is applied, the deformation is recorded for 100–1000 hours, and the creep rate is calculated.

Operational Points:
It needs to be protected by high-purity argon gas (99.999%) to prevent oxidation.
Samples need to be of standard size (e.g. 5 mm diameter) and the fixtures should be molybdenum or ceramic.
The temperature control accuracy is ± 10°C, and the strain curve is recorded.

Interpretation of results:
The degradation of strength at high temperatures may be due to grain growth and requires optimized sintering.
A creep rate that is too high may indicate insufficient doping and the formulation needs to be adjusted.

8.5.2 Corrosion Resistance Test

Test purpose: to evaluate the corrosion resistance of tungsten rods in acid, alkali or high temperature gas environments, suitable for chemical and electrode applications.

Detection Method:
Immersion test: Weight loss is measured by immersing the sample in a corrosive medium (e.g., 10% HNO_3 or NaOH) at a constant temperature (25–80°C) for 24–168 hours.
Gas corrosion test: Exposure to oxidizing or vulcanizing atmospheres (e.g. O_2, H_2S) in a high-temperature furnace to record surface changes.

Operational Points:
The sample should be weighed (accuracy ± 0.0001 g) and the surface should be uniformly polished.
The corrosive medium needs to be replaced regularly to ensure a stable concentration.
Gas tests require control of flow rate (0.1–1 L/min) and humidity.

Interpretation of results:
A weight loss of >0.1% indicates insufficient corrosion resistance and requires improved formulation.
The thickness of the oxide layer on the surface can be due to impurities and needs to be optimized for purification.

8.5.3 Conductivity and creep test

Test Purpose: Conductivity (about 18% IACS) and creep resistance are key properties of electrodes and high-temperature components, affecting arc stability and lifetime.

Detection Method:
Conductivity test: Using the four-probe method, a constant current is applied, the voltage drop is measured, and the conductivity is calculated.
Creep resistance test: Similar to the high temperature creep test, but with a focus on doped tungsten rods (such as WC20) to test deformation in arc environments.

Operational Points:
The conductivity test requires good contact and the probe is copper or silver.
Creep resistance tests simulate welding conditions (e.g., 6000°C arc) and record the amount of deformation.
Samples are tested multiple times and averaged.

Interpretation of results:
The low conductivity may be due to uneven distribution of the dopant.
Insufficient creep resistance may indicate insufficient doping of rare earths and the need for optimal mixing.

8.6 Key points of detection of different types of tungsten rods

Different types of tungsten rods (pure tungsten rods, high-purity tungsten rods, doped tungsten rods) have different detection focuses due to different compositions and uses.

8.6.1 Pure tungsten rod detection

Key points of detection:
Physical properties: density (≥19.0 g/cm³), hardness (350–450 HV) and tensile strength to ensure high temperature stability.
Chemical composition: Tungsten content ≥ 99.9%, oxygen, carbon and other impurities < 100 ppm to prevent high temperature brittleness.
Non-destructive testing: ultrasonic detection of internal pores, X-ray verification of large-size bar quality.

Applicable Scenarios:
Quartz furnace core rod and counterweight parts require low cost and stable performance.

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Key points:
The Archimedes method is preferentially used for density testing, which is cost-effective.
Impurity detection needs to pay attention to the oxygen content and optimize the sintering atmosphere.
Non-destructive testing covers the entire batch to ensure consistency.

8.6.2 High-purity tungsten rod detection

Key points of detection:
Chemical composition: Tungsten content ≥ 99.95%, trace impurities (e.g., O, N) < 30 ppm, using ICP-MS and GD-MS.
Microstructure: SEM and TEM observe grain size (5–15 μm) and dopant distribution to ensure cleanliness.
Performance verification: conductivity and corrosion resistance testing to meet semiconductor requirements.

Applicable Scenarios:
Sputtering targets and medical devices require high purity and clean production.

Key points:
The test should be carried out in a clean room (ISO class 5) to prevent contamination.
Trace element analysis requires highly sensitive instruments and regular calibration.
Performance testing simulates real-world operating conditions, such as a vacuum environment.

