Encyclopedia of Yttrium Tungsten Electrode

中钨智造科技有限公司

CTIA GROUP LTD

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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
Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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Directory

Chapter 1 Introduction to Yttrium Tungsten Electrodes

1.1 Definition and background of yttrium tungsten electrode

1.1.1 Chemical composition and basic principle of yttrium tungsten electrode

Yttrium Tungsten Electrode is a high-performance rare earth tungsten electrode mainly doped with an appropriate amount of yttrium oxide (Y_2O_3) in a high-purity tungsten matrixThe common industry grade is WY20, and the characteristic logo is blue coating. This electrode combines the physicochemical properties of tungsten metal and yttrium oxide, making it an important consumable in tungsten argon arc welding (TIG welding). The chemical composition of yttrium tungsten electrodes mainly includes high-purity tungsten (W, about 98% 99.5%) and a small amount of yttrium oxide (Y_2O_3, usually 1.8% to 2.2%), which may sometimes contain trace amounts of other impurities, but these impurities are strictly controlled to ensure performance stability.

As a transition metal, tungsten has an extremely high melting point (3422°C), excellent electrical and thermal conductivity, and chemical inertness, making it an ideal choice for electrode materials. However, pure tungsten electrodes have problems such as low electron emission efficiency and easy breakage in high-temperature welding. Doping of yttrium oxide significantly improved these deficiencies. Yttrium oxide is a low electron escape work material, and its electron escape work is about 2.5~2.7 eV, which is much lower than the 4.5 eV of pure tungsten. This allows yttrium tungsten electrodes to start arcing at lower voltages, exhibiting excellent arcing initiation performance. In addition, the addition of yttrium oxide increases the recrystallization temperature of the electrode (usually above 2000°C), thereby enhancing the resistance to high-temperature deformation and reducing the burnout rate.

From the basic principle, yttrium tungsten electrode is used as a non-consumable electrode in TIG welding, mainly used to generate a stable arc, heat and melt the workpiece and filling material. Its working principle is based on thermionic emission: when the electrode is excited by a high-frequency or DC power source, yttrium oxide particles in the tungsten matrix activate electron emission, forming a high-temperature arc (temperature up to 6000~7000°C). The stability of the arc is due to the slender and high compression of the arc column of the yttrium tungsten electrode, which makes it have a large penetration depth under moderate to high current conditions, making it particularly suitable for high-precision welding.

The physicochemical properties of yttrium tungsten electrodes also include high elastic modulus (about 410 GPa), good corrosion resistance, and oxidation resistance. These properties ensure the electrode's long-term stability in demanding environments, such as high temperatures, high humidity, or corrosive gases. In addition, the conductivity of yttrium tungsten electrodes (resistivity is about 5.6×10^{-8} Ω·m) and thermal conductivity (approximately 174 W/m·K) are better than other rare earth tungsten electrodes, making it superior in high-power welding.

1.1.2 R&D history and technological evolution of yttrium tungsten electrodes

The development of yttrium tungsten electrodes originated from the demand for high-performance welding materials in the mid-to-late 20th century. Tungsten electrodes were first used in the form of pure tungsten for TIG welding, but their limitations have gradually been exposed, especially in the context of the increasing requirements for welding quality in the aerospace and military industries. In the 60s of the 20th century, thorium tungsten electrodes (doped thorium oxide, ThO_2) became mainstream due to their excellent electron emission properties, but the radioactivity of thorium raised safety and environmental protection issues, prompting researchers to look for alternative materials.

In the 1970s, rare earth oxides (such as lanthanum oxide, cerium oxide, yttrium oxide) were introduced into the doping study of tungsten electrodes. Yttrium oxide has attracted attention due to its low electron escape work and high chemical stability. The early research and development of yttrium tungsten electrodes mainly focused on optimizing doping ratios and production processes. In the 1980s, some research institutions in the United States and Europe began experimenting with yttrium oxide into tungsten matrix, and found that it could significantly improve the arcing performance and durability of electrodes. In 1985, the first commercial yttrium tungsten electrode (WY20) entered the market, mainly used for precision welding in the aerospace field.

In the 21st century, with advancements in materials science and manufacturing technology, the production process of yttrium tungsten electrodes has been significantly optimized. The traditional powder metallurgy method has been improved, and the application of spray doping technology and high-temperature sintering process has made the distribution of yttrium oxide in the tungsten matrix more uniform. For example, modern production processes often include the following steps: spraying yttrium nitrate aqueous solution into the ammonium paratungstate or tungsten trioxide in the raw materials, tungsten yttrium coating powder is formed after drying; Uniform tungsten yttrium powder is obtained by two reductions; It is then pressed, sintered at high temperature (about 2800°C) and forged in multiple passes to make high-density, fine-grained yttrium tungsten electrode blanks. These process improvements reduce internal electrode defects, improve mechanical properties and arc stability.

In recent years, China has made significant progress in the field of yttrium tungsten electrode research and development. For example, a domestic company has developed a multi-composite tungsten electrode (WX4) and obtained a national invention patent. This electrode has achieved breakthroughs in doping process and performance optimization, and is widely used in high-performance welding scenarios. In addition, globally, the research and development focus of yttrium tungsten electrodes is gradually shifting towards environmental protection and cost-effectiveness, aiming to develop non-radioactive and low-cost alternative materials.

1.1.3 The rise of yttrium tungsten electrodes in high-performance welding

The rise of yttrium tungsten electrodes in high-performance welding is closely related to the development of aerospace, military industry, and high-end manufacturing. These fields demand high strength, precision, and reliability of welded joints, and yttrium tungsten electrodes are the material of choice due to their excellent arc properties and low burnout rate.

In the aerospace sector, yttrium tungsten electrodes are widely used for welding titanium alloys, stainless steels, and superalloys. For example, the manufacturing of aircraft engine blades requires extremely high welding accuracy, and the slender arc column and deep melting ability of yttrium tungsten electrodes ensure the uniformity and strength of the weld. In the military industry, yttrium tungsten electrodes are used for welding armored steel plates and missile shells, and their stable arc and low burnout rate can meet the high reliability requirements of complex structures. Additionally, in the nuclear industry and energy equipment manufacturing, yttrium tungsten electrodes are used to weld critical components, such as reactor pressure vessels, due to their corrosion resistance and high-temperature stability.

The rise of yttrium tungsten electrodes is also due to advances in TIG welding technology. Modern TIG welders offer precise current control and high-frequency arcing capabilities, closely matching the characteristics of yttrium tungsten electrodes. Additionally, the popularity of automated and robotic welding further drives the demand for yttrium tungsten electrodes, as their high stability and long lifespan significantly reduce production costs.

1.2 Market positioning of yttrium tungsten electrodes

1.2.1 Comparative analysis with other rare earth tungsten electrodes

As a kind of rare earth tungsten electrode, yttrium tungsten electrode has significant differences in performance and application from thorium tungsten electrode (WT20), lanthanum tungsten electrode (WL20) and cerium tungsten electrode (WC20). Here is a comparative analysis of several electrodes:

Thorium Tungsten Electrode (WT20)

Chemical composition: Doped with 2% thorium oxide (ThO_2), red coating.
Advantages: Strong electron emission ability, excellent arcing performance, suitable for high-current welding.
Disadvantages: Thorium oxide is radioactive and may cause harm to health and the environment with long-term use, requiring special storage and protective equipment.
Application: Mainly used for DC welding, suitable for carbon steel and stainless steel, but limited use due to environmental issues.

Lanthanum Tungsten Electrode (WL20)

Chemical composition: doped with 1.5%~2% lanthanum oxide (La_2O_3), blue coating head.
Advantages: No radioactivity, good arc initiation performance, high arc stability, suitable for AC and DC welding.
Disadvantages: The burnout rate is slightly higher than that of yttrium tungsten electrode at high current, and the durability is slightly lower.
Application: Widely used in AC welding of aluminum alloy and magnesium alloy, suitable for automated welding.

Cerium Tungsten Electrode (WC20)

Chemical composition: Doped with 2% cerium oxide (CeO_2), gray coating.
Advantages: No radioactivity, excellent arcing performance at low current, suitable for thin plate

welding.
Disadvantages: The arc stability is poor at high current, and the high temperature resistance is not as good as that of yttrium tungsten electrode.
Applications: Suitable for low-power precision welding, such as electronic components and thin-walled tubes.

Yttrium Tungsten Electrode (WY20)

Chemical composition: doped with 2% yttrium oxide (Y_2O_3), blue coating tip.
Advantages: non-radioactive, rapid arcing, stable arcing, low burnout rate, suitable for medium and high current deep melt welding.
Disadvantages: slightly higher production cost and more difficult processing.
Application: Widely used in aerospace and military industries, suitable for carbon steel, stainless steel, copper aluminum and other materials.

From the perspective of performance comparison, yttrium tungsten electrodes are better than other rare earth tungsten electrodes in terms of comprehensive performance, especially in high-current, deep-melt welding scenarios. Its non-radioactive nature makes it an ideal alternative to thorium tungsten electrodes, which have advantages in terms of high-temperature durability and arc stability compared to lanthanum tungsten and cerium tungsten electrodes.

1.2.2 Global market status and prospects of yttrium tungsten electrodes

The global tungsten electrode market is dominated by China because China's tungsten resource reserves account for more than 70% of the world's resources and annual output accounts for more than 80% of the world's output. Chinese companies occupy a leading position in the R&D and production of yttrium tungsten electrodes. In addition, the United States, Europe, and Japan also have significant influence in the tungsten electrode market, especially in high-end applications.

According to market research, the global tungsten electrode market size was about US$500 million in 2020 and is expected to grow at a compound annual growth rate (CAGR) of about 4.5% by 2030. Aerospace, military industry, and new energy equipment manufacturing are the main growth drivers. For instance, the rapid growth of the global aerospace market, which is expected to reach USD 1.2 trillion by 2030, is directly driving the demand for high-performance welding materials.

In terms of regional markets, Asia Pacific (especially China and India) is the largest consumer market for yttrium tungsten electrodes, accounting for more than 50% of the global market. The North American and European markets focus on high-end applications, focusing on the precision and reliability of electrodes. In the future, with the tightening of environmental regulations and the phase-out of thorium tungsten electrodes, the market demand for yttrium tungsten electrodes is expected to grow further. In addition, the rise of emerging technologies such as additive manufacturing (3D printing) and laser-TIG composite welding has also opened up new application scenarios for yttrium tungsten electrodes.

However, the yttrium tungsten electrode market also faces challenges. High production costs and fluctuating raw material prices are the main restraints. In addition, some developing countries still prefer to use thorium tungsten electrodes with lower costs, which may inhibit the popularity of yttrium tungsten electrodes in the short term. In the long run, with the enhancement of environmental awareness and the optimization of production processes, yttrium tungsten electrodes are expected to occupy a larger market share globally.

1.2.3 Unique advantages of yttrium tungsten electrodes

The unique advantages of yttrium tungsten electrodes are reflected in the following aspects:

Excellent arc performance: The arc column of yttrium tungsten electrode is slender and highly compressed, making it suitable for deep penetration welding at medium to high currents. The arc starting voltage is low (about 10~15 V), the arc ignites quickly, and the stability is high, making it suitable for high-precision welding.

Low burnout rate: The doping of yttrium oxide increases the recrystallization temperature, so that the electrode is not easy to deform or burn out at high temperatures, and the service life is about 30%~50% longer than that of pure tungsten electrodes.

Environmentally friendly and non-radioactive: Compared with thorium tungsten electrodes, yttrium tungsten electrodes do not contain radioactive substances, which meets modern environmental protection and safety standards, reducing the health risks of operators.

Wide Material Adaptability: Yttrium tungsten electrodes are suitable for welding various metals such as carbon steel, stainless steel, copper, aluminum, and titanium alloys, making them suitable for a variety of welding scenarios from thin to thick plates.

High Reliability: In the aerospace and military industries, yttrium tungsten electrodes ensure high strength and consistency in welds, meeting demanding quality requirements.

These advantages make yttrium tungsten electrodes irreplaceable in the field of high-end welding, especially in scenarios with high requirements for welding quality and environmental protection.

Chapter 2 Classification of Yttrium Tungsten Electrodes

As a high-performance, non-consumable electrode, yttrium tungsten electrode is widely used in tungsten argon arc welding (TIG), plasma arc welding, and other high-precision applications due to its excellent arc stability, low burnout rate, and non-radioactive properties. In order to meet the needs of different processes, materials, and environments, yttrium tungsten electrodes are classified according to yttrium oxide content, welding process, morphological specifications, application environment, and standard specifications. This chapter discusses these classification methods in detail, analyzing the performance, uses, and development trends of various types of electrodes.

2.1 Classification according to yttrium oxide content

The content of yttrium oxide (Y_2O_3) is the key influencing factor of the performance of yttrium tungsten electrode, which directly determines the electron escape work, arc stability and high temperature resistance of the electrode. According to the different content of yttrium oxide, yttrium tungsten electrodes can be divided into standard content (such as WY20) and customized content electrodes.

2.1.1 Performance and use of 2% yttrium oxide electrode (WY20).

Performance characteristics: WY20 electrode is the most common type of yttrium tungsten electrode at present, with a yttrium oxide content of 1.8%~2.2% (mass fraction), which complies with the international standard ISO 6848 and the domestic standard GB/T 4192.

Key features include:
Electron escape work: 2.5~2.7 eV, lower than pure tungsten electrode (4.5 eV), so that the arcing voltage is low (10~15 V), and the arcing time is < 0.1 seconds.
Arc stability: Arc drift rate <5%, suitable for DC positive polarity (DCEN) and alternating current (AC) welding, with a current range of 50~300 A.
Burnout rate: Under the condition of 200 A DC, the burndown rate < 0.2 mg/min, which is lower than that of thorium tungsten electrode (0.3~0.5 mg/min).
Mechanical properties: Vickers hardness (HV) 400~450, tensile strength > 1000 MPa, suitable for high-temperature welding environment (arc temperature 60007000°C).
Environmental protection: non-radioactive, better than thorium tungsten electrode (containing ThO_2, emitting α rays), in line with International Labour Organization (ILO) safety standards.

Manufacturing process: WY20 electrode is prepared by powder metallurgy process, tungsten powder purity ≥ 99.95%, yttrium oxide particle size 12 μm. The doping process uses spray doping or high-energy ball milling to ensure uniform distribution of yttrium oxide (deviation <± 0.1%). Sintering is carried out in vacuum or hydrogen atmosphere furnace at a temperature of 2000~2400°C and a density of more than 98%.

Main uses:
Aerospace: Welding titanium alloys (such as Ti-6Al-4V) and nickel-based alloys (such as Inconel 718) for turbine blades, engine combustion chambers, and fuselage structures. The WY20's low burn-out rate and stable arc ensure a weld strength of > 900 MPa, meeting aviation standards.
Energy industry: welding stainless steel pressure vessels for nuclear power equipment and nickel-based alloy parts for gas turbines, with a current of 150~250 A, and no pores or cracks in the welds.
Automotive manufacturing: welded stainless steel and aluminum alloy bodies with a current of 50~150 A and suitable for welding thin plates (<2 mm) with a small heat-affected zone (<0.5 mm).
Shipbuilding industry: welding high-strength steel plates, current 200~300 A, strong deep penetration ability, high weld toughness.

Advantages and limitations: The WY20 electrode performs well and is cost-effective in medium current and general-purpose welding scenarios, but for ultra-high currents (>400 A) or micro-welding (solder joints < 0.5 mm), the yttrium oxide content or tip design may need to be adjusted.

2.1.2 Development of customized yttrium oxide content electrodes
Background and Requirements: With the diversification of welding processes (e.g., ultra-high current plasma arc welding, micro-welding), standard WY20 electrodes may not meet specific needs. Customized yttrium oxide content electrodes (such as WY10 and WY30) optimize performance by adjusting the Y_2O_3 ratio (0.5%~3.5%) to meet special application scenarios.

Development direction:
Low yttrium oxide electrode (WY10, Y_2O_3 0.8%~1.2%):

Performance: Electronic escape power 2.7~2.9 eV, suitable for low current (<50 A) soldering, about 10%~15% lower cost. The arc stability is slightly inferior to that of WY20 (drift rate <7%), but the arcing performance is good.
Uses: Micro welding (e.g. chip packaging, medical devices), thin sheet stainless steel (<1 mm) welding.
Manufacturing: Low-doping spray process is used to reduce the amount of yttrium oxide, and the sintering temperature is 1800~2200°C.

High yttrium oxide electrode (WY30, Y_2O_3 2.5%~3.5%):
Performance: electron escape power 2.4~2.6 eV, burndown rate <0.1 mg/min, recrystallization temperature > 2100°C. Suitable for ultra-high current (>400 A) and high temperature environments.
Applications: plasma arc welding, spraying, and deep melt welding in nuclear industry and aerospace.
Manufacturing: Nanoscale yttrium oxide (particle size 10~50 nm) and discharge plasma sintering (SPS) are used, with a grain size of < 5 μm and a density > 99%.

Composite doped electrodes: combine yttrium oxide with lanthanum oxide (La_2O_3) or cerium oxide (CeO_2), such as Y-La-W (Y_2O_3 1.5%+La_2O_3 0.5%). This type of electrode combines low escape work and high heat resistance, with an arc drift rate of <3% and a 20%~30% longer life.

Challenges and Prospects:
Challenge: High yttrium oxide content increases production costs (about 15%~20%), and nano-doping technology requires more sophisticated equipment (such as high-energy ball mills, SPS furnaces).
Prospect: Customized electrodes can meet the needs of high-end markets (such as semiconductors and nuclear industries), and the market share is expected to increase to 15%~20% by 2030.

2.2 Classification according to welding process

Yttrium tungsten electrodes are divided into TIG welding special electrodes, plasma arc welding and cutting special and special process electrodes according to different welding processes, and each type of electrode is optimized for specific processes.

2.2.1 Yttrium tungsten electrode for TIG welding

Features: TIG welding (argon arc welding) is the main application field of yttrium tungsten electrode, with an arc temperature of 6000~7000°C and a current of 50~300 A. WY20 electrode is preferred due to its low escape work and arc stability, with a tip angle of 30°~45° and a diameter of 1.6~3.2 mm.

Performance Requirements:
The arcing voltage is < 15 V, and the arcing time is < 0.1 seconds.
The arc drift rate is <5%, making it suitable for DCEN and AC welding.
The burnout rate < 0.2 mg/min, and the life span is 100~150 hours.
Use:

Stainless steel welding: automobile exhaust pipe, pressure vessel, current 50~150 A, smooth weld seam, heat-affected zone < 0.5 mm.
Titanium alloy welding: aerospace structural parts, current 100~200 A, argon protection is required (flow rate 1015 L/min).
Aluminum alloy welding: AC welding, current 50~200 A, frequency 50~150 Hz, suitable for body and ship parts.

Optimized design:
The tip is ground to 30°~45° to ensure the arc is concentrated.
Electrochemical polishing of the surface (Ra<0.4 μm) to reduce arc drift.
Combined with the intelligent welding machine, the pulse frequency (1~10 Hz) is automatically adjusted to improve the weld quality.

2.2.2 Electrodes for plasma arc welding and cutting

Features: Plasma arc welding (PAW) and cutting use high energy density arc (temperature > 20000°C), current 100~500 A, requiring the electrode to have high current bearing capacity and high temperature resistance. The diameter of the WY20 or WY30 electrode is 2.4~4.8 mm, and the tip angle is 45°~60°.

Performance Requirements:
Arc stability (drift rate <3%) and supports deep penetration welding (penetration depth 10~15 mm).
The burnout rate < 0.15 mg/min, and the life span is 50~100 hours.
High recrystallization temperature (>2000°C), resistant to thermal shock.

Use:
Plasma arc welding: stainless steel pressure vessel for nuclear power equipment, current 200~400 A, weld without porosity.
Plasma cutting: carbon steel, stainless steel plate (thickness 20~100 mm), current 300~1000 A, cut width < 2 mm.
Plasma spraying: ceramic coating (zirconia) of aviation turbine blades, current 400~600 A, coating bonding strength > 70 MPa.

Optimized design:
Use WY30 electrode for enhanced high-temperature performance.
Equipped with a water-cooled welding torch to protect the electrode from overheating.
Argon-helium mixed protective gas (ratio 3:1) is used to improve arc temperature and stability.

2.2.3 Electrodes for special processes (vacuum welding, micro welding).

Features: Vacuum welding and micro-welding require electrodes with low volatility, high precision, and low heat input. WY20 electrodes (0.5~1.6 mm diameter) or customized miniature electrodes (0.3~0.8 mm diameter) are the main options.
Performance Requirements:

Low gas release rate (<10^{-6} Pa·m³/s), suitable for vacuum environments (10^{-3}~10^{-5} Pa).
The arc diameter < 0.5 mm, suitable for micro-welding.
The burning rate is <0.1 mg/min and the tip radius is <0.1 mm.

Use:
Vacuum welding: semiconductor equipment pipelines, spacecraft titanium alloy shells, current 10~50 A, vacuum degree 10^{-4} Pa.
Micro soldering: chip packaging, medical devices (such as surgical tools), current 5~20 A, solder joint diameter < 0.2 mm.
High-precision additive manufacturing: plasma arc repairs aerospace parts, current 20~50 A, stacking accuracy ± 0.05 mm.

Optimized design:
Developed a miniature needle-like electrode (tip radius <0.05 mm), achieved by laser micromachining.
Use high-purity helium (flow rate 8~12 L/min) to reduce arc diffusion.
Combined with a high-frequency arcing device (frequency 10~20 kHz), it ensures fast ignition.

2.3 Classification according to form and specification

The morphology and specifications of yttrium tungsten electrodes are divided into standard rods, micro needles, and non-standard customized electrodes according to application needs, meeting different welding precision and process requirements.

2.3.1 Standard rod electrode (diameter and length specifications)

Features: The standard rod electrode is the main form of yttrium tungsten electrode, with a diameter of 0.5~6.4 mm and a length of 50~175 mm, which meets ISO 6848 and GB/T 4192 standards. The tolerances are ± 0.05 mm in diameter, ± 1 mm in length, and the surface roughness is Ra<0.4 μm.

Specifications and Applications:
Diameter 0.5~1.6 mm: Micro welding and thin plate soldering, current 10~100 A, suitable for chip packaging and medical devices.
Diameter 1.6~3.2 mm: universal TIG welding, current 50~250 A, suitable for stainless steel, titanium alloy and aluminum alloy.
Diameter 3.2~6.4 mm: High current welding and plasma cutting, current 200~500 A, suitable for thick plates and deep melt welding.
Length 50~75 mm: Manual welding for easy operation.
Length 150~175 mm: Automatic welding, compatible with long welding guns.

Manufacturing process:
Precision drawing machine (tolerance ±0.01 mm) and laser cutting machine (length accuracy ± 0.1 mm) are used.
The surface is electrochemically polished to ensure smooth and defect-free.

Advantages: Standard rod electrodes have high production efficiency, low cost, strong versatility, and account for more than 70% of the market share.