8.6.3 Doped tungsten rod detection

Key points of detection:
Chemical composition: The content of dopants (such as 2% CeO_2, La_2O_3) is uniform, and thorium-doped rods need to be radioactively detected.
Performance verification: conductivity and arc stability testing, using an arc testing machine to simulate welding.
Microstructure: SEM-EDS to analyze the dopant distribution, XRD to verify the crystal orientation.

Applicable Scenarios:
Welding electrodes and high-temperature furnace components require excellent arc performance.

Key points:
The arc test requires standard welding conditions and records the burn-out rate.
The uneven distribution of the dopant requires an optimized mixing process.
The detection of thorium-doped tungsten rods is subject to radioactivity regulations.

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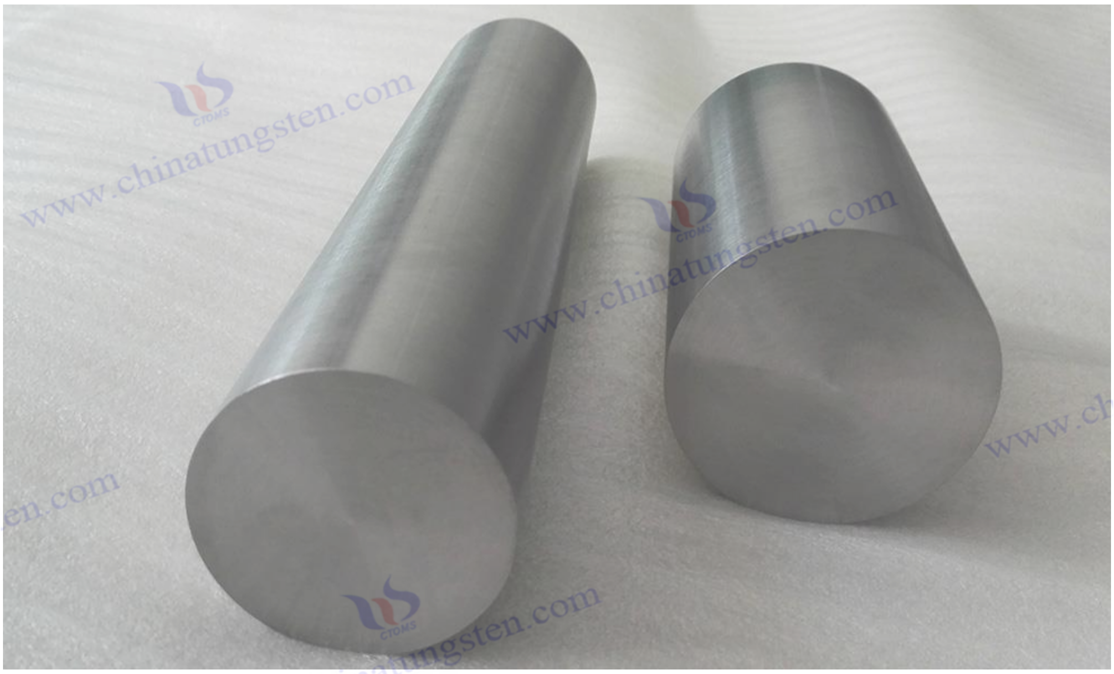

CTIA GROUP LTD tungsten rods

Chapter 9 Tungsten Rod Industry Status and Development Trend

As a strategic refractory metal material, tungsten rod plays an irreplaceable role in aerospace, electronics, welding and military fields due to its high melting point, high density and excellent mechanical properties. In recent years, the global tungsten rod market has shown a rapid growth trend, driven by changes in supply and demand, technological progress and environmental protection policies. This chapter analyzes the Chinese and international tungsten rod market, discusses technological development trends (new materials, green manufacturing, intelligent production), and evaluates the challenges and opportunities faced by the industry (technological bottlenecks, market competition, sustainable development).

9.1 Overview of tungsten rod market in China

China is the world's largest tungsten resource and tungsten rod producer, the market scale is expanding rapidly, and the supply and demand pattern is driven by policy regulation and downstream demand.

9.1.1 Market demand and supply analysis

Market Demand:

The market demand for tungsten rods in China mainly comes from the aerospace, electronics manufacturing, welding and tungsten carbide tool sectors.

Aerospace: Tungsten rods are used for high-temperature components (e.g., nozzle linings) and counterweights, driven by domestic large aircraft (e.g., C919) and aerospace programs (e.g., space stations), with steady growth in demand.

Electronics manufacturing: High-purity tungsten rods are a key material for semiconductor sputtering targets and electrodes, and with the localization of chips and the development of 5G equipment, the demand has surged.

Welding & Cutting: Doped tungsten rods (e.g. WC20, WT20) are widely used in TIG welding and plasma cutting, benefiting from the automotive, marine and construction industries, and the market continues to expand.

Tungsten carbide: As a raw material for tungsten carbide tools, tungsten rod is driven by the demand for CNC machine tools and high-end manufacturing, and accounts for a significant market share.

Supply Analysis:

Resource advantage: China's tungsten reserves account for 51% of the world's production, and the main production areas are Jiangxi, Hunan and Henan.

Production capacity: Major domestic enterprises have a complete industrial chain, covering from tungsten ore mining to bar processing, with high production capacity concentration.

Policy regulation: The government restricts tungsten mining through export quotas and environmental protection policies, and strengthens the use of recycled tungsten from 2023 to promote supply-side reform.

Challenge: Fluctuating raw material prices and rising environmental protection costs are compressing the profits of small and medium-sized enterprises, and high-end tungsten rods (such as high-purity and nano-scale) are still dependent on imports.

Trend Forecast:

Market demand is expected to grow at an average annual rate of 5-7%, and high-end manufacturing and new energy (such as photovoltaic and wind power) will become new growth points.

Supply will shift to high value-added products, and SMEs will need to upgrade their technology to cope with cost pressures.

9.2 Overview of the international tungsten rod market

The global tungsten rod market is highly competitive, with China leading the supply, Europe, the United States, Japan and South Korea dominating the high-end demand, and the supply chain restructuring and geopolitics affect the market structure.

9.2.1 Major Exporting Countries and Regions

Export Status:

China-led: China's tungsten exports reached 24,900 tonnes in 2022, accounting for the world's dominant supply, mainly to Japan (23%), South Korea (19%), Europe (35%) and the United States (11%).

Product structure: Exports are dominated by raw material grade tungsten rods and low value-added products, and cemented carbide rods account for 8.9 thousand tons, a year-on-year increase of 7.23%.

Export Trends:

Growth-driven: Exports are driven by increased aerospace and defense demand in Europe and the United States, especially tungsten alloy rods.

Regional changes: Exports to Europe and the United States will increase by 18.03% and 46.75%

respectively in 2022, while exports to Japan and South Korea will decline, reflecting the adjustment of the global industrial chain.
Challenge: Trade frictions and export quotas restrict the export of low-end products, and the high-end market is occupied by European and American companies, with low added value.

9.2.2 Import dependence and supply chain status

Import dependence:
China: High-end tungsten rods (e.g. high-purity tungsten rods, doped electrodes) are partially dependent on imports, with imports accounting for about 90% of exports, mainly from the United States, Germany and Japan, reflecting the technological gap.
Europe and the United States: Relying on China's tungsten raw materials, China accounted for 83% of the global tungsten ore supply in 2022, and the development of local mines in Europe and the United States is slow, making it difficult to be self-sufficient in the short term.
Japan and South Korea: Highly dependent on China's tungsten rod imports, processed for export of high value-added products (e.g. semiconductor targets).

Supply Chain Status:
Concentration risk: The global tungsten supply chain is highly dependent on China, and the risk of supply chain disruption has increased due to geopolitics and the pandemic.
Restructuring attempts: Europe and the United States are accelerating the development of overseas tungsten mines (such as Australia and Vietnam), but capital and cost constraints limit progress, and China's dominance is stable in the short term.
Recycled tungsten: The global recycling rate of tungsten scrap has increased to 30%, and Europe, the United States and China have promoted the recycled tungsten industry chain to alleviate the dependence on raw materials.