2.3.2 Micro needle electrodes (for ultra-precision welding)

Features: Micro needle electrode diameter 0.3~1.0 mm, tip radius < 0.1 mm, designed for ultra-precision welding. The electrode length was 20~50 mm, the tolerance was ±0.01 mm, and the surface roughness was Ra<0.2 μm.

Performance and Usage:

Performance: Arc diameter <0.5 mm, heat-affected zone < 0.1 mm, suitable for current 5~50 A.

Use:

Semiconductor chip package: soldering copper and gold leads, solder joint diameter < 0.2 mm.

Medical devices: welding micro stainless steel surgical knives, current 5~20 A.

Optoelectronics: Solder fiber optic connectors with an accuracy ± 0.01 mm.

Manufacturing process:

Use laser micromachining equipment to process the tip at an angle of 15°~30°.

Electrochemical polishing (voltage 5~10 V) is used to ensure a smooth surface.

It is equipped with a high-precision drawing machine (tolerance ± 0.005 mm) to produce ultra-fine electrodes.

Development trend: With the development of microelectronics and medical industries, the demand for micro needle electrodes is expected to increase by 20%~30%, promoting the application of laser processing and nano-doping technology.

2.3.3 Non-standard customized electrodes (special-shaped design and application)

Features: Non-standard customized electrodes are designed according to special process requirements, such as curved electrodes, tapered electrodes, or multi-tip electrodes. The diameter and length are customized according to customer requirements with tolerances ± 0.05 mm.

Application Scenarios:

Complex structural welding: Special-shaped welds of aerospace components require bending electrodes (radius of curvature 5~10 mm).

Multi-point soldering: Multi-lead soldering in battery assembly uses multi-tip electrodes (tip spacing 0.5~2 mm).

Additive manufacturing: plasma arc repair, using conical electrodes (tip angle 60°~90°) to improve stacking accuracy.

Manufacturing process:

Special-shaped electrodes are formed using CNC lathes or 3D printing technology.

Complex shapes are achieved using laser cutting and electrical discharge machining (EDM).

Surface coatings, such as zirconia, enhance high-temperature resistance.

Advantages and Challenges:
Advantages: meet special needs and improve welding efficiency.
Challenges: long production cycle and high cost (about 20%~30% higher).

2.4 Classification by application environment

Yttrium tungsten electrodes are divided into high-temperature, vacuum and inert gases, and special electrodes for corrosive environments according to the temperature, atmosphere and chemical characteristics of the application environment.

2.4.1 Welding electrodes in high-temperature environments

Features: High-temperature environments (such as plasma arc welding, spraying) require electrodes to have high recrystallization temperatures (>2000°C) and low burnout rates (<0.15 mg/min). WY30 electrode (Y_2O_3 2.5%~3.5%) is the main choice, with a diameter of 2.4~4.8 mm and a tip angle of 45°~60°.

Performance and Usage:
Performance: Thermal shock resistance, arc temperature > 10000°C, life 50~100 hours.
Use:
Nuclear industry: welded zirconium alloy fuel rods, current 300~500 A.
Aerospace: Nickel-based alloy turbine blade spraying, current 400~600 A.
Energy equipment: gas turbine combustion chamber welding, temperature > 1200°C.

Optimized design:
SPS sintering was used and the grain size was < 5 µm.
Surface nano-coatings (e.g., Y_2O_3-ZrO_2) to improve oxidation resistance.

2.4.2 Vacuum and inert gas environmental electrodes

Characteristics: Vacuum (10^{-3}~10^{-5} Pa) or inert gas (e.g., argon, helium) environment requires low electrode volatility (gas release rate < 10^{-6} Pa·). m³/s）。 The WY20 electrode (0.5~2.4 mm diameter) is suitable for this environment and has a tip radius < 0.2 mm.

Performance and Usage:
Performance: Low gas release, arc stability (drift rate <3%).
Use:
Semiconductor equipment: stainless steel pipe vacuum welding, current 10~50 A.
Spacecraft: Titanium alloy shell welded, vacuum degree 10^{-4} Pa.
Vacuum heat treatment: high temperature furnace electrode, temperature > 1500°C.

Optimized design:
High-purity tungsten (≥99.99%) and nano-yttrium oxide (10~50 nm) are used.
Use high-purity helium (flow rate 8~12 L/min) to reduce arc diffusion.

CTIA GROUP LTD
Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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

2.4.3 Special electrodes for corrosive environments

Characteristics: Corrosive environments (such as marine engineering, chemical equipment) require electrodes to resist oxidation and chemical corrosion. WY20 electrode (diameter 1.6~3.2 mm) with argon protection (flow rate 10~15 L/min) is the main choice.

Performance and Usage:
Performance: Antioxidant layer formation (WO_3 volatility <0.05 mg/min), surface roughness Ra<0.2 μm.
Use:
Marine engineering: welded stainless steel ship decks, resistant to chloride ion corrosion.
Chemical equipment: Hastelloy alloy pipe welding, resistant to acidic environment.
Energy industry: Nuclear power equipment pipeline welding, high temperature and high pressure resistance.

Optimized design:
Surface electrochemical polishing or coating (e.g., TiN) for enhanced corrosion resistance.
Combined with argon-helium mixture gas (ratio 4:1), the protection effect is improved.

2.5 Standards and Identification Specifications

Standards and labeling specifications ensure quality consistency and traceability of yttrium tungsten electrodes, covering international standards, domestic standards, and packaging requirements.

2.5.1 Classification and color scales in international standards (ISO 6848, AWS A5.12).

ISO 6848:2015:
Classification: Yttrium tungsten electrode is marked as WY20, Y_2O_3 content is 1.8%~2.2%, and the end is painted blue.
Color scale: The blue end is distinguished from thorium tungsten (red), lanthanum tungsten (gold), and cerium tungsten (gray).
Requirements: diameter 0.5~6.4 mm, tolerance ± 0.05 mm; length 50~175 mm, tolerance ± 1 mm; The burnout rate < 0.2 mg/min.

AWS A5.12:2009:
Classification: Labeled as EWY-2, Y_2O_3 content 1.8%~2.2%, blue end.
Requirements: Chemical composition (tungsten ≥99.5%), arc stability (drift rate <5%), surface roughness Ra<0.4 μm.
Certification: Performance test report and third-party testing agency certification are required.

Applications: International standards are applicable to global trade and are widely used in aerospace, nuclear industry, and microelectronics to ensure consistent electrode performance.

2.5.2 Classification and identification in domestic standards (GB/T 4192).

GB/T 4192-2017：
Classification: WY20 (Y_2O_3 1.8% 2.2%), and WY10 (0.8% 1.2%) and other non-standard models,

blue end.
Requirements: Tungsten purity ≥99.5%, impurities <0.05%, arc starting voltage <15 V, burn-in rate <0.2 mg/min.
Identification: The model, size, production batch and manufacturer information are marked on the electrode surface or packaging.

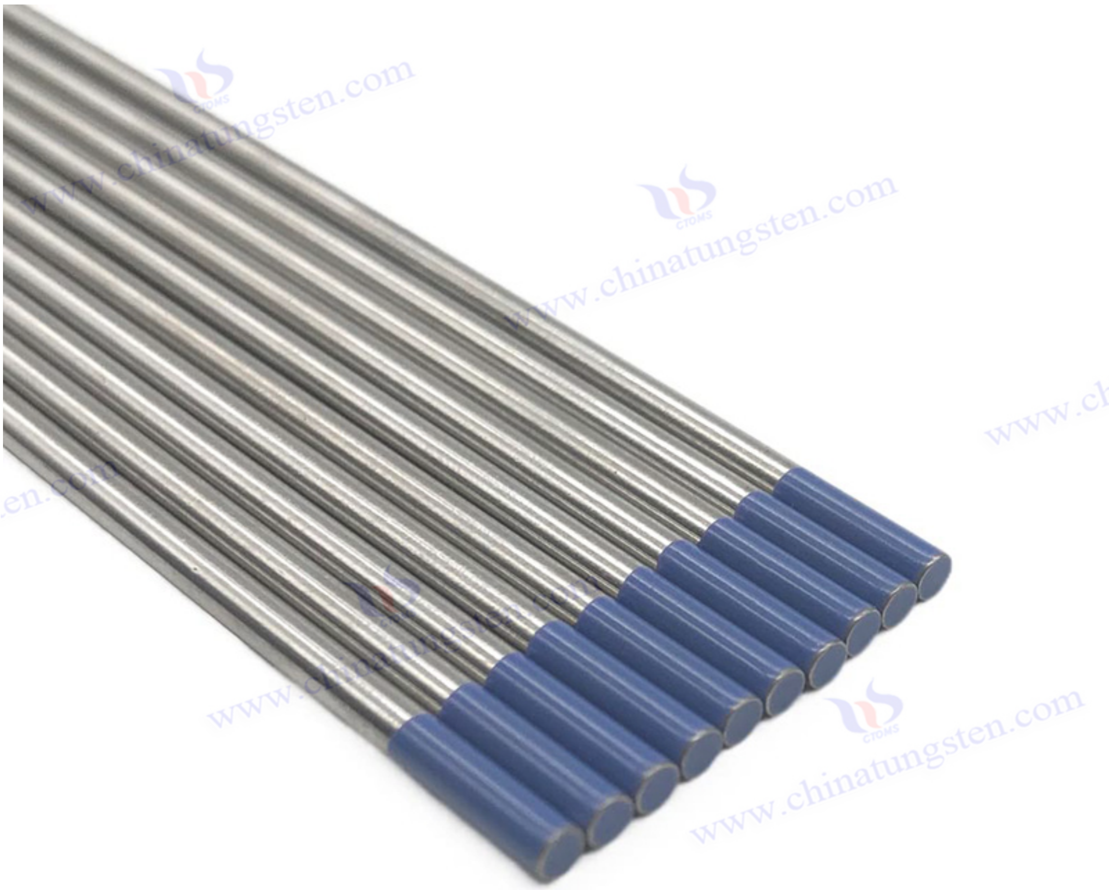
Application: Domestic standards combined with the actual production in China, flexibly support non-standard customization, and are widely used in the automobile, shipbuilding and energy industries.

2.5.3 Packaging and labeling requirements for yttrium tungsten electrodes

Packaging Requirements:
Moisture and Shockproof: Use sealed plastic boxes or vacuum packaging to prevent electrodes from being damp or collided.
Clear Identification: The packaging indicates the model (WY20), dimensions (diameter, length), batch number, production date, and manufacturer information.
Barcode/RFID: Modern packaging incorporates barcodes or RFID tags for easy inventory management and traceability.

Storage and Transportation:
Storage environment: Humidity < 60%, temperature 5~30°C to avoid oxidation or pollution.
Shipping requirements: Use shockproof packaging to prevent the electrode from bending or breaking.

Development trend: In the future, smart packaging (such as QR code link performance data) may be introduced to improve traceability and user experience.



Chapter 3 Performance Characteristics of Yttrium Tungsten Electrodes

3.1 Physical properties of yttrium tungsten electrodes

3.1.1 High melting point and high temperature stability of yttrium tungsten electrodes

Yttrium tungsten electrodes occupy a significant position in the welding industry with their exceptional high melting point and high-temperature stability. Yttrium tungsten electrodes are mainly composed of high-purity tungsten (W, purity about 98%~99.5%) and yttrium oxide (Y_2O_3, mass fraction about 1.8%~2.2%), and the melting point of tungsten is as high as 3422°C, which is one of the metals with the highest melting point in nature. This characteristic allows yttrium tungsten electrodes to maintain structural integrity in extremely high-temperature arcing environments (arc temperatures can reach 6000~7000°C) and are less prone to melting or severe burnout.

The doping of yttrium oxide further enhances the high-temperature stability of the electrode. Yttrium oxide has high thermal stability, and its decomposition temperature is much higher than the actual operating temperature during the welding process (about 2500°C or more). By doping yttrium oxide, the recrystallization temperature of yttrium tungsten electrode is significantly increased, usually reaching more than 2000°C, which is significantly higher than that of pure tungsten electrode 1700°C. This means that yttrium tungsten electrodes can maintain the stability of the grain structure during long-term high-temperature operation, reducing grain boundary slippage and the formation of microscopic cracks. This high-temperature stability is particularly important for high-

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current deep melt welding, such as when welding titanium alloys or superalloys in the aerospace sector, where the electrode can withstand sustained high-temperature arc impact without deformation or performance degradation.

In addition, the high-temperature stability of yttrium tungsten electrodes is also reflected in their thermal shock resistance. During the cycle of rapid heating and cooling, the electrode surface is not prone to thermal cracks. This property is due to the uniform microstructure of the tungsten matrix and the diffuse distribution of yttrium oxide particles, which play a role in nailing grain boundaries at high temperatures, inhibiting grain growth and thermal stress concentration.

3.1.2 Density, hardness and deformation resistance of yttrium tungsten electrodes

The density of yttrium tungsten electrode is close to the theoretical value of pure tungsten, which is about 19.1~19.3 g/cm³, which is a high-density material. This high density characteristic ensures that the electrode has high mechanical stability under the action of arcing, resisting deformation caused by arc shock and mechanical vibration. The doping of yttrium oxide has little effect on the density of the electrode, but by optimizing the production process (such as high-temperature sintering and multi-pass forging), the internal porosity of the electrode can be reduced to less than 1%, further improving the density uniformity.

In terms of hardness, the Vickers hardness (HV) of yttrium tungsten electrodes is usually between 400~450, which is slightly higher than that of pure tungsten electrodes (about 350~400 HV). The diffusion strengthening effect of yttrium oxide particles enhances the deformation resistance of the electrode, making it less prone to plastic deformation under high temperature and pressure. This high hardness and resistance to deformation are particularly important in scenarios requiring continuous welding for extended periods, such as in pipe welding or pressure vessel manufacturing, where the electrode can maintain the stability of the tip shape and reduce arc shift caused by deformation.

The increase in deformation resistance is also closely related to the grain size of the electrode. By precisely controlling the sintering temperature and doping process, modern yttrium tungsten electrodes can control the grain size in the range of 5~10 μm, which is significantly reduced compared with the 20~50 μm of traditional pure tungsten electrodes. The fine grain structure not only improves the hardness but also enhances the toughness of the electrode, making it less prone to fracture under mechanical stress.

3.1.3 Thermal conductivity and thermal expansion characteristics of yttrium tungsten electrodes

The thermal conductivity of yttrium tungsten electrode is about 174 W/m·K, which is close to that of pure tungsten (about 170~180 W/m·K), which is better than other rare earth-doped electrodes (such as thorium tungsten electrode, about 160 W/m·K). The high thermal conductivity allows the electrode to quickly dissipate heat under the action of high-temperature arcing, reducing the tip temperature and reducing the occurrence of burnout and thermal cracking. This is particularly important for high-power welding, where the electrode tip needs to withstand continuous heat input.

The coefficient of thermal expansion is another key physical property of yttrium tungsten electrodes. The coefficient of thermal expansion of tungsten is low, about 4.5×10^{-6} K^{-1} (20~1000°C), while the doping of yttrium oxide has little effect on the coefficient of thermal expansion. This low thermal expansion property ensures that the electrode undergoes minimal dimensional changes during high-temperature cycles, avoiding stress concentrations or tip deformation caused by thermal expansion. In practical applications, the low coefficient of thermal expansion allows yttrium tungsten electrodes to adapt to rapidly heating and cooling welding processes, such as pulsed TIG welding or plasma arc welding.

3.2 Chemical properties of yttrium tungsten electrodes

3.2.1 Chemical stability of yttrium oxide at high temperatures

Yttrium oxide (Y_2O_3), as a key doping component of yttrium tungsten electrodes, has extremely high chemical stability. Its melting point is about 2410°C, and the decomposition temperature is much higher than the actual temperature during the welding process (about 2000~2500°C). In high-temperature arcing environments, yttrium oxide remains chemically inert and does not react significantly with reactive gases (e.g., oxygen, nitrogen) or metal vapors in the arc. This stability ensures that no oxide or compound deposits form on the electrode surface during prolonged use, thereby maintaining the stability and purity of the arc.

The chemical stability of yttrium oxide is also reflected in its reduction resistance. In argon or helium-protected TIG welding, the electrode surface may be exposed to small amounts of reducing gases (such as hydrogen). The high bonding energy of yttrium oxide (Y-O bond energy of about 715 kJ/mol) makes it difficult to be reduced, maintaining the microstructural integrity of the electrode. This characteristic is particularly important for high-precision welding, where any chemical changes in the electrode surface can lead to arc drift or weld contamination.

3.2.2 Oxidation and corrosion resistance of yttrium tungsten electrodes

The oxidation resistance of yttrium tungsten electrode at high temperature is better than that of pure tungsten electrode. Pure tungsten is prone to oxidation in high-temperature (>1000°C) air, forming volatile WO_3, resulting in rapid electrode burnout. The doping of yttrium oxide significantly reduces the oxidation rate of the electrode surface by forming a stable oxide protective layer. Experiments show that the oxidation and weight gain rate of yttrium tungsten electrode is only 50%~60% of that of pure tungsten electrode in the oxidation environment of 1000°C.

In corrosive environments (such as industrial environments containing chlorides or acidic gases), yttrium tungsten electrodes exhibit good corrosion resistance. The tungsten matrix itself has good corrosion resistance, while the chemical inertness of yttrium oxide further enhances the electrode's resistance to corrosion. For example, in marine engineering welding, yttrium tungsten electrodes resist chloride ion corrosion in seawater, maintaining long-term performance stability.

3.2.3 Chemical behavior of yttrium tungsten electrodes in special environments (vacuum, inert gas, etc.)

In vacuum or inert gas environments, yttrium tungsten electrodes exhibit particularly excellent chemical behavior. In vacuum welding (such as vacuum electron beam welding), the electrode surface is almost non-contact with any active gas, and the low volatility of yttrium oxide (vapor pressure at 2000°C<10^{-5} Pa) ensures that the electrode does not release impurity gases, maintaining the purity of the vacuum environment. This feature makes it ideal for semiconductor fabrication and spacecraft seal soldering.

In inert gas environments (e.g., argon, helium-protected TIG welding), the chemical stability of yttrium tungsten electrodes further reduces the interaction between the electrode and the shielding gas. Yttrium oxide particles form a stable microscopic protective layer on the electrode surface, preventing the tungsten matrix from reacting with trace impurity gases such as oxygen or water vapor. This characteristic ensures the purity of the arc and the quality of the weld, which is especially advantageous in high-precision welding.

3.3 Electrical properties of yttrium tungsten electrodes

3.3.1 Electron escape work and arcing performance of yttrium tungsten electrode

The electron escape work of yttrium tungsten electrode is the core index of its electrical performance. The electron escape work of pure tungsten is about 4.5 eV, while the doping of yttrium oxide reduces it to 2.5~2.7 eV. This low escape work significantly improves the thermionic emission capability of the electrode, allowing the electrode to ignite the arc at a lower voltage (10~15 V), reducing the arc start time and energy consumption.

In practical applications, the arcing performance of yttrium tungsten electrodes is characterized by fast response and low arcing failure rate. Especially in pulsed TIG welding or high-frequency arcing processes, the electrode can form a stable arc column in milliseconds. This property is particularly important for precision welding, such as in micro-welding of electronic components or medical devices, to reduce heat input and protect the workpiece material.

3.3.2 Arc stability of yttrium tungsten electrode at high current density

The arc stability of yttrium tungsten electrodes at high current densities (50~500 A/mm²) is one of their main advantages. The doping of yttrium oxide makes the arc column more slender and compressed, the arc energy is concentrated, and the melt pool is controlled accurately. Experiments show that the arc drift rate of yttrium tungsten electrode is less than 5% under high current conditions of 200~300 A, which is significantly improved compared with pure tungsten electrode (about 10%~15%).

The improved arc stability is also related to the microstructure of the electrode tip. Yttrium oxide particles form a uniform emission point at the electrode tip, reducing local jumping or dispersion of the arc. This characteristic is particularly important in deep melt welding, such as in thick stainless steel or titanium alloy welding, where a stable arc ensures the uniformity and strength of the weld.

3.3.3 Conductivity and thermionic emission capacity of yttrium tungsten electrodes

The conductivity of yttrium tungsten electrode is close to that of pure tungsten, and the resistivity is about 5.6×10^{-8} Ω·m, which is slightly better than the thorium tungsten electrode (about 6.0×10^{-8}

Ω·m）。 The high conductivity ensures that the electrode can conduct current efficiently at high currents, reducing Joule heat loss and maintaining the stability of tip temperature.

The thermionic emission capability is another key electrical property of yttrium tungsten electrodes. The low escape work and high-temperature stability of yttrium oxide enable it to continuously emit thermal electrons in the arc environment and maintain the continuity of the arc. Compared with lanthanum tungsten electrode (WL20) or cerium-tungsten electrode (WC20), yttrium tungsten electrode has a higher thermionic emission efficiency at high current (>200 A), making it suitable for high-power deep melt welding.

3.4 Mechanical properties of yttrium tungsten electrodes

3.4.1 High temperature creep resistance of yttrium tungsten electrode

The creep resistance of yttrium tungsten electrode at high temperature is due to the diffusion strengthening effect of yttrium oxide. In a high-temperature arcing environment (about 2000~2500°C), pure tungsten electrodes are prone to creep, leading to tip deformation or breakage. The yttrium oxide particles significantly improve the creep resistance of the electrode by pinning the grain boundaries and inhibiting the dislocation movement. Experiments show that the creep rate of yttrium tungsten electrode at 2000°C is only 30%~40% of that of pure tungsten electrode.

This creep resistance allows yttrium tungsten electrodes to maintain shape stability during long periods of high-current welding. For example, in titanium welding in aerospace, where electrodes are subjected to hours of continuous operation, the anti-creep properties of yttrium tungsten electrodes ensure long-term stability in their tip shapes.

3.4.2 Wear resistance of the electrode tip of yttrium tungsten electrode

The wear resistance of the electrode tip is a critical factor affecting the quality of the weld and the lifespan of the electrode. Yttrium tungsten electrodes are formed with sharp tips (tip radius 0.1~0.5 mm) through precision grinding process, and wear resistance is improved by the strengthening effect of yttrium oxide. In high-current welding, the electrode tip is subjected to arc impact and ion bombardment, and the hardness of yttrium oxide particles (about 910 Mohs) effectively resists tip wear and erosion.

Compared with pure tungsten electrodes, the tip wear rate of yttrium tungsten electrodes is reduced by about 20%~30%, especially in alternating current (AC) welding. In AC welding, the electrode tip is subjected to rapid switching between positive and negative polarity, and the wear resistance of yttrium tungsten electrode ensures long-term stability of the tip shape, reducing arc drift and weld defects.

3.4.3 Analysis of low burn-loss characteristics and life of yttrium tungsten electrodes

The low burn-out rate of yttrium tungsten electrodes is one of their most significant mechanical properties. Burndown rate is usually defined as the rate of mass loss of an electrode at a specific current and time. Experiments show that the burnout rate of yttrium tungsten electrode is only 0.1~0.2 mg/min under 200 A DC welding conditions, which is significantly lower than that of pure tungsten electrode (0.3~0.5 mg/min).