Trend Forecast:
Global supply chains will diversify, with Vietnam and Australia likely to emerge as emerging suppliers, but China will remain dominant.
Importing countries will increase the research and development of high-end tungsten rods to reduce their dependence on China's technology.

9.3 Technology development trend of tungsten rods

Technological advancements are driving the transformation of the tungsten rod industry towards high performance, low cost and sustainability, encompassing materials, processes and production methods.

9.3.1 New materials and alloying technologies

Technical Direction:
High Purity Tungsten Rod: Purity increased to 99.99% by chemical vapor deposition (CVD) and plasma sintering (SPS) to meet semiconductor and aerospace needs.
Doping optimization: Development of non-thorium-doped tungsten rods (such as W-La_2O_3, W-CeO_2) to improve arc stability and environmental protection, and replace radioactive WT20 electrodes.

Tungsten alloy: Research and development of high-density alloys such as W-Ni-Fe and W-Cu to optimize strength and conductivity, which are used in military and electronics.
Nanotechnology: Nanocrystalline tungsten rods are prepared by ball milling and SPS, and the grain size is reduced to 5–10 μm, improving toughness and high-temperature performance.

Progress and Challenges:
Progress: Chinese enterprises such as Xiamen Tungsten have realized the localization of some high-purity tungsten rods, and the research and development of nano-tungsten rods has entered the pilot stage.
Challenge: The cost of high-purity refining and nano-processing is high, the equipment depends on imports, and the core technology needs to be broken through.

Trend Forecast:
Non-thorium-doped and nano-tungsten rods will become the mainstream, with a market share of 40% by 2030.
Alloying technology will focus on multi-functionality to meet new energy and defense needs.

9.3.2 Green manufacturing and energy-saving technologies

Technical Direction:
Recycled tungsten utilization: Waste tungsten is recovered through hydrometallurgy and electrolysis to reduce the dependence on raw ore mining, and the recovery rate is targeted to reach 50% by 2030.
Low-energy sintering: Microwave sintering and SPS technology are used to shorten the sintering time (5–15 minutes) and reduce energy consumption by 30%.
Cleaner production: develop fluorine-free purification process to reduce the use of hydrofluoric acid and reduce wastewater discharge.
Exhaust gas treatment: Equipped with high-efficiency dust removal and desulfurization systems to meet emission standards (e.g. SO_2<50 mg/m^3).

Progress and Challenges:
Progress: China has introduced policies to support the recycled tungsten industry, with recycled tungsten production accounting for 20% of total supply in 2023.
Challenge: The initial investment in green technology is high, which is difficult for small and medium-sized enterprises to afford, and needs policy subsidies.

Trend Forecast:
Green manufacturing will become the entry threshold of the industry, and the penetration rate of energy-saving technology is expected to reach 80% by 2030.
Recycled tungsten will account for more than 30% of the global supply, alleviating the pressure on resources.

9.3.3 Intelligent and automated production

Technical Direction:
Intelligent control: PLC and SCADA systems are used to monitor sintering, forging and processing

parameters in real time to improve consistency.

Automation equipment: The introduction of CNC rotary swaging machine, automatic drawing machine and robot assembly line has increased production efficiency by 20%.

Digital twin: Build a digital model of tungsten rod production to optimize process parameters and reduce trial-and-error costs.

Quality traceability: Record the whole chain data from raw materials to finished products through blockchain technology to ensure controllable quality.

Progress and Challenges:

Progress: Leading Chinese companies have deployed smart production lines, with an automation rate of 50% in 2023.

Challenges: The high cost of intelligent equipment, the low penetration rate of small and medium-sized enterprises, and the shortage of technical talents.

Trend Forecast:

In 2030, the automation rate of China's tungsten rod industry is expected to reach 70%, and intelligence will reshape the competitive landscape.

Digital twins and quality traceability will become standard in the high-end market.

9.4 Challenges and opportunities of tungsten rods

The tungsten rod industry is facing multiple challenges in technology, market and environmental protection in the rapid development, and at the same time contains huge opportunities.

9.4.1 Technical bottlenecks and breakthroughs

Challenge:

High-end technology gap: The core equipment of high-purity tungsten rod and nano-tungsten rod (such as SPS furnace) depends on imports, which has high cost and restricts localization.

Doping uniformity: The uneven distribution of rare earth dopants affects the arc performance, and the mixing process needs to be improved.

Insufficient R&D investment: Small and medium-sized enterprises have limited R&D funds, and it is difficult to break through key technologies.

Opportunity:

Localization accelerates: The national "14th Five-Year Plan" supports the research and development of new tungsten materials, and the localization rate of high-purity tungsten rods is expected to reach 80% in 2025.

Industry-university-research cooperation: Universities and enterprises jointly tackle key problems to accelerate technology transformation.

Policy support: The government provides R&D subsidies and tax incentives to reduce the cost of innovation.

Coping strategies:

Increase the research and development of core equipment and break through the dependence on

imports.
Establish an industry-university-research platform to accelerate technology iteration.
Optimize the doping process and improve product performance.

9.4.2 Market Competition and Globalization

Challenge:
International competition: European and American companies dominate the high-end market, while Chinese companies dominate low-value-added products.
Trade barriers: The United States and Europe have imposed tariffs on tungsten products, affecting export competitiveness.
Industrial concentration: small and medium-sized enterprises are technologically backward and face the risk of being acquired or eliminated.

Opportunity:
Global demand: Demand for aerospace, semiconductors, and new energy is growing, and the global market is expected to reach billions of dollars by 2030.
"One Belt, One Road": Chinese companies can expand the market in Southeast Asia and Africa, and export technology and production capacity.
Brand building: Through technological upgrading, Chinese companies are expected to occupy a place in the mid-to-high-end market.

Coping strategies:
Enhance the added value of products and develop high-purity and doped tungsten rods.
Strengthen international cooperation and circumvent trade barriers.
Promote industrial integration and enhance concentration.

9.4.3 Requirements for environmental protection and sustainable development

Challenge:
Environmental protection pressure: tungsten mining and smelting produce waste water and waste gas, and environmental protection costs account for 20% of production costs.
Carbon neutrality goal: Peak carbon emissions by 2030 require enterprises to reduce energy consumption, and traditional processes are difficult to meet the standard.
Radioactivity management: Thorium-doped tungsten rods need to be strictly controlled, which increases the cost of compliance.

Opportunity:
Green market: The demand for environmentally friendly tungsten rods (such as non-thorium electrodes) is growing, and the market prospect is broad.
Recycled tungsten potential: Waste tungsten recycling technology is mature, and the cost is lower than that of raw ore mining.
Policy dividends: the government subsidizes green manufacturing projects to reduce the cost of transformation.

Coping strategies:

Promote recycled tungsten and low-energy technology to reduce environmental protection costs.

Development of non-thorium-doped electrodes to meet environmental regulations.

Establish a carbon footprint management system to respond to the goal of carbon neutrality.

CTIA GROUP LTD tungsten rods

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Tungsten Rods Introduction

1. Overview of Tungsten Rods

Tungsten rods are high-performance metallic bars made from tungsten powder (purity ≥99.95%) using powder metallurgy processes such as pressing, sintering, and swaging. With their extremely high melting point, excellent mechanical properties, and outstanding chemical stability, tungsten rods are widely used in industrial fields that demand extreme conditions.

2. Characteristics of Tungsten Rods

✓ Ultra-high melting point: Up to 3410°C, suitable for extreme high-temperature environments
✓ Excellent strength and hardness: Maintains mechanical performance even at temperatures
✓ Good thermal and electrical conductivity: Ideal for precision applications in electronics and heating systems
✓ High-density material: Suitable for counterweights and radiation shielding
✓ Corrosion and wear resistance: Long service life and excellent stability
✓ Low thermal expansion coefficient: Suitable for precision structural components