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The low burn loss rate is achieved thanks to the following factors:

Yttrium oxide increases the recrystallization temperature of the electrode and reduces grain growth at high temperatures.
High thermal conductivity and low coefficient of thermal expansion reduce thermal stress at the tip and reduce microcracks.
The electrode surface smoothness is high (Ra<0.4 μm), which reduces material peeling caused by arc impact.

The life analysis shows that the service life of yttrium tungsten electrode under typical TIG welding conditions can reach 100~150 hours, which is about 30%~50% longer than that of pure tungsten electrode (50~80 hours). In high-current or high-frequency pulse welding, the lifetime advantage is even more obvious.

3.5 Safety and environmental protection characteristics of yttrium tungsten electrodes

3.5.1 The advantages of non-radioactivity and low toxicity of yttrium tungsten electrodes

The non-radioactivity of yttrium tungsten electrodes is their main advantage over thorium tungsten electrodes (WT20). Thorium tungsten electrodes pose health risks due to the presence of thorium oxide (ThO_2, which is α radioactive), and long-term exposure may lead to radiation exposure. The yttrium oxide in yttrium tungsten electrodes is not radioactive and meets the safety standards of the International Labour Organization (ILO) and the World Health Organization (WHO).

In addition, the low toxicity properties of yttrium tungsten electrodes make them have minimal impact on the health of operators during production and use. Yttrium oxide and tungsten are both chemically inert substances that are not prone to volatilization or produce harmful gases. During the welding process, the yttrium tungsten electrode does not emit toxic vapors, reducing the risk of respiratory and skin exposure for operators.

3.5.2 Environmental impact and sustainability assessment of yttrium tungsten electrodes

The environmental protection of yttrium tungsten electrodes is reflected in their low environmental impact during their production and use. Compared with thorium tungsten electrodes, yttrium tungsten electrodes do not require special radioactive waste treatment facilities, reducing the risk of environmental pollution. Modern processes, such as spray doping and high-temperature sintering, enhance sustainability during production by optimizing energy utilization and reducing waste emissions.

From a life cycle perspective, the long-life characteristics of yttrium tungsten electrodes reduce the frequency of electrode replacement, reducing resource consumption and waste generation. In addition, both tungsten and yttrium oxide can be recycled, achieving a recovery rate of more than 90% through high-temperature melting and chemical purification, which meets the requirements of the circular economy.

3.5.3 Occupational health and safety specifications for yttrium tungsten electrodes

The occupational health and safety specifications for yttrium tungsten electrodes mainly include the following aspects:

Operational safety: Protective glasses and gloves should be worn during welding to avoid damage to the eyes and skin by arc light.
Ventilation requirements: Although yttrium tungsten electrodes are non-toxic, they may produce a small amount of metal vapor during the welding process, so ensure that the workplace is well ventilated.
Storage and transportation: Electrodes should be stored in a dry and ventilated environment to avoid moisture or mechanical damage. Shockproof packaging is required during transportation to prevent electrodes from breaking.
Waste disposal: Waste electrodes should be sorted and recycled to avoid random discard.

3.6 Yttrium Tungsten Electrode MSDS from CTIA GROUP LTD

Part 1: Product Name
Name: Yttrium Tungsten Electrode (WY20)
CAS No.:7440-33-7

Part 2: Composition/Composition Information
Chemical composition: tungsten (W, 98%~99.5%), yttrium oxide (Y_2O_3, 1.8%~2.2%), trace impurities (<0.1%).
Physical state: solid rod shape, blue coating logo.

Part 3: Overview of Danger
Health hazards: This product is not irritating to the eyes and skin.
Explosion hazard: This product is non-flammable and non-irritating.

Part 4: First aid measures
Skin contact: Remove contaminated clothing and rinse with plenty of running water.
Eye contact: lift the eyelid and rinse with running water or saline. Medical treatment.
Inhalation: Leave the scene to fresh air. If breathing is difficult, give oxygen. Medical treatment.
Eating: Drink enough warm water to induce vomiting. Medical treatment.

Part 5: Fire protection measures
Harmful combustion products: natural decomposition products are unknown.
Fire extinguishing methods: Firefighters must wear gas masks and full-body firefighting suits to extinguish the fire in the upwind direction. Fire extinguishing agent: dry leather powder, sand.

Part 6: Leakage emergency treatment
Emergency treatment: isolate the leaking pollution area and restrict access. Cut off the fire source. It is recommended that emergency response personnel wear dust masks (full face masks) and anti-gas clothing. Avoid dust, sweep it up carefully, and transfer it to a safe place in a bag. If there is a

large amount of leakage, cover it with plastic sheeting or canvas. Collect and recycle or transport to waste treatment sites for disposal.

Part 7: Operation, disposal and storage

Operational precautions: Operators must undergo special training and strictly abide by operating procedures. It is recommended that operators wear self-priming filter dust masks, chemical safety protective glasses, anti-toxic penetration work clothes, and rubber gloves. Away from fire and heat sources, smoking is strictly prohibited in the workplace. Use explosion-proof ventilation systems and equipment. Avoid dust. Avoid contact with oxidants and halogens. When handling, it should be loaded and unloaded lightly to prevent damage to the packaging and containers. Equipped with corresponding varieties and quantities of fire-fighting equipment and leakage emergency treatment equipment. Empty containers may leave harmful substances behind.

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

Part 8: Contact Control/Personal Protection

China MAC (mg/m3): 6

Former Soviet MAC (mg/m3): 6

TLVTN:ACGIH 1mg/m3

TLVWN:ACGIH 3mg/m3

Monitoring method: Potassium thiocyanide-titanium chloride spectroluminometry

Engineering control: dust-free production process and full ventilation.

Respiratory system protection: When the dust concentration in the air exceeds the standard, a self-priming filter dust mask must be worn. When evacuating in an emergency, you should wear an air respirator.

Eye protection: Wear chemical safety glasses.

Body protection: wear anti-poison penetration work clothes.

Hand protection: wear rubber gloves.

Part 9: Physical and chemical properties

Main ingredients: pure product

Appearance and properties: solid, metallic bright white

Melting point (°C): N/A

Boiling point (°C): N/A

Relative density (water=1): 13~18.5 (20°C)

Vapor density (air=1): No data

Saturated vapor pressure (kPa): No data

Heat of combustion (kj/mol): No data

Critical temperature (°C): No data

Critical pressure (MPa): No data

Logarithmic value of water distribution coefficient: No data
Flash point (°C): No data
Ignition temperature (°C): No data
Explosive Limit % (V/V): No data
Lower explosion limit % (V/V): No data
Solubility: soluble in nitric acid and hydrofluoric acid
Main use: used to make shielding parts, tungsten alloy dart shafts, tungsten alloy balls, etc

Part 10: Stability and Reactivity
Prohibited ingredients: strong acids and alkalis.

Part 11:
Acute toxicity: no data
LC50: No data

Part 12: Ecological data
There is no data on this part

Part 13: Waste disposal
Waste nature waste disposal method: Refer to relevant national and local regulations before disposal. If possible, recycle.

Part 14: Shipping Information
Dangerous goods number: No information
Packaging category: Z01
Transportation precautions: The packaging should be complete and the loading should be secure. During transportation, ensure that the container does not leak, collapse, fall, or damage. It is strictly forbidden to mix and transport with oxidants, halogens, edible chemicals, etc. During transportation, it should be protected from sun exposure, rain, and high temperature. The vehicle should be thoroughly cleaned after transportation.

Part 15: Regulatory Information
Regulatory information: Regulations on the Safety Management of Chemical Dangerous Goods (issued by the State Council on February 17, 1987), Implementation Rules of the Regulations on the Safety Management of Chemical Dangerous Goods (Hua Lao Fa [1992] No. 677), Regulations on the Safe Use of Chemicals in the Workplace ([1996] Labor Department Fa No. 423) and other regulations, which make corresponding provisions on the safe use, production, storage, transportation, loading and unloading of chemical dangerous goods. The hygienic standard for tungsten in workshop air (GB 16229-1996) specifies the maximum allowable concentration and detection method of the substance in workshop air.

Part 16: Supplier information
Supplier: CTIA GROUP LTD; Phone: 0592-5129696/5129595

Chapter 4 Preparation Process and Technology of Yttrium Tungsten Electrode

4.1 Preparation of raw materials for yttrium tungsten electrodes

4.1.1 Screening and preparation of high-purity tungsten powder

The preparation of yttrium tungsten electrode begins with the screening and preparation of high-purity tungsten powder, and the quality of tungsten powder directly affects the physical, chemical and electrical properties of the electrode. Tungsten powder is typically prepared from ammonium paratungstate (APT) or tungsten trioxide (WO_3) through a hydrogen reduction process. The production of yttrium tungsten electrodes requires the purity of tungsten powder to reach more than 99.95% to ensure the stability of the electrode in the high-temperature arcing environment. The content of impurities (e.g., iron, nickel, carbon, etc.) should be kept below 50 ppm, as even trace amounts of impurities can cause electrode burnout or arc drift during the welding process.

The particle size distribution of tungsten powder is a key parameter for screening. The ideal particle size range of tungsten powder is 1~5 μm, and too large particles (>10 μm) will cause the grain to become coarse after sintering, reducing the mechanical strength of the electrode. Too small particles (<0.5 μm) may increase the difficulty of sintering and affect the density of the electrode. The modern preparation process uses airflow classification technology to screen tungsten powder, and by precisely controlling the airflow speed and screen size, tungsten powder with uniform particle size is separated. In addition, the morphology of the tungsten powder also needs to be optimized, and

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the near-spherical particles are preferred, as the spherical particles have better fluidity during subsequent mixing and sintering, which helps to improve the uniformity of the electrode.

The preparation process of tungsten powder typically involves the following steps:

Reduction: APT or WO_3 is reduced twice in a hydrogen atmosphere (600~900°C) to generate high-purity tungsten powder.
Sieving: Screening the target particle size tungsten powder through a vibrating screen or airflow grading equipment.
Cleaning: Pickling (dilute hydrochloric acid or nitric acid) is used to remove surface oxides and impurities.
Drying: Drying at low temperature (<200°C) in a vacuum or inert gas environment to prevent oxidation of tungsten powder.

4.1.2 Purification and quality control of yttrium oxide

Yttrium oxide (Y_2O_3) is a key doping component of yttrium tungsten electrodes, and its purity and quality directly affect the electrode's electron emission performance and high-temperature stability. Yttrium oxide is typically extracted from yttrium ores, such as monazite or fluorocerium, and purified to above 99.99% through solvent extraction and ion exchange processes. During the purification process, the content of impurity elements (such as calcium, silicon, iron) should be strictly controlled, and the total target impurity should be < 100 ppm to avoid negative effects on electrode performance.

Particle size control of yttrium oxide is also critical. The ideal size of yttrium oxide particles is 0.5~2 μm, and too large particles will lead to uneven doping and reduce the arc stability of the electrode. Particles that are too small (<0.1 μm) may agglomerate during the sintering process, affecting the microstructure of the electrode. Modern processes use spray drying technology to prepare yttrium oxide particles, ensuring uniformity and fluidity by controlling the spray rate and drying temperature.

Quality control measures include:

Chemical analysis: Inductively coupled plasma emission spectroscopy (ICP-OES) was used to detect the purity and impurity content of yttrium oxide.
Particle Size Analysis: Use a laser particle size analyzer to measure particle distribution, ensuring compliance with the target range.
Morphology examination: The morphology of yttrium oxide particles is observed by scanning electron microscopy (SEM), with preference for near-spherical particles.

4.1.3 Selection and optimization of auxiliary additives

In the preparation of yttrium tungsten electrodes, auxiliary additives are used to improve the fluidity of the powder, the sintering properties or the mechanical properties of the electrodes. Commonly used additives include:

Binders: such as polyvinyl alcohol (PVA) or polyethylene glycol (PEG), which are used to improve the molding performance of powders, usually 0.1%~0.5% added.
Dispersants: such as ammonium polyacrylate (PAA), which is used to prevent the agglomeration of yttrium oxide particles, with an addition amount of about 0.05%~0.2%.
Sintering auxiliaries: such as a small amount of lanthanum oxide (La_2O_3) or cerium oxide (CeO_2), which is used to reduce the sintering temperature and increase the electrode density, and the addition amount is < 0.1%.

The selection of additives should consider their volatility during the high-temperature sintering process to avoid residues affecting the electrical properties of the electrode. For example, PVA can be completely decomposed at 600~800°C without residual organic matter in the electrode. Experiments to optimize additive ratio are usually performed through orthogonal design to comprehensively evaluate the impact of additives on electrode density, hardness, and arc performance.

4.2 Powder metallurgy process of yttrium tungsten electrode

4.2.1 Mixing and doping technology of yttrium tungsten powder

Mixing and doping of yttrium tungsten powder is a key step in the preparation of homogeneous electrodes. Yttrium oxide needs to be evenly distributed in the tungsten matrix to ensure the arc stability and mechanical properties of the electrode. Commonly used doping techniques include:
Wet Doping: An aqueous solution of yttrium oxide, typically yttrium nitrate, is sprayed onto tungsten powder or tungsten trioxide raw material, ensuring uniform mixing through agitation and ultrasonic dispersion. Subsequently, the tungsten yttrium composite powder was formed by spray drying, and the particle size was controlled at 2~5 μm.
Dry doping: Yttrium oxide powder is directly mixed with tungsten powder, and mechanical alloying is carried out using high-energy ball milling equipment. During the ball milling process, the speed (200~400 rpm) and time (48 hours) need to be controlled to avoid too fine particles or contamination.
Plasma spraying doping: Plasma spraying technology is used to spray yttrium oxide particles onto the surface of tungsten powder to form a coating structure. This method is suitable for electrode preparation with high content of yttrium oxide (>2.5%).

The distribution uniformity of yttrium oxide should be strictly controlled during the doping process. Modern processes analyze the elemental distribution of doped powders by X-ray fluorescence spectroscopy (XRF) or energy dispersive spectroscopy (EDS), ensuring that the mass fraction deviation of yttrium oxide <± 0.1%.

4.2.2 High-pressure forming and isostatic pressing process

After yttrium tungsten powder is mixed, it needs to be made into electrode blanks by high-pressure molding. Common high-pressure forming methods include:

Compression molding: Doped powder is loaded into the mold and pressed into blank strips under a pressure of 50~100 MPa. Compression molding is suitable for low-volume production, but the internal density distribution of the blank can be uneven.

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Cold Isostatic Pressing (CIP): Powder is loaded into a flexible mold and a uniform pressure of 200~300 MPa is applied in the liquid medium. The CIP process can significantly increase the density of the billet (up to 60%~70% of the theoretical density) and reduce the internal porosity, making it suitable for high-performance electrode production.

The advantage of the isostatic pressing process is that the pressure is uniform, which avoids stress concentration in the billet bar. The process parameters (such as pressure, holding time) need to be optimized according to the powder particle size and additive ratio, usually the holding time is 30~60 seconds to ensure the shape stability and strength of the billet.

4.2.3 High temperature sintering and atmosphere control (hydrogen, vacuum sintering)

High-temperature sintering is a core step in the preparation of yttrium tungsten electrodes, aiming to improve the density and mechanical properties of the electrodes. Sintering is typically performed in a hydrogen or vacuum atmosphere, and the process parameters include:

Hydrogen sintering: Carried out in a hydrogen atmosphere of 1800~2200°C, hydrogen prevents the oxidation of tungsten powder while promoting the uniform distribution of yttrium oxide particles. The sintering time is 24 hours, and the heating rate is controlled at 5~10°C/min to avoid the rapid growth of the grains.
Vacuum sintering: Carried out in a vacuum environment of 10^{-3}~10^{-5} Pa, the sintering temperature is 2000~2400°C. Vacuum sintering can reduce the adsorption of gas impurities and is suitable for the preparation of high-purity electrodes.

During the sintering process, the atmosphere purity (oxygen content < 10 ppm) should be strictly controlled to prevent oxidation or the formation of WO_3 volatiles on the electrode surface. The electrode density after sintering can reach more than 98% of the theoretical density, and the grain size is controlled at 5~10 μm to ensure the mechanical strength and arc stability of the electrode.

4.3 Processing and finishing of yttrium tungsten electrodes

The processing and finishing of yttrium tungsten electrodes are the key steps in converting sintered blanks into electrode rods that meet standard specifications (ISO 6848, GB/T 4192), involving processes such as hot calendering, precision drawing, surface polishing, tip forming, and customized cutting. These processes directly impact the dimensional accuracy, surface quality, and arc performance of the electrodes.

4.3.1 Hot calendering and precision drawing

Hot calendering process: Hot calendering is the core process of processing sintered yttrium tungsten billet strips (diameter 10~20 mm, length 100~300 mm) into smaller diameter (3~5 mm) bars. Hot calendering is carried out in a high-temperature environment to reduce the hardness and ductility requirements of tungsten, ensuring uniform deformation and no cracks in the blank.

Process parameters:
Temperature: 1400~1600°C, lower than the recrystallization temperature of tungsten (>2000°C) to

prevent excessive grains.
Rolling passes: 5~10 passes, the diameter of each pass is reduced by 0.51 mm, and the cumulative deformation is 70%~80%.
Roll material: tungsten-molybdenum alloy or ceramic composite, resistant to high temperature (> 1500°C) and resistant to wear.
Protective atmosphere: argon or nitrogen gas (flow rate 10~15 L/min, oxygen content < 10 ppm) to prevent oxidation of tungsten surface to form WO_3 volatiles.
Heating rate: 5~10°C/min to avoid micro-cracks caused by thermal stress.

Equipment:
High-temperature hot calenders: Equipped with infrared thermometers (accuracy ±2°C) and atmosphere control systems to ensure temperature and oxidation control.
Multi-roll mill: four-roll or six-roll design, rolling force 100~200 kN, accuracy ± 0.1 mm.

Quality requirements:
Surface roughness Ra<1.0 μm, no visible scratches or oxide layers.
Diameter tolerance ±0.1 mm, roundness deviation <0.05 mm.

Challenges and Optimizations:
Challenge: The brittleness of tungsten at high temperatures can lead to cracks, requiring precise control of temperature and deformation rate.
Optimization: Multi-stage progressive rolling is adopted, the deformation amount is < 15% per pass, and the internal cracks are monitored using an online ultrasonic detector (frequency 5~10 MHz).

Precision Drawing Process: Precision drawing further processes the hot-calendered bar to the target diameter (0.5~4.8 mm) to meet high-precision welding needs (e.g., micro-welding, aerospace). The drawing process ensures that the electrode surface is smooth, dimensionally accurate and free from internal stresses.

Process parameters:
Drawing mold: diamond mold (hole diameter accuracy ± 0.01 mm), resistant to wear and smooth surface.
Pulling speed: 0.5~2 m/min, too high speed may cause surface scratches, too low speed will reduce efficiency.
Lubricant: graphite emulsion (viscosity 0.1~0.3 Pa·s) or molybdenum-based lubricant (MoS_2) to reduce the friction coefficient (<0.1).
Drawing passes: 10~15 passes, the diameter of each pass is reduced by 0.1~0.3 mm, and the cumulative deformation is > 90%.
Tension control: The pulling force (10~50 kN) is controlled by a servo motor to ensure dimensional consistency.

Equipment:
Precision drawing machine: Equipped with tension sensor (accuracy ±0.1 kN) and laser diameter

gauge (accuracy ±0.005 mm).
Lubrication system: Automatic spraying of lubricant, flow rate 0.1~0.5 L/min to prevent mold overheating.

Quality requirements:
Diameter tolerance ±0.05 mm, surface roughness Ra<0.4 μm.
No surface scratches, cracks or residual stress, and the internal defect rate < 0.5%.

Challenges and Optimizations:
Challenge: Dimensional deviations caused by wear of diamond molds, which needed to be replaced regularly (drawn every 100,000 meters).
Optimization: Introducing an online laser diameter gauge and X-ray tomography (XCT, resolution < 1 μm) to monitor dimensional and internal defects in real-time.

Development trend:
Develop high-temperature plasma-assisted rolling technology to reduce rolling temperature (1200~1400°C) and reduce energy consumption by 20%~30%.
Use nano-coated molds (such as TiN or CrN) to extend mold life by 50% and improve drawing accuracy.

4.3.2 Surface polishing and tip forming

Surface Polishing Process: Surface polishing is a critical step in improving the arc stability and longevity of yttrium tungsten electrodes. A smooth surface (Ra<0.4 μm) reduces arc drift (target <5%) and tip burnout (<0.2 mg/min) and reduces arc instability caused by surface defects.

Mechanical Polishing:
Process: Use diamond grinding wheel (grit size 2000~3000 mesh) or alumina polishing belt, polishing speed 13 m/min.
Equipment: CNC polishing machine, equipped with automatic feed system (accuracy ± 0.01 mm) and coolant circulation device (flow rate 5~10 L/min).
Quality requirements: Surface roughness Ra<0.4 μm, no scratches or micro-cracks.
Advantages: Suitable for high-volume production and low cost.
Disadvantages: Trace abrasive residues may be introduced, which need to be cleaned later.

Electrochemical Polishing:
Process: Sulfuric acid-phosphoric acid mixed electrolyte (ratio 1:1, concentration 10% 20%), voltage 515 V, current density 0.52 A/cm², polishing time 1030 seconds.
Equipment: Electrochemical polishing machine with constant current power supply (accuracy ± 0.1 V) and stirring system (speed 100~200 rpm).
Quality requirements: Surface roughness Ra<0.2 μm, no oxide layer or corrosion pit.
Advantages: High surface finish, suitable for high-precision soldering (e.g. semiconductors).
Disadvantages: High cost of electrolyte treatment and environmental protection measures.

Quality control:
Roughness was detected using a laser surface scanner (resolution < 0.01 μm).
Optical microscopes (magnification 100~500 ×) examine surface defects to ensure no scratches or signs of oxidation.

Tip Forming Process: Tip forming creates tips with specific angles (15°~60°) and radii (0.1~0.5 mm) through precision grinding to optimize arc concentration and arcing performance. Different welding processes have specific requirements for tip shapes:

Process parameters:
Angle selection:
15°~30°: Suitable for micro-welding (current 5~50 A), arc concentration, heat-affected zone < 0.1 mm.
30°~45°: General TIG welding (current 50~200 A) to balance arc stability and lifetime.
45°~60°: Plasma arc welding (current >200 A), suitable for deep melting and high-temperature environments.

Tip radius: 0.1~0.2 mm (micro-welding), 0.3~0.5 mm (high-current welding).
Grinding equipment: CNC grinding machine, equipped with diamond grinding wheel (grit size 3000 mesh), rotation speed 1000~5000 rpm.

Equipment:
CNC grinder: supports multi-axis control (accuracy ± 0.01°), programmable tip shape.
Cooling system: Use water-based coolant (flow rate 5~10 L/min) to prevent tip overheating.

Quality requirements:
The tip angle deviation is <±1° , and the radius deviation is <±0.02 mm.
No burrs or microcracks, surface roughness Ra<0.2 μm.

Challenges and Optimizations:
Challenge: Tip grinding consistency is difficult to guarantee, and manual operation can easily lead to deviation.
Optimization: Introduction of visual recognition system (resolution < 0.01 mm) to automatically detect tip shape; Develop specialized fixtures to ensure consistent grinding angles.