3. The Main Applications Tungsten Rods

✓ Aerospace and defense: Rocket nozzles, armor-piercing projectile cores, high-temperature structural parts
✓ Electronics industry: Cathodes, heat sinks, electrodes, contact materials
✓ High-temperature furnaces and metallurgy: Heating elements for vacuum furnaces, tungsten crucibles, support components
✓ Medical technology: Radiation shielding parts, precision surgical instruments
✓ Mechanical engineering: Counterweights, mold inserts, vibration dampers
✓ Scientific research equipment: Ultra-high temperature reactors, physical property testing components

4. Basic Data of Tungsten Rods

Item	Parameter
Density	19.3 g/cm³
Hardness (Vickers HV)	340–400 HV
Electrical Conductivity (20°C)	~30% IACS
Thermal Conductivity	~170 W/(m·K)
Coefficient of Thermal Expansion	~4.5 x 10^{-6} /K
Diameter Range	Ø1.0 mm – Ø100 mm (customizable)
Length Range	100 mm – 1000 mm (up to 2000 mm maximum)
Surface Condition	As-sintered (black), ground, polished

5. Procurement Information

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Chapter 10 Conclusions

As a high-performance refractory metal material, tungsten rod plays an irreplaceable role in aerospace, electronics, welding, military industry and new energy fields due to its excellent physical, chemical and mechanical properties. This chapter summarizes the core value and application prospect of tungsten rod, looks forward to its future development direction, puts forward suggestions for industry development, and reflects on the limitations and future research prospects of this research.

10.1 The core value and application prospect of tungsten rods

Core Values:

Tungsten rod has become a representative of key industrial materials due to its high melting point, high density, excellent hardness and high temperature and corrosion resistance. Its core values are reflected in the following aspects:

High performance guarantee: Tungsten rod remains stable in extreme environments (such as high temperature, high pressure, arc), and meets the high requirements of aerospace (such as nozzle lining), semiconductor (sputtering target) and military (armor-piercing bullet core).

Functional diversity: Pure tungsten rods, high-purity tungsten rods and doped tungsten rods (such as WC20 and WL20) serve different scenarios, doping optimization improves arc performance, alloying enhances strength and conductivity.

Strategic importance: Tungsten is a scarce strategic resource, the tungsten rod industry chain involves national security and high-end manufacturing, and the global supply chain depends on China (accounting for 83% of production), highlighting its geo-economic value.

Sustainable potential: Advances in recycled tungsten technology and green manufacturing processes reduce resource consumption and environmental impact, and enhance the long-term competitiveness of the industry.

Application prospects:

Aerospace: With the advancement of global space programs (such as China's space station and SpaceX's starship), the demand for tungsten rods for high-temperature components and counterweights will continue to grow, and the market share is expected to increase to 20% by 2030.

Electronics & Semiconductors: 5G, AI chips, and quantum computing are driving a surge in demand for high-purity tungsten rods, and the sputtering target and electrode market is expected to grow at an average annual rate of 8%.

New energy: The application of tungsten rods in photovoltaic (monocrystalline silicon clamping rods) and wind power (high-strength components) has expanded, benefiting from the global carbon neutrality goal, and the market potential is significant.

Welding & Manufacturing: Doped tungsten electrodes are widely used in the automotive, shipbuilding and construction industries, and the demand is growing steadily with the upgrading of high-end manufacturing.

Military & Medical: The demand for tungsten alloy rods in armor-piercing cores and radiation shielding parts is driven by global defense modernization and medical equipment renewal, and the market outlook is robust.

10.2 Future development direction of tungsten rods

Technological innovation:

High purity and nanotechnology: Improve the purity of tungsten rods to more than 99.99%, and develop nanocrystalline tungsten rods (grain size 5–10 μm) to enhance toughness and high-temperature performance to meet semiconductor and aerospace needs.

Non-thorium-doped electrodes: Research and development of environmentally friendly doped tungsten rods (such as W-La_2O_3, W-CeO_2) to replace radioactive WT20 electrodes to improve arc stability and market acceptance.

New tungsten alloy: Optimize the formula of W-Ni-Fe, W-Cu and other alloys, balance strength, conductivity and environmental protection, and expand military and electronic applications.