Development trend:
Laser polishing technology: Use pulsed laser (power 1~5 kW) to polish the electrode surface, roughness Ra<0.1 μm, no chemical waste liquid.
Intelligent Grinding System: Combines AI algorithms to optimize tip angles and radii, adapting to different welding scenarios and improving consistency by > 95%.

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CTIA GROUP LTD
Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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4.3.3 Electrode cutting and customized processing

Electrode Cutting Process: Electrode cutting cuts long rods into standard lengths (50~175 mm) to meet manual or automated welding needs. Cut to ensure that the incision is flat, burr-free, and avoid micro-cracks caused by thermal stress.

Diamond Cutting Wheel:

Process: Use diamond cutting wheel (particle size 500~1000 mesh), rotation speed 2000~5000 rpm, cutting speed 0.1~0.5 m/min.

Equipment: CNC cutting machine, equipped with coolant injection system (flow rate 10~20 L/min).

Quality requirements: incision flatness < 0.05 mm, no microcracks or heat-affected zones.

Advantages: Suitable for high-volume production and low cost.

Disadvantages: The cutting wheel is worn and needs to be replaced regularly.

Laser Cutting Technology:

Process: Fiber laser (power 13 kW) with a cutting speed of 0.52 m/min and a focal point diameter < 0.1 mm.

Equipment: Laser cutting machine, equipped with inert gas protection (argon, flow rate 10~15 L/min).

Quality requirements: Cutting accuracy ±0.1 mm, no thermal stress cracks.

Advantage: High precision, suitable for non-standard length cutting.

Disadvantages: High cost of equipment.

Quality control:

The incision quality was checked using a light microscope (50× magnification).

Ultrasonic detector (frequency 5~20 MHz) detects internal microcracks (length < 0.1 mm).

Customized Machining: Customized machining meets special welding needs, such as special-shaped electrodes (curved, tapered, multi-tip) or non-standard size electrodes.

Application Scenarios:

Bending electrodes: radius of curvature 5~10 mm, suitable for complex welds (e.g. aerospace components).

Conical electrode: tip angle 60°~90°, used for plasma arc additive manufacturing, stacking accuracy ± 0.05 mm.

Multi-tip electrode: 0.5~2 mm tip spacing, suitable for multi-point welding for battery assembly.

Craft:

CNC lathes: machining curved or tapered electrodes with an accuracy ± 0.05 mm.

Electrical Discharge Machining (EDM): Creates complex shapes with electrode clearances < 0.01 mm.

3D printing assistance: Used for prototyping to quickly verify the performance of special-shaped electrodes.

Quality requirements:

Dimensional tolerances ± 0.05 mm and surface roughness Ra<0.4 μm.
No internal defects, mechanical strength > 1000 MPa.

Challenges and Optimizations:
Challenges: Long customized processing cycle (2~5 days) and high cost (about 30% higher).
Optimization: Introduce modular design, develop universal fixtures, and shorten production cycles by 50%.

Development trend:
Ultra-short pulse laser cutting (pulse width < 10 ps) was developed with a heat-affected zone < 0.01 mm of the incision.
Special-shaped electrodes are directly formed using additive manufacturing techniques such as laser melting deposition, reducing processing steps.

4.4 Quality control technology of yttrium tungsten electrodes

Quality control technology ensures that the chemical composition, microstructure, and performance of yttrium tungsten electrodes meet standards (ISO 6848, GB/T 4192), covering yttrium oxide distribution, microstructure analysis, and process optimization.

4.4.1 Control of yttrium oxide distribution uniformity

Importance: The uniform distribution of yttrium oxide (Y_2O_3) directly affects the arc stability (drift rate <5%) and burnout rate (<0.2 mg/min) of the electrode. Uneven distribution can lead to localized hot spots, reducing life.

Control method:

Chemical Analysis:
XRF: X-ray fluorescence spectrometer detects yttrium oxide content in electrode cross-section, with an accuracy of ±0.05% and an analysis time of < 1 minute.
ICP-OES: Inductively coupled plasma spectrometer with detection limit < 1 ppb and accuracy ± 0.01%, suitable for high-precision laboratory analysis.
Process: Sampling 5~10 points (center, edge) to ensure that the Y_2O_3 content deviation <± 0.1%.

Microscopic observation:
SEM-EDS: Scanning electron microscopy combined with energy dispersive spectroscopy with a resolution < 1 μm to analyze the distribution of yttrium oxide particles (no agglomeration in the target, <5% in the agglomeration area).
EPMA: Electron probe microanalysis, detection depth of 5~10 μm, accuracy ± 0.01%, suitable for three-dimensional distribution analysis.

Process Optimization:
Spray doping: control the spray rate (0.1~0.5 L/min) and solution concentration (Y_2O_3 5%~10%) to ensure uniform doping.

High-energy ball mill: 1000~2000 rpm, time 48 hours, zirconia beads (diameter 0.1~0.5 mm) to reduce particle agglomeration.
Sintering parameters: temperature 2200~2400°C, heat preservation for 24 hours, atmosphere oxygen content < 10 ppm.

Quality requirements:
Y_2O_3 content is 1.8%~2.2%, with a deviation of <±0.1%.There was no obvious agglomeration, the particle size was 1~2 μm, and the distribution uniformity was > 95%.

Challenges and Optimizations:
Challenge: Uneven doping leads to reduced local performance and high detection costs.
Optimization: Introducing an online XRF detection system to monitor doping uniformity in real time; Develop AI algorithms to predict doping defects and adjust process parameters.

4.4.2 Microstructure Analysis (SEM, EDS, XRD)
Importance: Microstructure (e.g., grain size, porosity, phase composition) determines the mechanical strength and electrical properties of the electrode. Analytical techniques ensure the absence of defects and harmful phases (e.g. WO_3).
Analysis method:

WITHOUT:
Function: Observe the grain size (target 5~10 μm) and porosity (<1%) of the electrode cross-section.
Device: Field emission SEM with a resolution < 1 nm and a magnification of 1000~5000 ×.
Process: Sample polishing, etching (HF solution, concentration 5%), observing grain boundaries and pores.

EDS:
Function: Analyze yttrium oxide and impurity element (Fe, Si, C) distribution with an accuracy ± 0.05%.
Procedure: Scan the center and edge of the electrode to confirm Y_2O_3 uniformity and impurity content (<50 ppm).

XRD:
Function: Detect phase composition to ensure no WO_3 or other oxidizing phases.
Device: Cu Kα ray, scanning angle 10~90°, resolution ±0.01°.
Process: Analysis of tungsten matrix (bcc structure) and Y_2O_3 (cubic structure) peaks confirmed to confirm phase purity > 99%.

Quality requirements:
The grain size is 5~10 μm and the porosity is <1%.
The impurity content was < 50 ppm, and there was no WO_3 phase.
Yttrium oxide particles were evenly distributed, and the non-agglomeration area was >5%.

Challenges and Optimizations:

Challenge: SEM/EDS analysis takes a long time (30~60 minutes per sample) and is not suitable for batch testing.

Optimization: Introduce high-throughput SEM (multi-sample automatic analysis) and online XRD system to reduce detection time by 50%.

4.4.3 Optimization of process parameters and defect prevention

Process Optimization:

Orthogonal experiments: Multi-factor experiments (doping ratio, sintering temperature, drawing speed) were designed to optimize performance indicators (e.g., burnout rate <0.2 mg/min).

Response surface analysis: establish a mathematical model to predict the influence of process parameters on grain size and uniformity, and the optimization rate > 90%.

Key parameters:

Doping ratio: Y_2O_3 1.8%-2.2%, tolerance <±0.1%.

Isostatic pressure: 250-300 MPa, billet density >70%.

Sintering temperature: 2200-2400° C, heating rate 510° C/min.

Drawing speed: 0.52 m/min, tension 10-50 kN.

Defect prevention:

Pore: Increase the isostatic pressure (>250 MPa) and sintering temperature (>2200°C) using a vacuum sintering furnace (10^{-3}~10^{-5} Pa).

Crack: Control the heating/cooling rate (<10°C/min), and use gradient cooling (100~200°C/h).

Uneven doping: extended high-energy ball milling time (68 hours) with multi-stage spray doping (nozzle pressure 13 MPa).

Detect:

X-ray tomography (XCT, resolution < 1 μm) detects pores and cracks.

Ultrasonic inspection (frequency 5~20 MHz) to quickly screen for internal defects.

Development trend:

Develop digital twin technology to simulate the machining process and predict the defect rate (<0.5%).

Machine learning was introduced to optimize the process parameters and reduce the defect rate to <0.1%.

4.5 Advanced manufacturing technology of yttrium tungsten electrode

Advanced manufacturing technologies improve the performance and production efficiency of yttrium tungsten electrodes by introducing nanoscale doping, SPS sintering, and intelligent manufacturing.

4.5.1 Nanoscale yttrium oxide doping technology

Technical Overview: Nanoscale yttrium oxide doping (particle size 10~100 nm) was prepared by high-energy ball milling or sol-gel method, which significantly improved the electrode performance.

Preparation process:
High-energy ball mill: rotation speed 1000~2000 rpm, zirconia beads (diameter 0.1~0.5 mm), grinding time 4~6 hours, water or ethanol medium to prevent agglomeration.
Sol-gel method: Yttrium nitrate solution (concentration 5%~10%) is mixed with tungsten powder, spray dried (temperature 200~300°C) to form nanoparticles.

Performance Enhancements:
Recrystallization temperature: >2100°C, creep resistance increased by 30%.
Arc stability: drift rate <3%, arc starting voltage < 12 V.
Burn-in rate: <0.1 mg/min, life extended by 20%~30%.

Application prospects:
Ultra-high current welding (>400 A), such as nuclear industry reactor components.
Micro-soldering (solder joints < 0.2 mm), such as semiconductor chip packages.

Challenges and Optimizations:
Challenge: Nanoparticles are easy to agglomerate, increasing doping costs by 10%~15%.
Optimization: Ultrasonic dispersion device (frequency 20~40 kHz) was developed to improve particle dispersion by > 95%.

4.5.2 Discharge plasma sintering (SPS) process
Technical Overview: SPS completes sintering in 5~10 minutes with pulse current (1000~5000 A) and pressure (50~100 MPa), with a temperature of 1800~2000°C, which is lower than traditional sintering (2200~2400°C).

Process advantages:
High density: >99%, porosity <0.5%.
Fine grains: 3~5 μm, mechanical strength > 1200 MPa.
Energy saving and environmental protection: reduce energy consumption by 30%~40%, and shorten sintering time by 80%.

Equipment:
SPS sintering furnace: equipped with graphite mold (temperature resistant > 2000°C) and vacuum system (10^{-3} Pa).
Temperature control: infrared thermometer (accuracy ±2°C), current control accuracy ±1 A.

Apply:
High-performance electrodes: aerospace turbine blade welded with a current > 400 A.
Micro electrode: semiconductor micro-soldering, diameter 0.3~0.8 mm.

Challenges and Optimizations:
Challenge: High cost of SPS equipment.
Optimization: Development of modular SPS system reduces equipment costs by 20%.

4.5.3 Intelligent manufacturing and real-time monitoring technology

Technology Overview: Smart manufacturing optimizes production processes through sensors, Internet of Things (IoT), and machine learning, improving efficiency and consistency.

Real-time monitoring:
Infrared thermometer (accuracy ±1°C): monitor the sintering temperature (1800~2400°C).
Gas analyzer (detection limit < 1 ppm): Controls the oxygen content < 10 ppm in the atmosphere.
Online XRF: Detection of yttrium oxide content with an accuracy ± 0.05%.

Machine learning:
Establish a database of process parameters (doping, sintering, drawing) and predict performance indicators (such as burnout rate, grain size).
Using AI algorithms to optimize parameters, the defect rate was reduced to <0.5%.

Automated Production Line:
Six-axis robot (load 5~20 kg, positioning accuracy ±0.1 mm): for powder loading and unloading, blank handling and electrode packaging.
CNC machining equipment: drawing, grinding and cutting, the efficiency is increased by 50%.

Apply:
Mass production: 5000~10000 electrodes per day, defect rate <1%.
High-precision customization: special-shaped electrode production, cycle shortening by 30%.

Development trend:
Develop a digital twin platform to simulate the production process in real time and predict defects.
Blockchain technology is introduced to track the entire process of raw materials and electrode production to ensure traceability.

Chapter 5 Application Fields of Yttrium Tungsten Electrodes

5.1 Welding applications of yttrium tungsten electrodes

5.1.1 Application of TIG welding (argon arc welding) in superalloys

Tungsten argon arc welding (TIG welding) is one of the most widely used areas of yttrium tungsten electrode (WY20), especially in the welding of superalloys. Superalloys, such as nickel-based alloys (Inconel, Hastelloy) and cobalt-based alloys, are widely used in the aerospace, energy, and chemical industries due to their excellent resistance to high temperatures, corrosion, and fatigue. However, the high melting point (1300~1500°C) and complex composition of these alloys place extremely high demands on the welding process. Yttrium tungsten electrodes are ideal for TIG welding superalloys due to their low electron escape work (about 2.5~2.7 eV), excellent arc stability, and low burn-in rate.

In TIG welding, yttrium tungsten electrodes generate high-temperature arcs (about 6000~7000°C) through argon or helium protection, melting the workpiece and filling material to form high-quality welds. Its slender and compressed arc column enables precise control of the melt pool shape, reducing the heat-affected zone (HAZ) and thus reducing the risk of weld cracks and porosity. Yttrium tungsten electrodes are particularly prominent under direct current positive polarity (DCEN) conditions, typically in the current range of 50~300 A, and are suitable for alloy plates with thicknesses ranging from 0.5 mm to 20 mm.

Specific applications include:

Aero engine components: Welding of nickel-based alloy turbine discs and blades, requiring high strength and high temperature resistance of welds. The low burn-out rate of yttrium tungsten electrode (about 0.1~0.2 mg/min) ensures electrode stability during long-term welding.

Gas turbines: Welding of superalloy combustion chambers requires deep melting and uniform welds, and the high arc stability of yttrium tungsten electrodes (drift rate <5%) meets this need.

Chemical equipment: welding of Hastelloy alloy pipes, the corrosion resistance of yttrium tungsten electrodes ensures long-term stability of welds in acidic environments.

Yttrium tungsten electrode has excellent arcing performance and low arcing voltage (about 10~15 V), which can achieve rapid ignition and extinguishing in pulsed TIG welding, which is suitable for high-precision and automated welding scenarios. Additionally, its non-radioactive nature makes it an eco-friendly alternative to thorium tungsten electrodes, meeting safety standards in the aerospace industry.

5.1.2 High-precision applications of plasma arc welding

Plasma arc welding (PAW) is a high-energy-density welding process with an arc temperature of up to 20,000°C, suitable for high-precision and deep melt welding. The application of yttrium tungsten electrode in plasma arc welding benefits from its high-temperature resistance and high current bearing capacity (100~500 A). Plasma arc welding achieves higher energy concentration by compressing the arc (constrained by the nozzle), with a penetration depth of up to 10~15 mm, a small heat-affected zone, and high weld quality.

The advantages of yttrium tungsten electrodes in plasma arc welding include:

Arc concentration: The low escape work and uniform distribution of yttrium oxide make the arc column slender and stable, suitable for welding plates > 10 mm thick.

Low burnout rate: At high current density (>300 A/mm²), the burnout rate of yttrium tungsten electrode is only 0.15~0.25 mg/min, which extends the electrode life.

Material Adaptability: Suitable for welding stainless steel, titanium alloys, nickel-based alloys, and zirconium alloys.

Typical applications include:

Pressure vessels: The welding of stainless steel and zirconium alloy containers in nuclear power equipment requires the welds to be free of porosity and slag inclusions.

Shipbuilding: Deep welding of high-strength steel plates and nickel-based alloy decks, and the high arc stability of yttrium tungsten electrodes ensures weld consistency.

Medical devices: precision welding of stainless steel surgical instruments, and the fine arc of yttrium tungsten electrode (tip radius 0.1~0.5 mm) meets the needs of tiny welding joints.

Plasma arc welding typically requires a water-cooled or gas-cooled welding torch to protect the yttrium tungsten electrode from overheating. Modern processes also incorporate automated control systems to further enhance welding accuracy by precisely regulating current and gas flow.

5.1.3 Titanium alloy welding with nickel-based alloy in vacuum environment

Welding in vacuum environments is primarily used for processing high-precision and sensitive materials, such as titanium and nickel-based alloys, and is commonly used in the aerospace and semiconductor industries. Yttrium tungsten electrodes excel in vacuum TIG welding or vacuum plasma welding, with their low volatility and chemical stability ensuring the purity of the welding environment.

Titanium alloys such as Ti-6Al-4V are widely used in aerospace structural parts due to their high strength, low density, and excellent corrosion resistance, but their high chemical activity requires welding in a vacuum or inert gas environment to prevent oxygen and nitrogen contamination. The advantages of yttrium tungsten electrodes in a vacuum environment (10^{-3}~10^{-5} Pa) include:

Low Gas Release: The low vapor pressure of yttrium oxide (<10^{-5} Pa at 2000°C) ensures that the electrode does not release impurity gases, keeping the vacuum environment clean.
Arc stability: Low escape work and uniform emission point allow the arc to ignite quickly in a low-pressure environment, with a drift rate of < 3%.
Long life: In a vacuum environment, the electrode burnout rate is further reduced (<0.1 mg/min), making it suitable for long-term continuous welding.

Vacuum welding of nickel-based alloys, such as Inconel 718, is primarily used in spacecraft components and turbine blades, where its high melting point and complex composition require excellent high-temperature resistance of the electrode. The high recrystallization temperature (>2000°C) and creep resistance of yttrium tungsten electrodes allow them to withstand long-term high-temperature arc shocks and maintain the stability of the tip shape.

Typical applications include:

Spacecraft Seals: Vacuum welded titanium alloy shells to ensure airtightness and corrosion resistance.
Turbine blades: Nickel-based alloy blades are precision welded, and the welds must meet high fatigue strength requirements.
Semiconductor equipment: Welding of stainless steel and titanium pipes in a vacuum environment for chip manufacturing equipment.

5.2 Non-welding applications of yttrium tungsten electrodes

5.2.1 Plasma cutting and spraying

The application of yttrium tungsten electrodes in plasma cutting and plasma spraying benefits from their high current carrying capacity and high-temperature resistance. Plasma cutting melts and blows away metal materials through high-energy plasma arcs (temperatures up to 30000°C) and is widely used for cutting carbon steel, stainless steel, and aluminum alloys. The elongated arc and high stability of yttrium tungsten electrodes make them the electrode of choice for plasma cutting.
In plasma cutting, typical features of yttrium tungsten electrodes include:

High current adaptability: It can withstand ultra-high currents of 300~1000 A, suitable for cutting plates with a thickness of 20~100 mm.
Low burnout rate: At high energy density, the electrode life can reach 50~100 hours.
Cutting accuracy: high arc concentration, small cut width (<2 mm), high surface finish.

Plasma spraying is a surface strengthening technique that melts and sprays ceramic or metal powder onto the surface of a workpiece through a plasma arc to create a wear- or corrosion-resistant coating. Applications of yttrium tungsten electrodes in plasma spraying include:

Aerospace: Spraying ceramic coatings (such as zirconia) onto turbine blade surfaces to improve high-temperature resistance.
Industrial equipment: Spray wear-resistant coatings onto excavator buckets or pump body surfaces to extend service life.

5.2.2 Electrode Applications in Electrical Discharge Machining (EDM).

Electrical discharge machining (EDM) is a non-contact machining technique that removes material through spark discharge between the electrode and the workpiece, making it suitable for precision machining of high-hardness materials. Yttrium tungsten electrode is used for its high hardness (HV 400~450), wear resistance and electrical conductivity (resistivity is about 5.6×10^{-8} Ω·m) is used as an EDM electrode.

In EDM, the advantages of yttrium tungsten electrodes include:

High wear resistance: The strengthening effect of yttrium oxide makes the electrode less prone to wear during high-frequency discharge, maintaining shape stability.
Arc control: Low escape work ensures the stability of spark discharge, improving machining accuracy.
Material Adaptability: Suitable for machining titanium alloys, mold steels, and carbide.

Typical applications include:

Mold manufacturing: Used for precision machining of stamping molds and injection molds.
Aerospace: Machining titanium components with complex shapes, such as cooling holes in turbine blades.
Medical Devices: Machining high-precision surgical tools and implants.

5.2.3 Application in high-temperature discharge devices

Yttrium tungsten electrodes are used as arc generators or discharge electrodes in high-temperature discharge devices and are widely used in plasma research, thermal spraying equipment, and high-intensity light sources such as xenon lamps. Its high melting point (3422°C) and low burnout rate allow it to withstand extreme temperatures and frequent discharges.

Application scenarios include:

Plasma Research: In plasma generators, yttrium tungsten electrodes are used to generate high-temperature plasma (>10000°C) for material property testing or nuclear fusion research.
Xenon lamp manufacturing: Yttrium tungsten electrodes serve as the cathode of xenon lamps, which withstand high current discharge and produce strong light, which are used in movie projectors and lasers.
Thermal Spraying Equipment: In plasma spraying devices, yttrium tungsten electrodes act as arc generators to spray wear-resistant or high-temperature resistant coatings.

5.3 Application of yttrium tungsten electrode in the industry

5.3.1 Aerospace (Engine Components, Turbine Blades)

The aerospace industry is one of the largest application areas for yttrium tungsten electrodes, involving the welding of engine components, turbine blades, and fuselage structures. Titanium and nickel-based alloys are the most commonly used materials in aerospace, requiring welding processes with high precision, strength, and high-temperature resistance. The application of yttrium tungsten electrodes in TIG and plasma arc welding meets these needs.

Specific applications include:

Turbine blades: TIG welding of nickel-based alloy blades, which require the weld to withstand high temperatures (>1200°C) and fatigue resistance. The slender arc of the yttrium tungsten electrode ensures uniform welds, reducing cracks.
Engine combustion chamber: deep melt welding of titanium alloy and stainless steel combustion chamber, high current carrying capacity of yttrium tungsten electrode (>300 A) to meet deep melting needs.
Body structure: welding of titanium alloy skin and frame, low heat input of yttrium tungsten electrode reduces material deformation.

5.3.2 Defense and military industry (armor materials, missile components)

The field of defense and military industry has extremely high requirements for welding quality, involving the manufacture of armor materials, missile components and weapon systems. Yttrium tungsten electrodes are widely used due to their high reliability, non-radioactivity and long life.

Applications include:

Armored steel plates: Deep melt welding of high-strength steel plates, the high arc stability of yttrium tungsten electrodes ensures weld strength and toughness.
Missile Shell: Precision welding of titanium alloy and stainless steel shells, requiring airtightness and corrosion resistance of welds.
Weapon systems: welding of complex structures (such as radar antennas), the micro-welding capabilities of yttrium tungsten electrodes meet precision requirements.

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Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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

5.3.3 Energy Industry (Nuclear Power Equipment, Gas Turbines)

The energy industry has extremely high requirements for the safety and durability of welding materials, and yttrium tungsten electrodes play an important role in the manufacturing of nuclear power equipment and gas turbines.