Green manufacturing: Promote microwave sintering, plasma sintering (SPS) and fluorine-free purification processes, reduce energy consumption by 30%, and reduce wastewater and exhaust gas emissions.

Intelligent production: Integrate digital twin, PLC control and blockchain traceability technology to improve production efficiency by 20% and achieve full-chain quality management.

Market Expansion:

High-end market breakthrough: increase the research and development of high-purity tungsten rods and doped electrodes, seize the high-end market in Europe, America, Japan and South Korea, and reduce import dependence.

Emerging market development: Through the "Belt and Road" initiative, expand the market in Southeast Asia, Africa and South America, and export tungsten rod technology and production capacity.

Diversified applications: Explore new uses of tungsten rods in new energy sources (e.g., hydrogen devices), biomedical (e.g., high-precision surgical tools), and quantum technology.

Supply Chain Optimization:

Recycled tungsten utilization: increase the recycling rate of waste tungsten to 50%, build a circular economy model, and alleviate the pressure on resources.

Diversified supply: Support the development of emerging tungsten mines in Vietnam and Australia, and reduce the risk of concentration in the global supply chain.

Regional cooperation: Strengthen technical and trade cooperation with Japan, South Korea, and the European Union to avoid geopolitical influences.

Policies & Standards:

International standard formulation: Promote China-led international standards for tungsten rods (such as ISO 24370 update) to enhance global discourse.

Strengthened environmental regulations: Stricter emission and recycling standards have been set to promote the green transformation of the industry.

Industrial support policies: expand R&D subsidies and tax incentives, encourage technological innovation and the upgrading of small and medium-sized enterprises.

10.3 Recommendations for Industry Development

At the enterprise level:

Increase R&D investment: focus on high-purity tungsten rods, nanotechnology and non-thorium doping processes, break through the import dependence of core equipment (such as SPS furnaces), and recommend that R&D account for 5-8% of revenue.

Promote intelligent transformation: Deploy CNC equipment and SCADA systems, build intelligent production lines, and achieve an automation rate of more than 50% by 2025, reducing labor costs and improving consistency.

Strengthen brand building: Enhance the competitiveness of Chinese tungsten rod brands in the high-end market through international exhibitions (such as Hannover Messe) and certifications (such as ISO 9001).

Deepen the integration of the industrial chain: through mergers and acquisitions or cooperation, integrate the resources of small and medium-sized enterprises, enhance industrial concentration, and optimize the efficiency of the supply chain from ore to finished products.

Layout of recycled tungsten industry: Invest in hydrometallurgy and electrolytic recovery technology, increase the proportion of recycled tungsten production to 30% by 2025, and reduce the cost of raw materials.

At the government level:

Improve policy support: Introduce a special fund to support the research and development of new tungsten materials and green manufacturing, and extend the tax reduction and exemption for small and medium-sized enterprises to 2030.

Strengthen resource management: Optimize tungsten mining quotas, encourage the use of recycled tungsten, and reduce raw ore mining by 20% by 2030.

Promote international cooperation: Through the "Belt and Road" initiative, establish an international alliance of tungsten resources to expand technology output and market share.

Strengthen environmental supervision: Formulate tungsten smelting emission standards (such as SO_2<30 mg/m³), limit production of high-polluting enterprises, and promote the green transformation of the industry.