Applications include:

Nuclear power equipment: welding of reactor pressure vessels and pipelines, TIG or plasma arc welding using yttrium tungsten electrodes to ensure defect-free and corrosion-resistant welds.
Gas turbine: Welding of nickel-based alloy combustion chambers and blades, high-temperature stability of yttrium tungsten electrodes to meet long-term operation needs.
Wind power equipment: welding of towers and blades, the deep melting ability of yttrium tungsten electrodes is suitable for thick plate welding.

5.3.4 Semiconductor and Microelectronics Manufacturing

The semiconductor and microelectronics industries require ultra-high-precision soldering processes for the fabrication of chip packages, sensors, and microtubing. The tiny needle-like design (0.5~1.0 mm diameter) and low heat input of yttrium tungsten electrodes make them ideal choices.

Applications include:

Chip packaging: micro-soldering of copper and gold leads, and a fine arc (<0.5 mm) of yttrium-tungsten electrodes ensures solder joint accuracy.
Sensor manufacturing: welding of stainless steel and titanium alloy sensors, requiring minimal heat-affected zones.
Micro pipes: welding of pipes in a vacuum environment, and the low volatility of yttrium tungsten electrodes keeps the environment clean.

5.4 Typical case analysis of yttrium tungsten electrodes

5.4.1 Welding of titanium alloy aviation structural parts

Case background: An aerospace company needs to weld Ti-6Al-4V titanium alloy fuselage structural parts with a thickness of 5 mm, requiring high strength (>900 MPa) and airtightness of the weld. The process was vacuum TIG welding, and the electrode was yttrium-tungsten electrode (WY20, diameter 2.4 mm, tip angle 30°).

Process implementation:

Welding parameters: current 150 A (DCEN), argon flow rate 12 L/min, vacuum degree 10^{-4} Pa.
Electrode performance: The low escape power of yttrium tungsten electrode ensures rapid arc start, with an arc drift rate of <3% and no significant burnout during welding.
Result: The tensile strength of the weld reaches 950 MPa, with no pores or cracks, meeting aviation standards.

Analysis: The low volatility and high arc stability of yttrium tungsten electrodes ensure weld quality in a vacuum environment, reducing the risk of oxidation in titanium alloys. The electrode life is up to 120 hours, reducing production costs.

5.4.2 Superalloy repair and surface strengthening

Case background: A gas turbine manufacturer needed to repair worn areas of a nickel-based alloy (Inconel 718) turbine blade and reinforce the surface with plasma spraying. TIG weld repair and plasma spraying were performed using a yttrium tungsten electrode (WY20, 3.2 mm diameter).

Process implementation:

Welding repair: Pulse TIG welding, current 100~200 A, filling material is Inconel 718 welding wire. The slender arc of the yttrium tungsten electrode ensures precise pool control in the repair area.
Plasma spraying: spraying zirconia coating, current 400 A, high temperature resistance of yttrium tungsten electrode supports continuous spraying for 4 hours.
Result: The hardness of the repaired area reached HV 450 and the coating bond strength was > 70 MPa, which met the requirements of high-temperature operation.

Analysis: The high current adaptability and low burnout rate of yttrium tungsten electrodes in repair and spraying improve process efficiency and reduce the frequency of electrode replacement.

5.4.3 Welding of precision components in vacuum environment

Case background: A semiconductor equipment manufacturer needs to weld stainless steel micro pipes (2 mm diameter and 0.2 mm wall thickness) for a vacuum system in chip manufacturing equipment. Yttrium tungsten micro needle electrode (diameter 0.5 mm, tip radius 0.1 mm) was selected for vacuum TIG welding.

Process implementation:

Welding parameters: current 10~20 A (pulse mode), argon flow rate 8 L/min, vacuum degree 10^{-5} Pa.
Electrode Performance: The low heat input and fine arc (<0.5 mm) of yttrium tungsten electrodes ensure a small solder joint size with a heat-affected zone < 0.1 mm.
Results: The air tightness of the weld reached 10^{-9} Pa·m³/s, meeting semiconductor industry standards.

Analysis: The micro-welding capabilities and low volatility of yttrium tungsten electrodes ensure cleanliness and welding accuracy in vacuum environments, making them suitable for high-precision microelectronics applications.

Chapter 6 Production Equipment of Yttrium Tungsten Electrodes

6.1 Raw material preparation equipment for yttrium tungsten electrodes

The first step in manufacturing yttrium tungsten electrodes is raw material preparation, which involves the screening, purification, and optimization of high-purity tungsten powder and yttrium oxide. This stage of equipment needs to ensure high purity, particle size uniformity, and chemical stability of the raw materials to meet the performance requirements of yttrium tungsten electrodes in high-temperature welding.

6.1.1 Tungsten powder grinding and particle size sorting equipment

The preparation of tungsten powder is the basis of yttrium tungsten electrode production, which requires the purity of tungsten powder to reach more than 99.95% and the particle size to be controlled in the range of 1~5 μm to ensure the uniformity of subsequent sintering and doping. Here are the main devices and their features:

High-energy ball mill

The high-energy ball mill is used to grind coarse tungsten powder (initial particle size 10~50 μm) to the target particle size. The equipment is designed with planetary or vibrating design, equipped with zirconia or carbide grinding balls (diameter 5~10 mm) to reduce metal contamination contamination. The grinding process is carried out under the protection of inert gases (such as argon), the speed is controlled at 200~400 rpm, and the grinding time is 48 hours. Modern ball mills are equipped with temperature control systems that prevent oxidation of tungsten powder due to overheating. Advantages: high efficiency, uniform particle size distribution; Disadvantages: Prolonged grinding may introduce trace impurities.

Airflow classifier

The airflow classifier is used to screen out tungsten powder with a particle size of 15 µm and reject particles that are too large or too small. The equipment disperses the tungsten powder by high-speed gas flow (speed 10~50 m/s) and separates it according to the particle size, with an accuracy of ±0.1 µm. Classifiers are often equipped with multi-stage cyclones and precision filters, ensuring powder-free contamination. Advantages: high-precision sorting, large output (100~500 kg per hour); Disadvantages: Equipment maintenance costs are high.

Ultrasonic cleaning equipment

Cleaning equipment is used to remove oxides and impurities (e.g., iron, carbon) from the surface of tungsten powder. The equipment uses dilute hydrochloric acid or nitric acid solution (concentration 5%~10%), combined with ultrasonic oscillation (frequency 20~40 kHz) to clean the tungsten powder, and then remove the water by vacuum drying (<200°C). Advantages: Effectively remove surface impurities; Disadvantages: The concentration of the solution needs to be strictly controlled to avoid corrosion of tungsten powder.

Laser particle size analyzers are used to monitor the particle size distribution of tungsten powder in real time, ensuring that the particle size meets the target requirements. The equipment adopts the principle of laser diffraction, with a detection range of 0.01~1000 µm and an accuracy of ±1%. Advantages: fast and accurate; Disadvantages: The equipment is expensive.

These devices work together to ensure that the purity, particle size, and morphology of the tungsten powder meet the demands of yttrium tungsten electrode production. Modern factories also introduce automated control systems to achieve continuous operations of grinding, sorting, and cleaning through PLCs (Programmable Logic Controllers), improving production efficiency.

6.1.2 Yttrium oxide purification and nanopreservation equipment

Yttrium oxide (Y_2O_3) is used as a dopant, and its purity (>99.99%) and particle size (0.52 µm, nanoscale 10~100 nm) are crucial for the performance of yttrium tungsten electrodes. Purification and nano-processing equipment includes:

Solvent extraction equipment

Solvent extraction equipment is used to extract high-purity yttrium oxide from yttrium ores, such as monazite. The equipment includes an extraction tank, centrifugal separator, and ion exchange column that separates yttrium from other rare earth elements using organic extractants such as TBP or P204. The extraction process is carried out in an acidic environment (pH 24) with a typical cycle of 10~20 cycles to ensure < 100 ppm of impurities (e.g., calcium, silicon). Advantages: high purity, suitable for industrial production; Disadvantages: high cost of waste liquid treatment.

Spray dryer

Spray dryers are used to prepare yttrium nitrate solutions into yttrium oxide powder. The equipment atomizes the solution through a high-pressure nozzle (pressure 0.52 MPa), and the hot air (200~300°C) quickly dries it to form micro- or nano-scale particles. The spray rate and drying temperature need to be precisely controlled to ensure particle uniformity (target particle size 0.5~2 μm). Advantages: good particle morphology, high fluidity; Disadvantages: High energy consumption.

Nano grinder

Nano mills are used to further grind micron-scale yttrium oxide to the nanoscale (10~100 nm). The equipment adopts wet grinding, the medium is zirconia beads (diameter 0.1~0.5 mm), the rotation speed is 1000~2000 rpm, and the grinding time is 26 hours. The grinding process takes place in water or ethanol media, preventing particles from agglomerating. Advantages: It can produce nanoscale particles to improve doping uniformity; Disadvantages: Equipment wear requires regular maintenance.

The chemical analysis equipment Inductively Coupled Plasma Mass Spectrometer (ICP-MS) is used to detect the purity and impurity content of yttrium oxide with a detection limit of < 1 ppb to ensure compliance with electrode production requirements. Advantages: High sensitivity; Disadvantages: Complex operation and professional work.

These devices provide high-quality yttrium oxide raw materials for the doping process of yttrium tungsten electrodes through multi-stage purification and particle size control.

6.2 Powder metallurgy equipment for yttrium tungsten electrodes

Powder metallurgy is the core process of yttrium tungsten electrode preparation, involving powder mixing, shaping, and sintering. The equipment needs to ensure uniform distribution of yttrium oxide and high density of the electrodes.

6.2.1 High-precision mixing and doping system

Mixing and doping equipment is used to evenly disperse yttrium oxide in tungsten powder, which affects the arc stability and mechanical properties of the electrode.

High energy mixer

The high-energy mixer adopts a three-dimensional or V-shaped mixing design, equipped with frequency conversion control (rotation speed 50~200 rpm), and the mixing time is 48 hours. The equipment operates under the protection of inert gases such as argon, which prevents oxidation of tungsten powder. Some equipment is integrated with ultrasonic dispersion device (frequency 20~40 kHz) to improve the dispersion of yttrium oxide particles. Advantages: Mix evenly, suitable for mass production; Disadvantages: large equipment size and large footprint.

Spray Doping System

The spray doping system achieves doping by spraying a yttrium nitrate solution onto tungsten powder or tungsten trioxide feedstock. The equipment includes a high-pressure nozzle (pressure 13

MPa), a stirring tank and a drying chamber, and the spray rate is controlled at 0.1~0.5 L/min. After drying, tungsten yttrium composite powder was formed, and the content deviation of yttrium oxide was <±0.1%. Advantages: uniform doping, suitable for high content of yttrium oxide (>2%); Disadvantages: The process is complex and the solution concentration needs to be strictly controlled.

X-ray fluorescence spectroscopy (XRF) XRF is used to monitor the elemental distribution of doped powders in real time to ensure that the yttrium oxide content meets the target value (1.8%~2.2%). The detection accuracy of the equipment ± 0.05%, and the analysis time < 1 minute. Advantages: fast and lossless; Disadvantages: expensive equipment.

6.2.2 Cold isostatic pressing and hot pressing equipment

The forming equipment presses the doped powder into electrode blanks, ensuring high density and mechanical strength.

Cold Isostatic Press (CIP)
The cold isostatic press applies uniform pressure (200~300 MPa) through a liquid medium (usually water or oil) to press the powder into blank strips with a diameter of 10~20 mm. The equipment is equipped with a high-pressure pump and a flexible mold, with a heat holding time of 30~60 seconds and a density of 60%~70% of the theoretical value of the billet strip. Advantages: uniform density, no stress concentration; Disadvantages: high equipment cost and complex maintenance.

Heat press
The hot press applies a pressure of 50~100 MPa at 1000~1400°C, which is suitable for the preliminary forming of high-performance electrodes. The equipment is equipped with a graphite mold and a vacuum system to prevent oxidation. The hot pressing process can increase the density of the billet to more than 80%. Advantages: suitable for small batches and high-precision production; Disadvantages: high energy consumption, fast mold wear.

6.2.3 High temperature vacuum sintering furnace and atmosphere furnace

Sintering equipment is the core of yttrium tungsten electrode preparation and is used to improve the density and mechanical properties of the electrodes.

High temperature vacuum sintering furnace
The vacuum sintering furnace operates in a vacuum environment of 10^{-3}~10^{-5} Pa, with a sintering temperature of 2000~2400°C, a heating rate of 5~10°C/min, and a holding time of 24 hours. The equipment uses molybdenum or tungsten heating elements to ensure high-temperature stability. The vacuum environment reduces the adsorption of gas impurities, and the electrode density can reach more than 98%. Advantages: High purity, suitable for high-end electrodes; Disadvantages: High equipment cost and complex maintenance of vacuum system.

Hydrogen gas atmosphere furnace
The hydrogen atmosphere furnace was operated at 1800~2200°C, the hydrogen flow rate was 10~20 L/min, and the oxygen content was controlled at <10 ppm. The equipment is equipped with an

infrared thermometer and a gas analyzer to monitor the sintering conditions in real time. Hydrogen protection prevents oxidation of tungsten powder and promotes uniform distribution of yttrium oxide. Advantages: low cost, suitable for mass production; Disadvantages: Hydrogen purity needs to be strictly controlled.

The atmosphere control system is equipped with a high-precision gas analyzer (detecting oxygen content <1 ppm) and a flow controller to ensure the stability of the sintered atmosphere. Advantages: Improve the consistency of electrode quality; Disadvantages: Requires regular calibration.

6.3 Processing and forming equipment for yttrium tungsten electrodes

The processing and forming equipment processes the sintered blank strips into standard electrode rods, ensuring dimensional accuracy and surface quality.

6.3.1 Precision calendering and drawing machine

Hot calender The hot calender reduces the diameter of the billet from 10~20 mm to 3~5 mm at 1400~1600°C. The equipment adopts multi-pass rolling (5~10 passes) and is equipped with an inert gas protection system (argon flow rate 10~15 L/min). The roll material is tungsten-molybdenum alloy, which is resistant to high temperature and wear. Advantages: high efficiency, suitable for mass production; Disadvantages: Precise temperature control is required to avoid surface oxidation.

Precision drawing machine

The precision drawing machine pulls the calender rod to the target diameter (0.5~4.8 mm) with a tolerance ± 0.05 mm. The equipment uses diamond molds, drawing speed of 0.52 m/min, and the lubricant is graphite emulsion or molybdenum-based lubricant. The drawing process is equipped with a tension control system to ensure a smooth electrode surface. Advantages: high dimensional accuracy; Disadvantages: Mold wear needs to be replaced regularly.

6.3.2 CNC grinding and polishing equipment

CNC grinding machine CNC grinding machine is used to shape the electrode tip (angle 15°~60°, tip radius 0.1~0.5 mm). The equipment adopts diamond grinding wheel, with a processing accuracy of ±0.01 mm and a rotation speed of 1000~5000 rpm. CNC systems are programmed to control tip shapes, ensuring consistency. Advantages: High precision, suitable for complex cutting-edge designs; Disadvantages: Slower processing speed.

Electrochemical polishing machine

The electrochemical polisher polishes the electrode surface with an electrolyte (usually a sulfuric acid-phosphoric acid mixture) and a DC power supply (voltage 5~15 V) with a target roughness of Ra<0.4 μm. The equipment is equipped with automatic mixing and temperature control system, and the polishing time is 10~30 seconds. Advantages: high surface finish, reduced arc drift; Disadvantages: The electrolyte needs to be treated regularly.

6.3.3 Laser cutting and electrode shaping equipment

Laser cutting machine

The laser cutter uses a fiber laser (power 13 kW) to cut the electrode rod to standard lengths (50~175 mm). The equipment is equipped with a cooling system to prevent microcracks caused by thermal stress. The cutting accuracy ± 0.1 mm, and the cut is flat and burr-free. Advantages: High precision, suitable for non-standard lengths; Disadvantages: High cost of equipment.

Electrode shaping machine

Shaping machines are used to process special-shaped electrodes (such as curved or tapered electrodes) using CNC lathes or specialized fixtures. The equipment supports customized design with a machining accuracy ± 0.05 mm. Advantages: high flexibility to meet special needs; Disadvantages: long production cycle.

6.4 Inspection and quality monitoring equipment for yttrium tungsten electrodes

Quality testing equipment is used to ensure that the chemical composition, microstructure, and performance of yttrium tungsten electrodes meet standards.

6.4.1 Chemical Composition Analysis Equipment (ICP-MS, XRF)

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) ICP-MS is used to detect the purity and impurity content (Fe, Ca, Si, etc.) of tungsten and yttrium oxide with a detection limit of < 1 ppb and an analysis time of < 5 minutes. The equipment is equipped with an automatic sample injection system to support batch testing. Advantages: High sensitivity, suitable for trace element analysis; Disadvantages: Complex operation and professional work.

X-ray fluorescence spectroscopy (XRF) XRF is used to non-destructively detect the uniformity of yttrium oxide content and distribution of electrodes with an accuracy ± 0.05%. The equipment supports fast scanning (< 1 minute) and is suitable for real-time monitoring on the production line. Advantages: fast and lossless; Disadvantages: Low sensitivity to light element detection.

6.4.2 Microstructure and Morphology Analysis Equipment (SEM, TEM)

Scanning electron microscopy (SEM) SEM was used to observe the grain size (target 5~10 μm), porosity (<1%), and yttrium oxide distribution of the electrodes. The device has a resolution < 1 nm and is equipped with an energy dispersive spectroscopy (EDS) accessory to analyze elemental distribution. Advantages: Intuitive display of microstructure; Disadvantages: long sample preparation time.

Transmission electron microscopy (TEM) TEM is used to analyze the distribution and crystal structure of yttrium oxide particles at the nanoscale with a resolution < 0.1 nm. The equipment is suitable for studying the microscopic properties of nano-doped electrodes. Advantages: high resolution; Disadvantages: Expensive equipment and complex operation.

6.4.3 Performance Test Equipment (Arc Stability, Burnout Rate Tester)

Arc Stability Tester The tester simulates TIG welding conditions (current 50~300 A, argon flow rate 10~15 L/min) and measures arc drift rate (target <5%) and arc starting voltage (10~15 V). The equipment is equipped with a high-frequency power supply and a spectrum analyzer to record the arc light intensity and stability. Advantages: Realistic simulation of welding environment;

Disadvantages: Higher testing costs.

Burnout Rate Tester The burnout rate tester measures electrode mass loss under standard welding conditions (200 A, 1 hour) with a target burnout rate < 0.2 mg/min. The equipment is equipped with a high-precision balance (accuracy ± 0.01 mg) and a temperature monitoring system. Advantages: Accurate measurement of lifetime; Disadvantages: Long test cycle.

6.5 Intelligent production equipment for yttrium tungsten electrodes

Intelligent production equipment improves production efficiency and quality consistency through automation and data analysis.

6.5.1 Automated production lines and industrial robots

Automated production line The automated production line integrates grinding, doping, forming, sintering and processing equipment to achieve continuous production through conveyor belts and PLC systems. The production line supports multi-station parallel operation, and the output can reach 1000~5000 pieces/day. Advantages: high efficiency, low labor cost; Disadvantages: large initial investment.

Industrial robots Industrial robots are used for powder loading and unloading, billet handling, and electrode packaging. The six-axis robot (load 5~20 kg) is equipped with a vision recognition system with a positioning accuracy of ± 0.1 mm, which is suitable for high-precision operation. Advantages: high flexibility, reduced manual error; Disadvantages: High maintenance costs.

6.5.2 Online quality monitoring and data analysis system

Online monitoring system

The online monitoring system integrates an infrared thermometer (accuracy ±1°C), a gas analyzer (oxygen content <1 ppm) and XRF to monitor sintering temperature, atmosphere purity and doping uniformity in real time. The system uploads data to the cloud through Internet of Things (IoT) technology to generate real-time reports. Advantages: fast feedback, reduce defects; Disadvantages: Requires stable network support.

Data analysis system

The data analysis system analyzes the relationship between process parameters (temperature, pressure, doping ratio) and electrode performance (burnout rate, arc stability) based on machine learning algorithms to optimize production parameters. The system predicts defect rates down to <1%. Advantages: intelligent optimization; Disadvantages: Requires a lot of historical data to support.

Chapter 7 Domestic and Foreign Standards for Yttrium Tungsten Electrodes

As a high-performance welding material, the quality and performance of yttrium tungsten electrodes are subject to strict standardized management. Domestic and foreign standards regulate the production, testing, and application of yttrium tungsten electrodes through clear classifications, performance requirements, and testing methods. This chapter discusses in detail the international standards, domestic standards, standard comparisons and development trends of yttrium tungsten electrodes.

7.1 International standard for yttrium tungsten electrodes

International standards provide unified technical specifications for the manufacturing and application of yttrium tungsten electrodes, mainly including relevant standards from the International Organization for Standardization (ISO), the American Welding Society (AWS), and the European Committee for Standardization (EN). These standards detail the chemical composition, dimensional tolerances, performance testing, and marking requirements for yttrium tungsten electrodes.

7.1.1 ISO 6848: Classification and technical requirements for tungsten electrodes

ISO 6848:2015 "Welding consumables — Non-consumable tungsten electrodes for arc welding" is an international standard for tungsten electrodes, suitable for processes such as tungsten argon arc welding (TIG welding) and plasma arc welding. The standard clearly classifies and performs yttrium tungsten electrodes (WY20).

Classification and Identification: Yttrium tungsten electrodes are classified as WY20, with yttrium oxide (Y_2O_3) content of 1.8%~2.2% (mass fraction), and the electrode tip is marked with blue coating. The standard also specifies the classification of other rare earth doped electrodes (such as lanthanum tungsten, cerium tungsten) to ensure the distinction between different types of electrodes. Identification requirements include electrode model, size, production batch, and manufacturer information, often in the form of laser engraving or packaging labels.

Chemical composition: The purity of the tungsten matrix is required to ≥ 99.5%, and the total content of impurities (such as iron, silicon, carbon) < 0.05%. The uniform distribution of yttrium oxide was detected by X-ray fluorescence spectroscopy (XRF) or energy dispersive spectroscopy (EDS) with a content deviation of <±0.1%.

Dimensions and tolerances: electrode diameter ranges from 0.5~6.4 mm, tolerance ±0.05 mm; The length range is 50~175 mm, and the tolerance is ± 1 mm. The surface should be smooth, free of cracks, inclusions or oxide layers, with a roughness of Ra<0.4 µm.

Performance Requirements:

Arc starting performance: Arc starting voltage < 15 V, arc drift rate <5%, test conditions are DC positive polarity (DCEN), current 50~200 A.
Burnout rate: Under 200 A DC welding conditions, the burnout rate < 0.2 mg/min.
Mechanical properties: Vickers hardness (HV) 400~450, tensile strength > 1000 MPa.

Test Methods: The standard specifies specific methods for chemical composition analysis (ICP-MS), microstructure testing (SEM), arc stability testing, and burnout rate testing. The test should be performed under standard welding conditions (argon flow rate 10~15 L/min).

ISO 6848 provides a unified framework for the global production and trade of yttrium tungsten electrodes, which are widely used in aerospace, energy, and automotive manufacturing. Its stringent performance requirements ensure the electrode's reliability in high-precision welding.

7.1.2 AWS A5.12: Tungsten Electrode Specifications and Performance

AWS A5.12:2009 "Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding" is a tungsten electrode standard developed by the American Welding Society and widely used in the North American market. The specifications and performance requirements for yttrium tungsten electrodes (EWY-2) are highly consistent with ISO 6848, but pay more attention to practical applications in some details.

Classification and identification: Yttrium tungsten electrodes are labeled as EWY-2, with yttrium oxide content of 1.8%~2.2%, and the end is painted blue. The standard requires that the electrode packaging be clearly marked with AWS classification, size, and batch number for easy user identification.

Chemical composition: The purity of tungsten is required to be ≥ 99.5%, and the content deviation of yttrium oxide is <±0.1%. The standard places special emphasis on the control of impurities (e.g., molybdenum, iron) and requires ICP-MS or XRF detection.

Dimensions: diameter range 0.5~6.4 mm, tolerance ±0.05 mm; The length is 50~175 mm, and the tolerance is ± 1 mm. The standard also allows for custom lengths, subject to mutual agreement.

Performance Requirements:

Arc stability: At 100~300 A current, the arc drift rate is <5%, and the arc start time is < 0.1 seconds.
Burnout rate: In a 200 A, 1-hour test, the burnout rate < 0.2 mg/min.
Surface quality: No cracks, oxides or oil stains on the electrode surface, roughness Ra<0.4 μm.

Testing and certification: AWS A5.12 requires manufacturers to provide performance test reports, including arc initiation, burnout rate, and high-temperature creep resistance. A certification body, such as AWS or a third-party laboratory, can sample the electrodes for testing.

AWS A5.12 has a wide presence in the North American market, especially in the aerospace and defense industries, where manufacturers are required to strictly adhere to standards to meet customer requirements.

7.1.3 EN 26848: European standard for tungsten electrodes

EN 26848:1991 is a standard for tungsten electrodes developed by the European Committee for Standardization, which is largely consistent with ISO 6848, but has specific applications in the European market. The standard specifies the classification, performance and test methods of yttrium tungsten electrode (WY20).

Classification and identification: Yttrium tungsten electrode is marked as WY20, yttrium oxide content is 1.8%~2.2%, and the end is painted blue. The standard requires that the electrode surface or packaging be clearly labeled with the model and manufacturer information.

Chemical composition: Tungsten matrix purity ≥ 99.5%, impurity content < 0.05%. The distribution uniformity of yttrium oxide needs to be detected by EDS, and the deviation <± 0.1%.

Dimensions and tolerances: diameter 0.5~6.4 mm, tolerance ±0.05 mm; The length is 50~175 mm, and the tolerance is ± 1 mm. The standard allows non-standard sizes, subject to contractual requirements.

Performance Requirements:
Arcing Performance: Arc starting voltage < 15 V, suitable for DC and AC welding.

Arc stability: At 100~200 A, the arc drift rate <5%.
Burnout rate: At 200 A DC, the burnout rate < 0.2 mg/min.
Test Methods: The standard specifies specific procedures for chemical composition analysis (ICP-MS), surface quality inspection (microscopic observation), and arc performance testing. Testing is performed on standard TIG welding equipment.

EN 26848 is widely used in the European market for automotive manufacturing, shipbuilding industry and energy equipment production, and its requirements are highly compatible with ISO 6848 for easy international trade.

7.2 Domestic standards for yttrium tungsten electrodes

As the world's largest producer of tungsten electrodes, China has formulated a number of national standards and industry standards to regulate the production and application of yttrium tungsten electrodes. These standards put forward more specific technical requirements based on international standards and combined with the actual domestic production.

7.2.1 GB/T 4192: Technical conditions for tungsten electrodes

GB/T 4192-2017 "Tungsten Electrode" is a Chinese national standard for tungsten electrodes for TIG welding and plasma arc welding, including yttrium tungsten electrodes (WY20).

Classification and identification: Yttrium tungsten electrode is marked as WY20, yttrium oxide content is 1.8%~2.2%, and the end is painted blue. The standard also includes non-standard models such as WY10 (1% yttrium oxide), which need to be marked with the model, size and batch number on the packaging.

Chemical composition: Tungsten purity ≥ 99.5%, total impurity (such as iron, silicon) < 0.05%. Yttrium oxide content deviation <± 0.1% and was detected by XRF or ICP-MS.

Dimensions and tolerances: diameter 0.5~6.4 mm, tolerance ±0.05 mm; The length is 50~175 mm, and the tolerance is ± 1 mm. The surface should be free of cracks and inclusions, and the roughness Ra<0.4 μm.

Performance Requirements:

Arc starting performance: Arc starting voltage < 15 V, arc starting time < 0.1 seconds.
Arc stability: At 100~300 A, the arc drift rate <5%.
Burnout rate: At 200 A DC, the burnout rate < 0.2 mg/min.
Mechanical properties: hardness HV 400~450, tensile strength > 1000 MPa.

Test Methods: The standard specifies specific methods for chemical composition analysis (ICP-MS), microstructure testing (SEM), arc stability testing, and burnout rate testing. The test equipment must comply with the national metrology standards.

GB/T 4192 is the core standard of China's tungsten electrode industry, widely used in domestic aerospace, energy and automobile manufacturing fields.

7.2.2 JB/T 12706: Standard for tungsten electrodes for welding

JB/T 12706-2016 "Tungsten electrode for welding" is a mechanical industry standard, suitable for TIG and plasma arc welding equipment, supplementing some requirements of GB/T 4192.

Classification and Identification: Yttrium tungsten electrode marked WY20, end painted blue. The standard requires the electrode packaging to indicate the model, size, date of manufacture and manufacturer information.

Chemical composition: tungsten purity ≥99.5%, yttrium oxide content 1.8%~2.2%. The standard emphasizes impurity control (e.g., carbon < 0.01%), which needs to be verified by chemical analysis.

Dimensions and tolerances: diameter 0.5~6.4 mm, tolerance ±0.05 mm; The length is 50~175 mm, and the tolerance is ± 1 mm. Custom non-standard sizes are allowed.

Performance Requirements:

Arcing Performance: Arc starting voltage < 15 V, suitable for DC and AC welding.
Arc stability: At 50~200 A, the arc drift rate <5%.
Burnout rate: At 200 A, the burnout rate < 0.2 mg/min.

Testing and Certification: The standard requires manufacturers to provide quality certificates, including chemical composition, dimensional accuracy, and arc performance. Third-party testing bodies can be certified.

JB/T 12706 is widely used in the field of machine building, especially in small and medium-sized enterprises, and is popular due to its relatively flexible requirements.

7.2.3 Industry-specific standards and specifications

In addition to national standards, some industries in China have developed special specifications that put forward additional requirements for yttrium tungsten electrodes for specific application scenarios:

Aerospace industry: Chinese aviation industry standards (such as HB series) require yttrium-tungsten electrodes to have higher arc stability and low volatility in the welding of titanium alloys and nickel-based alloys, with a burnout rate of < 0.15 mg/min and a gas release rate of < 10^{-6} Pa· in a vacuum environment m^3/s。
Nuclear industry: Nuclear industry standards (such as the HJB series) emphasize the non-radioactivity and corrosion resistance of electrodes, with a deviation of yttrium oxide content <± 0.05% to ensure the long-term stability of welds in high-temperature and high-pressure environments.

Shipbuilding industry: Marine industry specifications require yttrium tungsten electrodes to have excellent corrosion resistance in high-humidity, chlorine-containing environments, and the surface must be specially polished (Ra<0.2 μm).

These industry standards are typically based on GB/T 4192 but add application-specific testing requirements such as corrosion resistance testing and high-temperature fatigue testing.

7.3 Standard comparison and application of yttrium tungsten electrode

7.3.1 Differences and applicability of domestic and foreign standards

There are certain differences in the classification, performance requirements and testing methods of yttrium tungsten electrodes at home and abroad, which are mainly reflected in the following aspects:

Chemical composition requirements: ISO 6848 and AWS A5.12 have stricter requirements for impurity content (<0.05%), while GB/T 4192 allows slightly higher impurity limits (<0.1%) to adapt to the actual situation of domestic raw materials. EN 26848 is consistent with ISO 6848, but has more loose control over trace elements such as carbon.

Dimensions and Tolerances: International standards (ISO, AWS, EN) align with the requirements for diameter tolerances (±0.05 mm) and surface roughness (Ra<0.4 μm), while GB/T 4192 and JB/T 12706 allow for non-standard sizes, suitable for the diverse needs of the domestic market.

Performance Testing: ISO 6848 and AWS A5.12 require comprehensive arc performance testing (e.g., arc voltage, drift rate) and specify standard welding conditions (argon flow rate 10~15 L/min). GB/T 4192 and JB/T 12706 have similar test methods but allow for more flexible testing conditions and are suitable for small and medium-sized businesses.

Applicability:

International Standards: Applicable to global trade and high-end applications, such as aerospace and nuclear industries, emphasizing performance consistency and certification requirements.
Domestic standard: more cost-effective and practical production, suitable for domestic small and medium-sized enterprises and general industrial applications.
Industry Standards: Higher requirements for specific fields (e.g., aviation, nuclear industry), suitable for high precision and demanding environments.

7.3.2 The guiding role of standards in the production process

Domestic and foreign standards provide important guidance on the production process of yttrium tungsten electrodes through clear performance indicators and testing methods:

Raw material preparation: The standard calls for high-purity tungsten (≥99.5%) and yttrium oxide (≥99.99%), prompting manufacturers to adopt advanced purification equipment (e.g., solvent extraction, spray drying) and quality inspection methods (e.g., ICP-MS).
Doping and Sintering: The standard's requirement for yttrium oxide distribution uniformity

(deviation <±0.1%) drives the application of spray doping and vacuum sintering techniques to ensure the microstructural consistency of the electrodes.
Machining and forming: Standard dimensional tolerances (±0.05 mm) and surface roughness (Ra<0.4 μm) require manufacturers to use precision drawing machines and CNC grinding equipment to improve machining accuracy.
Quality Control: The multiple tests required by the standard (such as arc stability, burnout rate) have prompted manufacturers to introduce SEM, XRF, and other testing equipment to establish a comprehensive quality management system.

For example, ISO 6848's burnout rate requirement (<0.2 mg/min) drives the optimization of high-temperature sintering furnaces with precise temperature control (±5°C) and atmosphere management (oxygen content < 10 ppm).

7.3.3 The normative role of standards on application scenarios

The standard regulates the use of yttrium tungsten electrodes in different application scenarios through performance and safety requirements:

Aerospace: ISO 6848 and AWS A5.12 require electrodes to have excellent arc stability and low volatility in high current (>200 A) and vacuum environments, ensuring high strength and airtightness of titanium and nickel-based alloy welds.
Nuclear industry: GB/T 4192 and industry standards require electrodes to be non-radioactive and corrosion-resistant, suitable for welding of reactor pressure vessels, and prevent welds from failing at high temperatures and pressures.
Automotive manufacturing: The flexible size requirements of JB/T 12706 support the customization of non-standard electrodes, meeting the diverse needs of body sheet welding.
Microelectronics: The standard requirements for the precision of microelectrodes (diameter 0.5~1.0 mm) have promoted the application of CNC grinding and electrochemical polishing techniques to ensure the accuracy of micro welding.

The standard also specifies the packaging, storage, and transportation requirements for electrodes, such as requiring moisture-proof and shock-resistant packaging and clear labeling to reduce the risk of damage during transportation.

7.4 Standard development trend of yttrium tungsten electrode

With the continuous development of new materials, new processes, and environmental protection requirements, the standards for yttrium tungsten electrodes are also continuously updated to meet industry needs and technological advancements.

7.4.1 The impact of new materials and processes on standards

Nanoscale doping technology: The application of nano-yttrium oxide (particle size 10~100 nm) improves the arc stability and burnout resistance of the electrode. Future standards may add a classification of nano-doped electrodes (e.g., WY-Nano) and specify stricter particle size distributions (deviation <± 10 nm) and performance test methods (e.g., TEM analysis).

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Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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

Composite doping electrodes: such as yttrium tungsten electrodes are composite doping with lanthanum oxide or cerium oxide (such as WX4) to improve the comprehensive performance. Standards may introduce classifications and performance indicators for composite doped electrodes, such as creep resistance (creep rate $<10^{-6}\ s^{-1}$) and thermionic emission efficiency.

Advanced Manufacturing Processes: The application of discharge plasma sintering (SPS) and smart manufacturing techniques improves the density (>99%) and consistency of electrodes. Future standards may increase requirements for grain size (<5 μm) and defect rate (<0.5%) for SPS electrodes.

These new technologies and materials require standards to update test methods, such as the addition of high-resolution TEM analysis and real-time arc performance monitoring, to validate the performance of new electrodes.

7.4.2 Updates to environmental protection and safety standards

Environmental protection and safety requirements are important drivers of standard updates. The radioactivity of thorium tungsten electrodes has promoted the widespread application of yttrium tungsten electrodes, and future standards will further strengthen environmental protection and safety specifications:

Radioactivity-Free Certification: Standards may require manufacturers to provide radioactivity-free certificates (such as gamma ray test reports) to ensure that the electrodes meet International Labor Organization (ILO) and World Health Organization (WHO) standards.
Waste Recycling Specifications: Future standards may specify the recycling rate (>90%) of yttrium tungsten electrodes and waste disposal processes to reduce environmental pollution.

Occupational health requirements: The standard may add welding fume emission limits (e.g., <0.1 mg/m^3) and operational protection requirements (e.g., forced ventilation and protective equipment) to protect the health of operators.

In addition, as global environmental regulations tighten (such as the EU RoHS directive), standards may require that energy consumption and waste liquid emissions in the electrode production process meet specific limits, promoting the application of green manufacturing technologies.

Chapter 8 Detection Technology of Yttrium Tungsten Electrodes

As a high-performance welding material, the quality of yttrium tungsten electrode directly affects the welding effect and application reliability. The detection technology ensures that the electrodes comply with international and domestic standards (e.g., ISO 6848, AWS A5.12, GB/T 4192) through a comprehensive evaluation of chemical composition, physical properties, electrical properties, microstructure, and environmental safety. This chapter discusses the detection technology of yttrium tungsten electrodes in detail, covering chemistry, physics, electricity, microstructure, and environmental safety, and introduces related equipment and emerging technologies.

8.1 Chemical composition detection of yttrium tungsten electrodes

Chemical composition testing is the core of quality control of yttrium tungsten electrodes, focusing on the uniformity of yttrium oxide content, impurity elements, and component distribution to ensure the stability and performance of the electrode in high-temperature arcing environments.

8.1.1 Accurate measurement of yttrium oxide content

Yttrium oxide (Y_2O_3) content is the key index of yttrium tungsten electrode (WY20), and the standard requires a content of 1.8%~2.2% (mass fraction), with a deviation of <± 0.1%. Accurate measurement of yttrium oxide content requires highly sensitive analytical techniques.

Inductively Coupled Plasma Mass Spectrometry (ICP-MS)

ICP-MS detects the mass fraction of yttrium by plasma ionization of the sample, with a detection limit of < 1 ppb and an accuracy of ± 0.01%. The sample needs to be dissolved with nitric acid or hydrofluoric acid, and the analysis time is about 5 minutes. ICP-MS is capable of detecting both tungsten and yttrium oxide levels for high-precision laboratory analysis. Advantages: High sensitivity, suitable for trace element analysis; Disadvantages: Complex sample preparation and high equipment cost.

X-ray fluorescence spectroscopy (XRF)

XRF excites the sample surface with X-rays, analyzes the characteristic fluorescence intensity of yttrium and tungsten, and measures yttrium oxide content with an accuracy of ± 0.05%. XRF is non-destructive testing with an analysis time of < 1 minute, making it suitable for rapid inspection on the production line. Advantages: fast and lossless; Disadvantages: Less sensitive to light elements.

Chemical titration method

Chemical titration measures yttrium content by acid-base reaction or complexation reaction with an accuracy ± 0.1%. Although the method is traditional, it is suitable for small and medium-sized enterprises, with low cost and simple operation. Advantages: low cost, easy to operate; Disadvantages: Low accuracy and longer time-consuming.

Multiple samples (at least 3 different locations) were taken during the measurement process to ensure that the yttrium oxide content was representative. The standard requires a deviation of <± 0.1% to ensure consistent electrode performance.

8.1.2 Impurity elements and trace analysis

Impurity elements (such as iron, silicon, carbon, calcium) have a significant impact on the arc stability and burnout rate of yttrium tungsten electrodes, and the standard requires a total impurity content of <0.05%. Trace analysis requires the use of highly sensitive equipment.

ICP-MS

ICP-MS can detect a wide range of impurity elements (Fe, Si, C, Ca, etc.) with a detection limit of < 0.1 ppb, making it suitable for trace analysis. The sample needs to be completely dissolved, and the analysis time is about 5~10 minutes. Advantages: simultaneous detection of multiple elements, high accuracy; Disadvantages: Complex sample preparation.

Glow Discharge Mass Spectrometry (GD-MS)

GD-MS was used to ionize the sample surface by glow discharge to analyze trace elements with a detection limit of < 0.01 ppb. The device is suitable for direct analysis of solid-state electrodes without the need to dissolve the sample. Advantages: High sensitivity, non-loss; Disadvantages: Expensive equipment and complex operation.

Atomic Absorption Spectroscopy (AAS)

AAS is used to detect specific impurity elements (e.g., Fe, Ca) with a detection limit of < 1 ppm and an accuracy ± 0.1%. The method is suitable for single-element analysis and is less costly. Advantages: low cost, simple operation; Disadvantages: Detect elements one by one, low efficiency.

Impurity analysis covers the cross-section and surface of the electrode to ensure no local enrichment. The standard calls for 50 ppm of iron <, 20 ppm of silicon <, and 10 ppm of carbon < to avoid arc drift or increased burnout.

8.1.3 Detection of uniformity of component distribution

The uniform distribution of yttrium oxide directly affects the arc stability and mechanical properties of the electrode. The detection method evaluates the composition distribution inside and on the surface of the electrode.

Energy Dispersive Spectroscopy (EDS)

EDS combined with scanning electron microscopy (SEM) analyzes the elemental distribution of electrode cross-sections by X-ray energy spectroscopy with a resolution of < 1 μm and an accuracy of ± 0.05%. The detection area covers the center and edge of the electrode to analyze the distribution uniformity of yttrium oxide. Advantages: Intuitive display of element distribution; Disadvantages: Limited to superficial or shallow analysis.

Electron Probe Microanalysis (EPMA)

EPMA uses electron beam excitation to analyze the two-dimensional distribution of yttrium and tungsten with a resolution < 0.1 μm and an accuracy of ± 0.01%. The equipment is suitable for high-precision analysis with detection depths of several microns. Advantages: High resolution, suitable for complex samples; Disadvantages: expensive equipment, long analysis time.

X-ray tomography (XCT)

XCT scans the inside of the electrode with X-rays to generate a 3D composition map with a resolution < 1 μm. The device can detect agglomeration or segregation of yttrium oxide and is suitable for non-destructive analysis. Advantages: 3D non-destructive testing; Disadvantages: high cost of equipment and complex data processing.

The uniformity test required that the content of yttrium oxide deviate <±0.1%, and the local agglomeration area < 5%. The results guide the optimization of the doping and sintering process.

8.2 Physical properties of yttrium tungsten electrodes

Physical Properties Testing evaluates the density, hardness, mechanical properties, surface quality, and high-temperature characteristics of yttrium tungsten electrodes, ensuring their stability and durability during welding processes.

8.2.1 Density, hardness and mechanical properties test

Density test

Density is the key index to measure electrode density, and the standard requires it to be close to the theoretical density (19.1~19.3 g/cm³). The Archimedes drainage method uses a high-precision electronic balance (accuracy ± 0.001 g) to calculate the density by measuring the mass of the electrode in air and water. Advantages: simple and accurate; Disadvantages: Multiple measurements required to ensure consistency. Modern factories also use X-ray density meters to measure density by X-ray absorption intensity without destroying samples with an accuracy ± 0.01 g/cm³.

Hardness test

The Vickers hardness (HV) test uses a Vickers hardness test, applies a load of 1050 N, and measures the hardness of the electrode cross-section, with a target value of 400450 HV. The test points cover the center and edge of the electrode, ensuring uniformity. Advantages: high precision, reflecting material strength; Disadvantages: Requires preparation of flat samples.

Mechanical Properties Test

Tensile and flexural strength tests use a universal material testing machine with a tensile or three-point bending load applied with a target tensile strength > 1000 MPa and a flexural strength > 800 MPa. The test was conducted at room temperature and high temperature (1000°C) to evaluate the electrode's resistance to deformation. Advantages: Comprehensive evaluation of mechanical properties; Disadvantages: High temperature testing equipment is complex.

8.2.2 Surface quality and dimensional accuracy testing

Surface roughness test

Surface roughness (Ra<0.4 μm) is measured by a contact profiler or laser surface scanner to detect scratches, oxides, or inclusions on the electrode surface. The resolution of the device < 0.01 μm, and the scan length is 2~5 mm. Advantages: High precision, suitable for inspection on the production line; Disadvantages: Requires regular calibration.

Dimensional accuracy inspection

Dimensional accuracy (diameter ± 0.05 mm, length ± 1 mm) is measured using a high-precision laser diameter gauge or digital caliper. The laser diameter gauge scans the electrode diameter with an accuracy of ± 0.01 mm through a laser beam, making it suitable for batch inspection. Advantages: fast and lossless; Disadvantages: Higher equipment cost.

Microscopic examination

Optical microscopes (magnification 100~500 ×) are used to inspect surface cracks, pores, or inclusions at a depth < 10 μm. Serious defects (e.g., crack length >0.1 mm) need to be rejected. Advantages: intuitive and simple; Disadvantages: Limited to surface inspection.

8.2.3 High temperature physical property test

High-temperature performance testing evaluates the stability of the electrode in a welding environment (>2000°C).

High temperature recrystallization temperature

The test uses a high-temperature furnace (2000~2500°C) to heat the electrode, combined with a differential scanning calorimeter (DSC) to measure the recrystallization temperature, and the target > 2000°C. The test is carried out under argon protection against oxidation. Advantages: accurately reflect high temperature stability; Disadvantages: long test time.

Coefficient of thermal expansion test

The thermal dilatometer measures the thermal expansion coefficient of the electrode at 20~1000°C, with a target of about 4.5×10^{-6} K^{-1}. The device records dimensional changes by laser interferometry with an accuracy ± 0.1×10^{-6} K^{-1}. Advantages: high precision; Disadvantages: Requires high-temperature equipment support.

Thermal conductivity test

The thermal conductivity of the electrode was measured by laser flash method (target 174 W/m·K), and a high-temperature laser flash analyzer was used to test the temperature range of 20~1000°C. Advantages: fast and accurate; Disadvantages: expensive equipment.