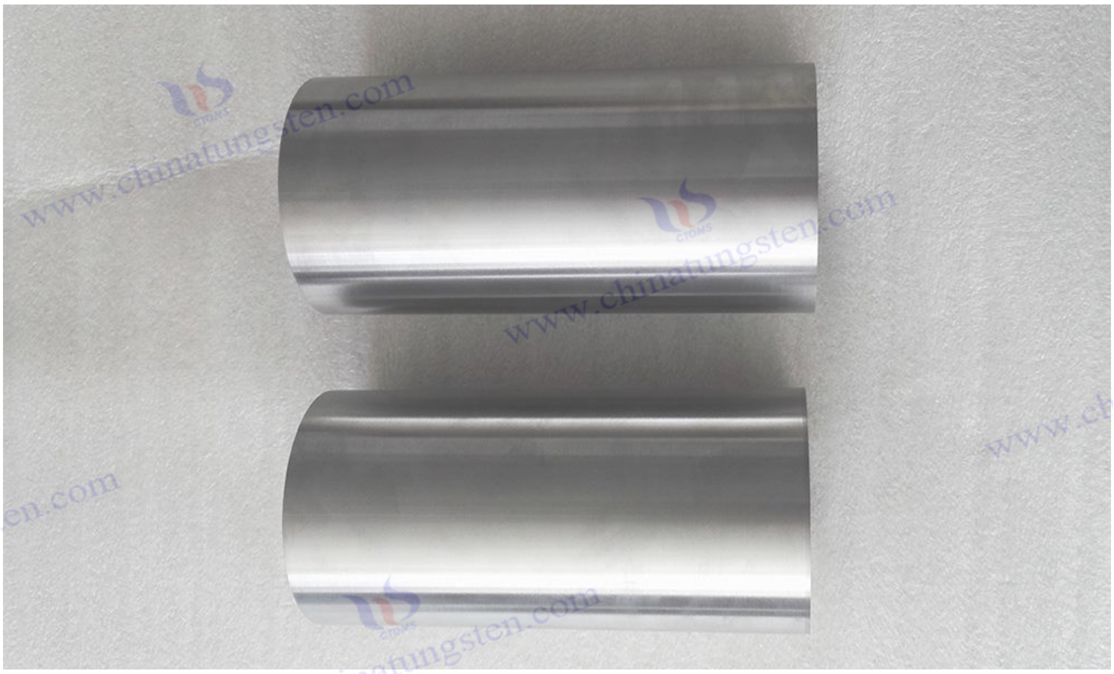
Support industry-university-research collaboration: Funding joint laboratories of universities and enterprises (such as Tsinghua University and Xiamen Tungsten) to accelerate technology transformation and achieve 10 key technological breakthroughs by 2025.

At the level of industry associations:

Formulate industry standards: revise tungsten rod production and testing standards (such as GB/T 4187) to integrate with international standards and improve product quality.

Build a communication platform: Organize an annual tungsten industry forum to promote cooperation between enterprises, universities and governments, and share green manufacturing and intelligent experience.

Carry out market research: Regularly publish global tungsten rod market reports to guide enterprises to accurately layout emerging markets.



CTIA GROUP LTD tungsten rods

Appendix

A. Glossary

Tungsten Rod: A rod-like material with tungsten or its alloys as the main component, usually prepared by powder metallurgy process.

Powder Metallurgy: The process of preparing materials by mixing, pressing, and sintering metal powders.

Thermal Expansion Coefficient: The rate at which the volume or length of a material changes at temperature.

High Density: Refers to the compact internal structure of the material and the low porosity, which is usually related to high strength.

Sintering: The process of combining metal powder particles into a solid material at high temperatures.

Hot Forging: Forging a metal at high temperatures to change its shape and properties.

Rotary Forging: The process of processing metal by rotation and pressure, suitable for bar production.

Hot Extrusion: The process of extruding metal through a mold at high temperatures.

Tungsten Alloy: A composite material with tungsten as the matrix and the addition of nickel, iron, copper and other elements.

Doped Tungsten Rod: A tungsten rod that improves its properties by adding rare earths or other elements.

Corrosion Resistance: The ability of a material to resist chemical attack.

Thermal Conductivity: The ability of a material to conduct heat.

Electrical Conductivity: The ability of a material to conduct an electric current.

Creep Resistance: The ability of a material to resist deformation at high temperatures and under constant stress.

Non-Destructive Testing: A method of testing the performance and defects of a material without damaging its structure.

ICP-MS (Inductively Coupled Plasma Mass Spectrometry): An instrument for the analysis of trace elements in materials.

SEM/TEM (Scanning/Transmission Electron Microscopy): A microscopy technique used to observe the microstructure of materials.

RWMA (Resistance Welding Manufacturers' Association): Resistance Welding Manufacturers Association, which develops standards related to tungsten materials.

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