8.3 Electrical Properties Detection of Yttrium Tungsten Electrode

Electrical performance testing evaluates the electron emission capability, arc stability, and high current resistance of yttrium tungsten electrodes, ensuring their performance in TIG and plasma arc welding.

8.3.1 Electron escape work and thermionic emission test

Electron escape work test

Electron escape work (target 2.5~2.7 eV) is measured by photoelectron spectrometry (PES) or thermionic emission device. PES uses ultraviolet light to excite electrons and analyze the escaped energy; The thermionic emission device heats the electrode (10001500°C) in a vacuum environment and measures the emission current. Advantages: Accurate measurement of electron emission capabilities; Disadvantages: The equipment is complex and requires a vacuum environment.

Thermionic emission test

The thermionic emission test was performed under simulated welding conditions (current 50~200 A, vacuum or argon environment) and the emission current density (target > 10 A/cm²) was measured using a high-frequency power supply and an ammeter. Advantages: directly reflect welding performance; Disadvantages: The test conditions need to be strictly controlled.

8.3.2 Arc initiation performance and arc stability test

Arc initiation performance test

The arcing performance test was conducted using a TIG welder (current 50~200 A, argon flow rate 10~15 L/min) to measure the arc voltage (<15 V) and arc start time (<0.1 seconds). The equipment is equipped with a high-frequency ignition device and a spectrum analyzer to record the arc light intensity and ignition speed. Advantages: Realistic simulation of welding environment; Disadvantages: Requires standard welding machine support.

Arc stability

Test Arc stability tests are performed at 100~300 A current, recording arc drift rate (target <5%) and voltage fluctuations (<±1 V). The device uses a high-speed camera (frame rate > 1000 fps) to observe the arc morphology and analyze the stability in combination with a voltage/current recorder. Advantages: Intuitively reflect the arc quality; Disadvantages: Expensive test equipment.

8.3.3 Burnout rate test under high current conditions

The burnout rate test was performed at 200 A DC for 1 hour to measure electrode mass loss (target < 0.2 mg/min). The equipment includes a high-precision electronic balance (accuracy ±0.01 mg) and a TIG welder, and the test is carried out under argon protection. Advantages: direct evaluation of electrode life; Disadvantages: Long test cycle. The high-temperature burnout test (>300 A) also uses a plasma arc welder to evaluate the durability of the electrode under extreme conditions.

8.4 Microstructure detection of yttrium tungsten electrodes

Microstructure detection evaluates the electrode's grain size, yttrium oxide distribution, and internal defects, ensuring its mechanical and electrical properties.

8.4.1 Grain structure and size analysis

Scanning electron microscopy (SEM)

The SEM was used to observe the grain structure of the electrode cross-section, with a target grain size of 510 μm and a resolution < 1 nm. The sample needs to be polished and etched with a magnification of 1000~5000 ×. Advantages: high resolution, intuitive display of grain morphology; Disadvantages: Complex sample preparation.

Light microscope

Optical microscopes (magnification 200~1000 ×) are used for rapid analysis of grain size and distribution, suitable for preliminary inspection on the production line. Advantages: simple operation and low cost; Disadvantages: Lower resolution than SEM.

8.4.2 Distribution and phase analysis of yttrium oxide particles

Energy Dispersive Spectroscopy (EDS)

EDS combined with SEM analyzed the distribution of yttrium oxide particles with a resolution < 1 μm. The detection covers the cross-section of the electrode, and the target distribution deviation is <± 0.1%. Advantages: Intuitive display of element distribution; Disadvantages: Limited to surface analysis.

X-ray diffraction (XRD)

XRD analyzed the phase composition of the electrode to confirm the absence of WO_3 or other oxidizing phases. The device uses Cu Kα rays, with a scanning angle of 10~90° and a resolution ± 0.01°. Advantages: non-destructive testing phase structure; Disadvantages: Requires professional data analysis.

8.4.3 Internal defect (crack, porosity) detection

X-ray tomography (XCT)

XCT generates a three-dimensional image of the electrode to detect internal cracks and pores with a resolution < 1 μm. The equipment is suitable for non-destructive analysis with a detection depth of several millimeters. Advantages: 3D non-destructive testing; Disadvantages: Expensive equipment and complex data processing.

Ultrasonic testing

Ultrasonic detection scans the inside of the electrode by high-frequency acoustic waves (5~20 MHz) to detect cracks and pores with an accuracy of ± 0.1 mm. The equipment is suitable for high-volume rapid inspection. Advantages: fast and lossless; Disadvantages: Less sensitive to minor defects.

8.5 Environmental and safety testing of yttrium tungsten electrodes

Environmental and safety testing ensures that yttrium tungsten electrodes are non-radioactive, low toxic and sustainable, meeting environmental and occupational health requirements.

8.5.1 Non-radioactive certification

The non-radioactivity of yttrium tungsten electrodes is their main advantage over thorium tungsten electrodes. Detection methods include:

Gamma ray detection

The radioactivity level of the electrode is measured using a gamma-ray detector (sensitivity <0.01 μSv/h) to ensure that there are no α, β, or γ rays. The test was performed in a shielded chamber for 24 hours. Advantages: High sensitivity to ensure safety; Disadvantages: expensive equipment.

Radionuclide analysis

The radionuclides in the electrode (e.g., Th-232, U-238) were analyzed using a high-purity germanium detector, and the detection limit was < 0.1 Bq/g. Advantages: Accurate detection of trace radioactivity; Disadvantages: long analysis time.

The test results must meet the International Labour Organization (ILO) and World Health Organization (WHO) standards, proving that the electrode is free of radioactivity.

8.5.2 Environmental impact and recyclability assessment

Environmental impact testing

Environmental impact testing evaluates emissions (e.g., waste liquid, soot) during electrode production and use. Welding fume concentrations (target < 0.1 mg/m³) were measured using a gas analyzer and heavy metals in waste liquid were analyzed by liquid chromatography (HPLC). Advantages: Comprehensive assessment of environmental impacts; Disadvantages: Requires multiple equipment to cooperate.

Recovery assessment

Recovery tests evaluate the recovery of electrodes by high-temperature melting and chemical purification (target > 90%). The equipment includes an electric arc furnace and a solvent extraction system to test the recovery efficiency of tungsten and yttrium oxide. Advantages: Support the circular economy; Disadvantages: The recycling process is complex.

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Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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8.5.3 Occupational health and safety testing

Welding fume detection

The concentration of soot during welding was measured using a particulate matter sampler, with a target < 0.1 mg/m³. The equipment is equipped with a high-efficiency filter, and the sampling time is 1~2 hours. Advantages: Direct assessment of health risks; Disadvantages: Field testing required.

Arc light detection

The UV intensity of arc light (wavelength 200~400 nm) is measured using a spectrometer to assess the potential harm to the eyes and skin. Testing is performed under standard TIG welding conditions. Advantages: Protect the operator; Disadvantages: Requires professional protective equipment.

8.6 Testing technology and equipment of yttrium tungsten electrode

8.6.1 Common testing instruments and principles

ICP-MS: Detection of chemical composition by plasma ionization and mass spectrometry with an accuracy ± 0.01%.

XRF: Analyzes elemental content by X-ray fluorescence, suitable for rapid non-destructive detection.

SEM/EDS: Detects microstructure and elemental distribution through electron beam imaging and energy spectroscopy.

XRD: X-ray diffraction analysis of the phase composition to confirm the absence of harmful oxidizing phases.

XCT: Generates 3D images through X-ray scanning to detect internal defects.

Vickers Hardness Tester: Measures hardness by indentation and evaluates mechanical properties.

Laser diameter gauge: Dimensional accuracy measured by laser scanning, with an accuracy ± 0.01 mm.

8.6.2 Advanced Detection Technologies (AI-Assisted, In-Situ Analysis, etc.)

AI-assisted detection

AI technology analyzes SEM, XRF, and XRD data through machine learning algorithms to predict electrode performance (e.g., burn-out rate, arc stability). The system optimizes the detection parameters based on historical data, and the defect recognition rate > 95%. Advantages: improve efficiency, reduce manual error; Disadvantages: Requires a lot of training data.

In-situ analysis techniques

In-situ analysis combines high-temperature furnace and SEM/TEM to observe the microstructure changes of electrodes at high temperatures (>2000°C) in real time. The equipment is equipped with a high-temperature sample stage and a dynamic imaging system with a resolution < 1 nm. Advantages: Intuitively reflect high temperature performance; Disadvantages: Complex equipment and high cost.

Online spectral analysis

The online spectrum analyzer evaluates arc stability and impurity volatilization by monitoring the arc spectrum in real time, with an analysis time of < 0.1 seconds. Advantages: fast feedback, suitable for monitoring on the production line; Disadvantages: Requires a high-precision spectrometer.

These advanced technologies improve inspection efficiency and accuracy, promoting the intelligent development of yttrium tungsten electrode quality control.

Chapter 9 User Common Problems and Solutions for Yttrium Tungsten Electrodes

Yttrium tungsten electrode (WY20) is widely used in TIG welding, plasma arc welding, and non-welding applications due to its excellent arc stability, low burnout rate, and non-radioactive properties. However, users may encounter problems such as unstable arcing, rapid tip burnout, and difficulty in arcing during use. This chapter analyzes the causes of these issues in detail and provides targeted solutions to help users optimize welding performance and electrode life.

9.1 Possible causes of arc instability of yttrium tungsten electrodes

Arc instability is a common problem in the use of yttrium tungsten electrodes, manifesting as arc drift, intermittency, or difficulty controlling the weld pool, which can lead to a decrease in weld quality. The following analyzes the causes from four aspects: electrode tip geometry, current parameters, shielding gas, and surface contamination.

9.1.1 Improper electrode tip geometry

Reason: The geometry of the electrode tip (e.g., angle, radius) directly affects the concentration and stability of the arc. The tip angle of yttrium tungsten electrode is usually 15°~60°, and the tip radius is 0.1~0.5 mm. If the angle is too small (<15°), the arc is too concentrated, which may cause the tip to overheat; If the angle is too large (>60°), the arc will be dispersed and the stability will decrease. Additionally, uneven tip grinding or the presence of burrs can cause arc shift.

Solution:
Precise machining of the tip using a CNC grinding machine, with a recommended angle of 30°~45° and a tip radius of 0.2~0.3 mm, suitable for most TIG welding scenarios.
Regularly check the tip shape and use a diamond grinding wheel for grinding to ensure a smooth and burr-free surface.
Adjust the angle according to the welding material: 30° for titanium alloy (deep penetration welding), 45° for stainless steel (medium penetration depth).
After grinding, the tip is inspected using a microscope (100× magnification) to ensure there are no microcracks or irregular shapes.

Precautions:
Establish standard operating procedures (SOPs) for cutting-edge grinding and train operators.
Use a special grinding fixture to ensure consistent grinding angles.

9.1.2 Current type and parameter setting problems
Reason: The type of current (DC positive polarity DCEN, DC reverse polarity DCEP, or AC AC) and parameter settings have a significant impact on arc stability. Yttrium tungsten electrodes are suitable for DC positive polarity (DCEN) or AC welding with a current range of 50~300 A. If DCEP is used, the electrode tip is overheated, which can easily lead to arc drift; If the current is too high (>300 A), the electrode burnout will be aggravated; If the current is too low (<50 A), it is difficult to maintain stability in the arc.

Solution:
DCEN is preferred, the current is controlled at 100~200 A, suitable for titanium alloy and stainless steel welding.
For AC welding (e.g. aluminum alloy), use square wave AC power supply with a frequency of 50~150 Hz and balance control at 50%~70% to reduce tip overheating.
Adjust the current according to the thickness of the workpiece: 50~100 A for thin plates (<2 mm) and 150~250 A for thick plates (>5 mm).
Using pulse TIG welding, the pulse frequency is 110 Hz, and the peak current is 20%~30% higher than the base current, which improves the arc stability.

Precautions:
Using a database of welding parameters, the optimal current setting is selected based on material and thickness.
Calibrate the welding machine regularly to ensure stable current output.

9.1.3 Insufficient quality or flow rate of the shielding gas

Cause: The mass and flow rate of the shielding gas (usually argon or helium) directly affects the arcing environment. Argon gas needs to be ≥ 99.99% pure and oxygen content < 10 ppm. If the gas contains impurities (e.g., oxygen, water vapor), the electrode surface may oxidize, resulting in arc instability. Insufficient flow (<8 L/min) can expose the arc to air, while excessive flow rate (>20 L/min) can cause turbulence that can disrupt the arc.

Solution:
Uses high-purity argon (99.999%) and is equipped with a gas filter to remove water vapor and oxygen.
Adjust the gas flow rate: 8~12 L/min for thin plate welding and 12~15 L/min for thick plate welding.
Inspect gas lines to ensure there are no leaks or contamination, and use flow meters to control flow precisely.
In high-precision welding, argon-helium mixtures (ratio 3:1) can be used to improve arc temperature and stability.

Precautions:
Regularly test gas purity using a gas analyzer (detection limit < 1 ppm).
Establish gas storage and use specifications to avoid moisture or contamination of the gas.

9.1.4 Contamination or oxidation of the electrode surface

Cause: Electrode surface contamination (e.g., oil, dust) or oxidation (formation of WO_3) can interfere with electron emission, leading to arc instability. Contamination can result from unclean storage environments or improper handling, while oxidation usually occurs when the electrodes are exposed to air or high temperatures.

Solution:
Use anhydrous ethanol or acetone to clean the electrode surface, and use an ultrasonic cleaner (frequency 20~40 kHz) to remove oil and oxide layers.
Grind the electrode tip to remove the oxide layer and restore the surface finish (Ra<0.4 μm).
Store the electrodes in sealed packaging and place in a dry, ventilated environment (humidity < 60%).
Inspect the electrode surface before welding and use an optical microscope (magnification 50×) to confirm that there are no traces of contamination or oxidation.

Precautions:
Establish specifications for electrode storage and use to avoid contact with oil or moisture.
Maintain a continuous supply of protective gas during the welding process to avoid exposing the electrode to air.

9.2 Causes and countermeasures of rapid burning of yttrium tungsten electrode tips

Rapid tip burnout is a common problem among users, manifested by rapid wear or melting of the electrode tip, reducing its lifespan. The following is an analysis of the reasons and a countermeasure.

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9.2.1 Excessive current or wrong polarity selection

Cause: Excessive current (>300 A) or wrong polarity (e.g. DCEP) can cause the tip to overheat, accelerating burnout. The burnout rate of yttrium tungsten electrode is about 0.1~0.2 mg/min under DCEN conditions, but it may increase to more than 0.5 mg/min under DCEP or high current.

Solution:

With DCEN, the current is controlled at 100~250 A to avoid overheating of the tip.
For AC welding, adjust the balance control (forward time <30%) to reduce tip heating time.
In high-current scenarios (>200 A), larger diameter electrodes (3.2~4.8 mm) are used to increase heat capacity.
Monitor the output of the welding machine and use a current logger to ensure stable current without sudden changes.

Precautions:
Select the appropriate current and polarity according to the welding material, with reference to the ISO 6848 standard.
Using a smart welding machine, the current is automatically adjusted to protect the electrode.

9.2.2 Optimize the tip grinding angle and surface treatment

Cause: Too small tip angle (<15°) or rough surface (Ra>0.4 μm) can lead to excessive current density and accelerate burnout. Uneven grinding can create localized hot spots, exacerbating tip melting.

Solution:
Grind the tip to 30°~45°, the tip radius is 0.2~0.3 mm, and the diamond grinding wheel is used to ensure a smooth surface.
Electrochemical polishing (sulfuric acid-phosphoric acid electrolyte, voltage 5~15 V) was used to reduce the surface roughness to Ra<0.4 μm.
Check the grinding quality and use a microscope (magnification 100×) to confirm that there are no burrs or microcracks at the tip.
Regrind the tip regularly and check every 1~2 hours of welding.

Precautions:
Using CNC grinding machines, ensure consistent tip angles and surface quality.
Train operators to master the correct grinding techniques.

9.2.3 Adjust the type and flow rate of the shielding gas

Cause: Insufficient protective gas or impurities will cause oxidation of the tip, the formation of WO_3 volatiles, and accelerate burnout. A high proportion of helium (>50%) can increase the arc temperature and exacerbate tip loss.

Solution:
High-purity argon gas (99.999%) is used, with a flow rate of 10~15 L/min, to ensure that the tip is

protected from oxidation.
In high-current welding, try an argon-helium mixture (ratio 4:1) to balance the arc temperature and the protection effect.
Check the gas line and use a flow meter (accuracy ± 0.1 L/min) to ensure a stable flow.
In vacuum or high-precision welding, high-purity helium (flow rate 8~12 L/min) is used to reduce tip burnout.

Precautions:
Regularly maintain the gas supply system, check filter and line tightness.
Record gas usage parameters to ensure compliance with welding process requirements.

9.2.4 Replace the electrode with a higher yttrium oxide content
Reason: Standard WY20 electrodes (yttrium oxide 1.8%~2.2%) may burn out quickly at ultra-high currents (>400 A) or extreme environments (such as plasma arc welding). Electrodes with higher yttrium oxide content (such as WY30, yttrium oxide 2.5%~3.0%) have higher recrystallization temperatures and burnout resistance.

Solution:
In high-current or high-temperature scenarios, the burnout rate can be reduced by 20%~30% by using WY30 electrode.
Consult with suppliers to customize electrodes with high yttrium oxide content to ensure compliance with ISO 6848 or GB/T 4192 standards.
Electrodes with different yttrium oxide contents were tested, and burnout rates were recorded (target < 0.15 mg/min).
Weighing cost and performance, the price of WY30 electrode is about 10%~20% higher.

Precautions:
Choose the appropriate electrode model according to the welding task to avoid over- or under-performance.
Establish an electrode performance database to record the applicable scenarios of different models.

9.3 How to choose the appropriate yttrium oxide content
Yttrium oxide content affects the arc stability, thermionic emission capacity, and lifetime of the electrode. The following analyzes the selection principles from the aspects of welding material, current type, environment and cost.

9.3.1 Selected according to the welding material (titanium alloy, nickel-based alloy, etc.).
Analysis: Different welding materials have different requirements for electrode performance. Titanium alloys require low heat input and stable arcing, nickel-based alloys require high current-bearing capacity, and stainless steels are suitable for moderate currents and general-purpose properties.
Suggestion:

Titanium alloy: WY20 (yttrium oxide 1.8%~2.2%), current 100~200 A, tip angle 30°, suitable for vacuum or argon gas protection welding.
Nickel-based alloy: WY30 (yttrium oxide 2.5%~3.0%), current 150~300 A, tip angle 45°, to meet the needs of deep melt welding.
Stainless steel: WY20 or WY15 (yttrium oxide 1.0%~1.5%), current 50~150 A, strong versatility.
Aluminum alloy: WY20, AC welding, current 50~200 A, balance control 50%~70%.

Implement:
Refer to the material welding manual to match the electrode model and process parameters.
Electrodes with different yttrium oxide contents are tested to evaluate weld quality and electrode life.

9.3.2 Matching of current type and intensity

Analysis: DC positive polarity (DCEN) is suitable for most metal welding, AC welding is used for aluminum alloys, etc. The yttrium oxide content affects the current carrying capacity of the electrode.

Suggestion:
DCEN: WY20, current 50~250 A, suitable for titanium alloys, stainless steel and nickel-based alloys.
AC: WY20, current 50~200 A, frequency 50~150 Hz, suitable for aluminum alloy and magnesium alloy.
High current (>300 A): WY30, enhanced burn resistance and suitable for thick plate welding.
Low current (<50 A): WY15, reduced cost, suitable for micro-soldering of thin sheets.
Implement:
Use a welder parameter to optimize current type and intensity.
Regularly test electrode performance to ensure matching welding tasks.

9.3.3 Selection under special environment (vacuum, high temperature).

Analysis: Vacuum or high-temperature environments (e.g., plasma arc welding) require low volatility and high recrystallization temperatures for electrodes. WY20 performs well in vacuum environments, and WY30 is suitable for ultra-high temperature scenarios.

Suggestion:
Vacuum environment: WY20, vacuum degree 10^{-3}~10^{-5} Pa, burndown rate <0.1 mg/min, suitable for semiconductor and aerospace welding.
High temperature environment: WY30, arc temperature > 10000°C, suitable for plasma arc welding or spraying.
Corrosive environment: WY20, with argon protection, strong oxidation resistance, suitable for marine engineering.

Implement:
Choose electrodes that comply with ISO 6848 or GB/T 4192 standards to ensure low volatility.
Test the electrode's performance in the target environment, recording burnout rate and arc stability.

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Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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9.3.4 Balance analysis of performance and cost

Analysis: High yttrium oxide content (such as WY30) improves performance, but the cost increases by 10%~20%. Users need to choose the right electrode according to the needs of the task and budget.

Suggestion:
High-precision welding: Priority WY30 for excellent performance and suitable for aerospace and nuclear industry.
General industry: Choose WY20, cost-effective, to meet most TIG welding needs.
Low-cost scenario: WY15, reduce procurement costs, suitable for thin plate or low-current welding.
Life priority: WY30, 20%~30% longer life, reduce replacement frequency.

Implement:
Establish an electrode selection cost model, comprehensively considering procurement cost, life and welding efficiency.
Communicate with suppliers to reduce costs by purchasing in bulk.

9.4 Countermeasures for the difficulty of arcing of yttrium tungsten electrodes

Arcing difficulties manifest as delayed or failed arc ignition, affecting welding efficiency. The following analyzes the reasons and proposes solutions.

9.4.1 Check the surface cleanliness and tip status of the electrodes

Cause: Contamination of the electrode surface (oil, oxides) or wear of the tip can increase the arc voltage and reduce the efficiency of electron emission.

Solution:
Use anhydrous ethanol to clean the electrode and use an ultrasonic cleaning machine (frequency 20~40 kHz) to remove contamination.
Regrind the tip at an angle of 30°~45° and a radius of 0.2~0.3 mm, using a diamond grinding wheel.
Check the tip condition and use a microscope (magnification 100×) to confirm that there are no oxides or microcracks.
Use airtight packaging when storing electrodes to avoid contamination.
Precautions:
Formulate electrode cleaning and inspection specifications, which must be inspected before welding.
Use special fixtures to secure the electrodes to prevent contamination of the operation.

9.4.2 Optimize the high-frequency arc starting parameters

Cause: Improper parameters of the high-frequency arc starter (such as too low frequency or insufficient voltage) will cause arc initiation failure. The low escape work (2.5~2.7 eV) of yttrium tungsten electrode is suitable for high-frequency arcing, but it needs to be set reasonably.

Solution:
Adjust the high-frequency arcing frequency to 10~20 kHz and the voltage to 5~10 kV to ensure fast arc ignition.

Check the high-frequency device of the welding machine, clean the electrode chuck and ground wire, and reduce the contact resistance.
The use of pulse high-frequency arcing and pulse width of 0.1~0.5 ms can improve the arcing success rate.
Test arc start time, target < 0.1 seconds.

Precautions:
Regularly maintain the high-frequency device of the welding machine to ensure stable output.
Using an intelligent welding machine, the arc starting parameters are automatically optimized.

9.4.3 Adjust the distance between the electrode and the workpiece
Reasons: The distance between the electrode and the workpiece is too large (>3 mm) to lead to insufficient electric field strength and difficulty in arcing. A distance that is too small (<1 mm) may cause a short circuit or contamination.
Solution:

The distance between the electrode and the workpiece is adjusted to 1.5~2.5 mm, which is suitable for most TIG welding scenarios.
Use a welding torch to secure the electrode to ensure a stable distance.
In micro-welding, the distance can be reduced to 1~1.5 mm to improve the arc concentration.
Distance was checked using a laser rangefinder (accuracy ±0.1 mm).

Precautions:
Train operators to master the correct distance setting.
In automated welding, sensors are used to monitor distances in real time.

9.4.4 Replace the electrode or check the stability of the power supply
Cause: Aging of the electrode or fluctuations in the supply voltage may cause difficulty in arcing. The lifespan of yttrium tungsten electrodes is generally 100~150 hours, and the electron emission efficiency decreases after the life.

Solution:
Replace the electrode with a new one, choose WY20 or WY30, ensure compliance with the standard (ISO 6848).
Check the stability of the power supply and monitor output voltage fluctuations (<±5%) using a voltmeter (accuracy ±0.1 V).
Clean the welder contact points to ensure that the electrode chuck is not oxidized or loose.
Test electrode performance, record arc voltage and time.

Precautions:
Establish electrode replacement cycles and record the time of use.
Calibrate the welding machine regularly to ensure a stable power supply.

9.5 Yttrium tungsten mixed with other tungsten electrodes

Mixing different types of tungsten electrodes (e.g., yttrium tungsten, thorium tungsten, lanthanum tungsten) can lead to reduced performance or confusion in operation. The following analyzes the impact of mixing and management recommendations.

9.5.1 Effects of mixing on arc performance

Reason: The electron escape work and thermal stability of different electrodes vary greatly. Yttrium tungsten electrodes (escape work 2.5~2.7 eV) are suitable for DCEN and AC welding, while thorium tungsten (WT20, escape work 2.6~2.8 eV) performs better at DCEP, and lanthanum tungsten (WL20, escape work 2.8~3.0 eV) is suitable for low currents. Mixing can lead to unstable arcing or difficulty arcing.

Solution:
Avoid mixing, prefer WY20, match the welding material and current type.
If mixed, test the arc performance and record the drift rate (target <5%) and arc start time (< 0.1 seconds).
In AC welding, the use of yttrium tungsten electrodes is preferred to avoid overheating problems of thorium tungsten electrodes.
Use the welding parameter database to optimize current and gas settings for mixed-use scenarios.

Precautions:
Establish an electrode classification and storage system to avoid confusion.
Train operators to understand the performance differences between different electrodes.

9.5.2 Electrode loss problems caused by mixing

Cause: Mixing may lead to increased electrode burnout. For example, thorium tungsten electrodes have a high burnout rate (0.3~0.5 mg/min) at high currents, while yttrium tungsten electrodes have a burnout rate of 0.1~0.2 mg/min. Mixing may accelerate loss due to improper parameters.

Solution:
Using WY20 electrode, it has a low burnout rate and a long life (100~150 hours).
Electrode losses are monitored, and burnout rates are measured using a high-precision balance with an accuracy ±0.01 mg).
Adjust the welding parameters to match the electrode type, for example, WY20 uses DCEN, current 100~250 A.
Replace the electrodes regularly to avoid performance degradation due to wear.

Precautions:
Record the lifespan of each electrode and establish a replacement plan.
Use an intelligent monitoring system to detect electrode losses in real time.

9.5.3 Suggestions for electrode identification and management

Cause: The mixed use of electrodes is often caused by unclear labeling or improper management.

Yttrium tungsten electrodes (blue end) are confused with thorium tungsten (red end) and lanthanum tungsten (gold end).

Solution:
Strictly follow the identification requirements of ISO 6848 or GB/T 4192, check the color of the electrode tip and the packaging label.
Manage electrode inventory using barcodes or RFID tags, record models and batches.
Partitions store different types of electrodes and use special containers to avoid confusion.
Train operators to familiarize themselves with electrode identification and usage specifications.

Precautions:

Establish an electrode management database to track usage and inventory.
Check your inventory regularly to ensure clear identification.

9.5.4 Substitution analysis of yttrium tungsten electrodes

Analysis: Yttrium tungsten electrodes can replace thorium tungsten (WT20), lanthanum tungsten (WL20), and cerium tungsten (WC20) electrodes, but they need to be selected according to the application scenario. The non-radioactivity and low burn-out rate of yttrium tungsten electrodes make them a preferred choice.

Suggestion:
Alternative to Thorium Tungsten: Thorium tungsten is radioactive (ThO_2 releases α rays) and WY20 can be completely replaced, making it suitable for the aerospace and medical industries.
Alternative to lanthanum tungsten: Lanthanum tungsten is suitable for low-current welding, and WY20 performs better at high currents (>200 A).
Alternative to cerium tungsten: Cerium tungsten arcing performance is slightly inferior, and WY20 performs better in micro-welding and vacuum environments.
Test the performance of the alternative electrode, recording arc stability, burnout rate, and weld quality.

Implement:
Communicate with suppliers to understand performance data for alternative electrodes.
Gradually replace high-risk electrodes (such as thorium tungsten) to meet environmental and safety requirements.

Chapter 10 Future Development Trend of Yttrium Tungsten Electrodes

As a high-performance, non-radioactive welding material, yttrium tungsten electrode (WY20) is widely used in TIG welding, plasma arc welding, and non-welding applications due to its excellent arc stability, low burnout rate, and environmental protection characteristics. With the development of material science, manufacturing technology and market demand, the future of yttrium tungsten electrode will show new trends in technological innovation, application expansion and market policy. This chapter explores these trends in detail, analyzing their impact on the yttrium tungsten electrode industry.

10.1 Technological innovation direction of yttrium tungsten electrode

Technological innovation is the core driving force behind the development of yttrium tungsten electrodes, covering new doping technologies, ultra-high temperature and ultra-precision electrode research and development, and green manufacturing technologies. These innovations aim to improve electrode performance, extend lifespan, and reduce production costs.

10.1.1 New rare earth composite doping technology

Background: The performance of yttrium tungsten electrode mainly depends on the doping of yttrium oxide (Y_2O_3), which is usually 1.8%~2.2%. However, a single doping may not meet higher performance requirements at ultra-high currents (>400 A) or extreme environments such as vacuum or high temperatures. The new rare earth composite doping technology optimizes the electrode performance by introducing a variety of rare earth oxides (such as lanthanum oxide La_2O_3 oxide and cerium oxide CeO_2).

Innovation direction:

Multi-rare earth doping: Develop composite doped electrodes, such as yttrium-lanthanum tungsten (Y-La-W) or yttrium-cerium tungsten (Y-Ce-W), with a yttrium oxide content of 1.5%~2.0%, supplemented by 0.2%~0.5% lanthanum oxide or cerium oxide. Composite doping can reduce electron escape work (2.4~2.6 eV), improve arc stability (drift rate <3%) and burnout resistance (burnout rate < 0.1 mg/min).

Nanoscale doping: Nanoscale rare earth oxides (particle size 10~50 nm) were used to improve the doping uniformity (deviation <±0.05%). Nanoparticles can increase the density of grain boundaries and increase the recrystallization temperature of the electrode (> 2100°C).

Doping process optimization: Develop plasma spray doping or chemical vapor deposition (CVD) technology to evenly coat rare earth oxides on the surface of tungsten powder to reduce agglomeration.

Intelligent Doping Control: Utilizes machine learning algorithms to optimize doping ratios and distribution, adjusting spray rates and ball mill parameters through real-time monitoring (XRF, EDS).

Potential impact: Composite doped electrodes can increase electrode life by 30%~50%, making them suitable for high-demand scenarios such as aerospace and nuclear industries. Future standards (e.g., ISO 6848 revision) may add composite doped electrode classifications (e.g., WY-La or WY-Ce).

10.1.2 Research and development of ultra-high temperature and ultra-precision electrodes

Background: With the increase of the demand for plasma arc welding (arc temperature >20000°C) and micro-welding (solder joint diameter <0.5 mm), yttrium tungsten electrodes need to have higher high temperature resistance and processing accuracy.

Innovation direction:

Ultra-high temperature electrode: developed a high yttrium oxide electrode (Y_2O_3 content 2.5%~3.5%), which was prepared by discharge plasma sintering (SPS) process, with a grain size controlled at 35 μm and a density > 99%. The recrystallization temperature of these electrodes can reach 2200°C and the burnout rate <0.08 mg/min, making them suitable for ultra-high current (>500 A) soldering.

Ultra-precision electrodes: Developed miniature yttrium tungsten electrodes (diameter 0.3~0.8 mm, tip radius < 0.1 mm) to achieve high precision (tolerance ±0.01 mm) through laser micromachining and electrochemical polishing. These electrodes are suitable for micro-soldering of semiconductors and medical devices.

Surface modification technology: ion implantation or nano-coating (such as zirconia coating) is used to enhance the oxidation resistance and thermal stability of the electrode surface, extending the service life by 20%~30%.

High-temperature performance testing: Develop an in-situ high-temperature test device to analyze the microstructural changes of electrodes in real-time at >2000°C in combination with SEM and XRD.

Potential impact: Ultra-high temperature electrodes will drive the development of plasma spraying and nuclear fusion equipment, and ultra-precision electrodes will meet the needs of chip manufacturing and microelectronics industries. These technologies may increase production costs by 10%~15%, but performance improvements can lead to higher market competitiveness.

10.1.3 Green manufacturing and low-carbon production technology

Background: Global environmental regulations (such as the EU RoHS directive and carbon neutrality goals) require yttrium tungsten electrode production to reduce energy consumption and emissions. Traditional sintering and purification processes have high energy consumption (about 5000~8000 kWh per ton of electrode), and waste liquid and exhaust gas emissions need to be further optimized.

Innovation direction:

Low energy consumption sintering: Promote the SPS process, shorten the sintering time to 510 minutes, and reduce energy consumption by 30%~40%. Development of high-efficiency vacuum sintering furnaces (temperature control accuracy ±2°C) to reduce hydrogen consumption.

Green purification technology: Ion exchange and membrane separation technology is used to purify yttrium oxide, reducing waste liquid emissions by more than 50%. Recycled tungsten powder and rare earth materials, with a recovery rate of > 90%.

Smart Energy Management: Optimize energy consumption of production equipment through the Internet of Things (IoT) and AI, monitoring electricity and gas consumption in real time to reduce carbon footprint.

Renewable energy applications: Solar or wind power supply is introduced at production sites, with the goal of achieving 30%~50% of energy from renewable energy by 2030.

Potential impact: Green manufacturing can reduce production costs by 5%~10%, comply with environmental regulations, and enhance brand image. In the future, carbon emission standards (such as 2 tons of CO_2 per ton of electrodes< may be introduced to promote the industry's transformation to low-carbon.

10.2 Expansion of application fields of yttrium tungsten electrodes

The application field of yttrium tungsten electrodes is expanding from traditional welding to emerging industries such as new energy, aerospace, and microelectronics, catering to high-performance and precision manufacturing needs.

10.2.1 New Energy Equipment Manufacturing (Batteries, Wind Power)

Background: New energy equipment (such as lithium batteries, wind power blades, and hydrogen energy equipment) has high requirements for welding quality, requiring high precision, low heat input, and environmentally friendly materials. The non-radioactivity and arc stability of yttrium

tungsten electrodes make them ideal choices.
Application direction:

Lithium battery manufacturing: Yttrium tungsten electrode is used for micro-welding of copper and aluminum foils (solder joint diameter <0.5 mm), current 10~50 A, tip diameter 0.5~1.0 mm. Arc stability (drift rate <3%) ensures solder joint strength and airtightness.
Wind turbine blades: welded carbon steel and stainless steel towers, thickness 10~50 mm, current 200~400 A. The deep melting capabilities of yttrium tungsten electrodes reduce weld defects and extend equipment life.
Hydrogen energy equipment: welded stainless steel hydrogen storage tanks with vacuum environment (10^{-4} Pa) and low volatile electrodes. The low gas release rate of WY20 electrode ($<10^{-6}$ Pa·m³/s) to meet the requirements.
Photovoltaic equipment: micro-welding of silicon wafers and copper wires, ultra-precision tips of yttrium tungsten electrodes (radius < 0.1 mm) to support high-precision production.

Development trend: The rapid growth of the new energy industry (the annual growth rate of the global lithium battery market is expected to be >15% in 2025~2030) will drive the demand for yttrium tungsten electrodes by 20%~30%. Customized micro electrodes will become a key research and development direction.

10.2.2 Deepening applications in the aerospace and defense fields

Background: The demand for yttrium tungsten electrodes in the aerospace and defense industries is concentrated in the welding of high-strength alloys (such as titanium alloys, nickel-based alloys), which require high current bearing capacity and long life.
Application direction:
Aero engine: welded nickel-based alloy turbine blades, current 150~300 A, tip angle 45°. The low burn-out rate of the yttrium tungsten electrode (<0.1 mg/min) ensures that the weld is resistant to high temperatures (> 1200°C).
Spacecraft structure: Vacuum TIG welding of titanium alloy shell, vacuum degree 10^{-5} Pa. The low volatility of the WY20 electrode prevents environmental pollution, and the weld strength > 900 MPa.
Defense equipment: deep melt welding of armored steel plates and missile shells, current > 400 A. Developed WY30 electrode (yttrium oxide 2.5%~3.0%) to support ultra-high current applications.
Additive manufacturing: Yttrium tungsten electrodes are used in plasma arc additive manufacturing, repairing aerospace components, arc stability (drift rate <2%) to improve stacking accuracy.
Development trend: The aerospace market is expected to grow at an annual rate of 8% by 2030, driving the demand for high-performance yttrium tungsten electrodes. Composite doped and ultra-high temperature electrodes will further meet the needs of extreme environments.

10.2.3 Precision welding in the microelectronics and semiconductor industry

Background: The microelectronics and semiconductor industries require ultra-high-precision soldering (e.g., chip packaging, sensor manufacturing) with electrode diameters < 1.0 mm and solder joint sizes < 0.2 mm. The micro-welding capabilities and low heat input characteristics of yttrium tungsten electrodes make them a preferred choice.

Application direction:
Chip package: soldered copper and gold leads, current 5~20 A, tip radius < 0.1 mm. The fine arc of the yttrium tungsten electrode (<0.5 mm) ensures solder joint accuracy.
Sensor manufacturing: micro-welded stainless steel and titanium alloy sensors with a heat-affected zone < 0.1 mm. The low volatility of the WY20 electrode is suitable for vacuum environments.
MEMS devices: Soldering of microelectromechanical systems (MEMS) with a current < 10 A. Developed ultra-precision electrodes (diameter 0.3~0.5 mm) to support nanoscale accuracy.
Optoelectronics: Soldering fiber optic connectors, the high arc stability of yttrium tungsten electrodes reduces solder joint defects.

Development trend: The semiconductor market is expected to reach $1 trillion in 2030, and the demand for micro-welding will drive the research and development of ultra-precision yttrium tungsten electrodes, and the market share is expected to increase by 15%~20%.

10.3 Market and policy trends of yttrium tungsten electrodes

Market and policy trends will profoundly impact the supply and demand pattern, production costs, and international competitiveness of yttrium tungsten electrodes.

10.3.1 Global Yttrium Tungsten Electrode Market Demand Forecast

Background: The global welding equipment market is expected to grow at an annual rate of 6%~8% in 2025~2030, and the demand for yttrium tungsten electrodes as high-end welding materials will grow simultaneously. China, the United States, and Europe are the main markets, accounting for more than 70% of global demand.

Forecast:
Demand growth: The expansion of aerospace, new energy, and microelectronics industries will drive the annual growth of yttrium tungsten electrode demand by 10%~15%, and the global market size is expected to reach US$500 million by 2025.
Regional distribution: China accounts for 40% of the market share (thanks to the advantages of rare earth resources), the United States and Europe each account for 20%. Asia Pacific (India, Southeast Asia) saw the fastest growth in demand (>12%).
Application-driven: New energy (batteries, wind power) accounted for 30% of demand growth, aerospace accounted for 25%, and microelectronics accounted for 20%.
High-end electrodes: The market share of WY30 and composite doped electrodes will increase from 10% to 20% to meet high-performance demands.

Influencing factors:
The proliferation of automated welding equipment is increasing the demand for high-performance electrodes.
Environmental regulations are driving the replacement of thorium tungsten electrodes, and the market share of yttrium tungsten electrodes is expected to increase to 50%.

CTIA GROUP LTD
Yttrium Tungsten Electrode Introduction

1. Overview of Yttrium Tungsten Electrode

The Yttrium Tungsten Electrode (WY20) is a non-radioactive, high-performance tungsten electrode doped with 2% yttrium oxide (Y_2O_3). Specially engineered for demanding TIG and plasma welding applications, this electrode offers exceptional arc stability, minimal electrode wear, and high current tolerance, making it the top choice for aerospace, defense, nuclear, and high-precision industries.

2. Key Features of Yttrium Tungsten Electrode

- **Excellent Arc Stability:** Delivers a stable, concentrated arc with minimal flicker.
- **High Current Capacity:** Ideal for high-load DC or AC welding operations.
- **Low Burn-Off Rate:** Exceptional resistance to electrode erosion, even under intense heat.
- **Radiation-Free & Eco-Friendly:** 100% free of radioactive thorium—safe for people and the environment.
- **Superior Penetration:** Supports deep weld pools for thick, high-strength materials.
- **Reliable Ignition:** Consistent arc starting even under low current or pulsed settings.

3. Typical Specifications of Yttrium Tungsten Electrode

Type	Y_2O_3 Content	Color Code	Length (mm)	Diameter (mm)
WY20	1.8% – 2.2%	Blue	50 – 175	1.0 – 6.4

4. Applications of Yttrium Tungsten Electrode

- TIG Welding of stainless steel, nickel alloys, titanium, molybdenum, and high-temperature alloys.
- Plasma Arc Welding and Precision Spot Welding in aerospace and defense manufacturing.
- Micro-welding & vacuum applications where arc stability and cleanliness are critical.
- Suitable for DC (Direct Current) or AC/DC mixed-mode operations.

5. Why Choose Yttrium Tungsten Electrode?

From high-frequency ignition systems to robotic TIG welders, the WY20 Electrode adapts to your most challenging tasks—without compromising operator safety. Whether you're manufacturing jet engine blades, medical implants, or nuclear-grade components, WY20 delivers unmatched performance where it matters most.

6. Procurement Information

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

10.3.2 The impact of rare earth resource policy on production

Background: The production of yttrium tungsten electrodes relies on rare earth resources (yttrium oxide) and tungsten resources. China has 70% of the world's rare earth reserves and 80% of tungsten reserves, but strict resource extraction and export policies affect production costs and supply chain stability.

Policy trends:

China's rare earth policy: China strengthens environmental supervision of rare earth mining, rare earth quotas may be reduced by 10%~15% from 2025, and yttrium oxide prices are expected to rise by 5%~10%.

Export Restrictions: Rare earth export tariffs may increase, prompting manufacturers to optimize recycling technologies (recycling rates > 90%).

Alternative resource development: Australia and the United States are accelerating rare earth ore development, with global supply expected to increase by 20% by 2030, easing China's dependence on resources.

Green mining technology: Promote low-pollution purification technologies (such as ion exchange and membrane separation) to reduce waste liquid discharge and comply with environmental regulations.

Impact: Rare earth policies may push up the production cost of yttrium tungsten electrodes by 5%~10%, but recycling technology and global supply chain diversification will ease the pressure. Manufacturers need to invest in green purification equipment to ensure resource stability.

10.3.3 International trade and supply chain optimization

Background: The global yttrium tungsten electrode supply chain involves China (major producers), the United States (technology innovation centers), and Europe (high-end application markets). Trade barriers, transportation costs, and geopolitics impact supply chain efficiency.

Trend:

Trade barriers: The United States and Europe may impose tariffs on rare earth products (5%~10%), and Chinese manufacturers need to optimize their export strategies and expand the Southeast Asian and South American markets.

Supply chain localization: The United States and Europe invest in local tungsten electrode production, and it is expected that local production capacity will account for 20%~30% by 2030, reducing dependence on China.

Digital Supply Chain: Employ blockchain technology to trace the origin of tungsten and rare earth raw materials, ensuring transparency and compliance.

Logistics optimization: Reduce transportation costs by 10%~15% and shorten delivery cycles through intelligent logistics systems (AI forecasting demand).

Impact: Supply chain optimization will improve the global competitiveness of yttrium tungsten electrodes and reduce logistics costs. Chinese manufacturers need to strengthen technological innovation and brand building to cope with international competition.


Tungsten
Electrodes
3.0mm ×150mm
[approx.0.118" x 6"]
Yttriated (WT20)
10 Pieces
Ground Finish
ANSI/AWSA5.12M-98
ISO6848
Tungsten
Electrodes
4.0mm ×150mm
[approx.5/32" x 6"]
Yttriated (WY20)
10 Pieces
Ground Finish
ANSI/AWSA5.12M-98
ISO6848
Tungsten
Electrodes
3.2mm ×150mm
[approx.1/8" x 6"]
Yttriated (WY20)
10 Pieces
Ground Finish
ANSI/AWSA5.12M-98
ISO6848

Appendix

A. Glossary

Yttrium Tungsten Electrode: A non-radioactive electrode doped with 1%~2% yttrium oxide based on tungsten, suitable for superalloy welding and plasma processes.

Yttrium Oxide (Y_2O_3): A rare earth oxide additive that improves the high-temperature stability and arc properties of tungsten electrodes.

Electron Escape Work Function: The minimum amount of energy required for electrons to escape from the electrode surface determines the arcing performance.

Arc Starting Performance: The ability of the electrode to form a stable arc at low currents.

Arc Stability: The arc maintains a continuous and non-jittering characteristic during welding process.

Burn-off Rate: The mass loss rate of the electrode during high-temperature welding.

TIG Welding (Tungsten Inert Gas Welding): A tungsten argon arc welding process that uses inert gas protection.

Plasma Arc Welding: A process that uses high-temperature plasma arcs for high-precision welding.

Powder Metallurgy: A technology for preparing yttrium tungsten electrodes through powder mixing, pressing, and sintering.

Microstructure: The grain and phase distribution characteristics of the electrode material under a microscope.

ISO 6848: Standard for classification and technical requirements for tungsten electrodes developed by the International Organization for Standardization.

AWS A5.12: A specification standard for tungsten electrodes developed by the American Welding Society.

SEM (Scanning Electron Microscope): A scanning electron microscope used to analyze the surface morphology and microstructure of electrodes.

ICP-MS (Inductively Coupled Plasma Mass Spectrometry): Inductively coupled plasma mass spectrometry for the detection of yttrium oxide and impurity content.

Spark Plasma Sintering (SPS): A rapid sintering technique used to prepare high-performance yttrium-tungsten electrodes.

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