Encyclopedia of Thorium 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.

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Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8－1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7－2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8－3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8－4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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Directory

Chapter 1 Introduction

1.1 Definition and overview of thorium tungsten electrode

Thorium tungsten electrode is an alloy electrode with high-purity tungsten as the matrix and doped with a small amount of thorium oxide (ThO_2, usually between 0.9% and 4.2%), which is widely used in high-precision welding processes such as tungsten inert gas shielded welding (TIG welding). Its main component, tungsten, has an extremely high melting point (about 3422°C) and excellent electrical conductivity, while the addition of thorium oxide significantly reduces the electron work of the electrode (about 2.63 eV), thereby improving the arc initiation performance and arc stability. Thorium tungsten electrodes are usually classified by different thorium oxide contents, and the most common models in the world include WT10 (0.9-1.2% ThO_2, yellow coating), WT20 (1.8-2.2% ThO_2, red coating tip), WT30 (2.8-3.2% ThO_2, purple applicator) and WT40 (3.8-4.2% ThO_2, orange-yellow applicator). These models are color-coded for easy differentiation in production and use.

The appearance of thorium tungsten electrodes is rod-shaped, usually between 0.5 mm and 10 mm in diameter, and the length is generally 150 mm or 175 mm, and the surface is precision ground and polished to ensure stability during the welding process. Its unique properties stem from the high melting point of tungsten and the thermal electron emission capability of thorium oxide, which allows it to maintain a stable arc under high current loads while reducing electrode burnout. The doping of thorium oxide not only enhances the high temperature resistance of the electrode, but also makes it excellent in DC anode (DCEN) welding, especially suitable for the welding of carbon steel, stainless steel, nickel alloy and titanium alloy.

However, thorium tungsten electrodes are characterized by trace amounts of radioactivity (mainly α and β particle radiation due to their thorium oxide content, which makes them require special precautions during production, storage and use. Despite its low radioactivity levels (thorium-232 has an exempt activity concentration of 1 Bq/g), long-term exposure may still have potential health and environmental effects. Therefore, in recent years, non-radioactive electrodes such as cerium tungsten and lanthanum tungsten have gradually become substitutes, but thorium tungsten electrodes still occupy an important position in specific fields due to their excellent welding properties.

1.2 The importance of thorium tungsten electrodes in the welding industry

Thorium tungsten electrodes are of irreplaceable importance in the welding industry, especially in high-precision processes such as tungsten argon arc welding (TIG welding) and plasma welding. TIG welding is a welding method that uses an inert gas (such as argon or helium) to protect the arc and weld pool, and is widely used in the aerospace, nuclear industry, automobile manufacturing and shipbuilding industry. Thorium tungsten electrodes have become the preferred electrode material for TIG welding due to their excellent arc initiation performance and arc stability.

First of all, the thorium tungsten electrode performs well in DC anode welding. Its low electron escape work allows the electrode to easily initiate arcing, and the arc remains stable at high currents, reducing spatter and welding defects. This is especially important for welding metals with high melting points, such as titanium alloys and stainless steels. For example, in the aerospace industry, where the welding of titanium components requires extremely high precision and surface quality, thorium tungsten electrodes ensure uniformity and strength of the weld. In addition, the low burn-out rate of thorium tungsten electrodes under high current loads prolongs the service life of the electrodes and reduces production costs.

Secondly, the high conductivity and thermal stability of thorium tungsten electrodes make them suitable for welding a wide range of materials, including carbon steel, alloy steel, copper alloys, and nickel-based alloys. Electrodes with different thorium oxide contents, such as WT20 and WT40, can be selected according to the welding current and material type to meet different process needs. For example, WT20 is most widely used in medium-current welding due to its moderate thorium oxide content (1.8-2.2%), while WT40 is more suitable for high-current, heavy-duty industrial scenarios.

In addition, thorium tungsten electrodes also have important applications in plasma welding and arc cutting. Plasma welding requires the electrode to maintain stability in a high-temperature and high-pressure plasma environment, and the high-temperature resistance of thorium tungsten electrodes makes it an ideal choice. In arc cutting, thorium tungsten electrodes can provide a high-strength arc to ensure cutting efficiency and precision. These properties make thorium tungsten electrodes indispensable in modern industry, and although their radioactivity problems have led to the study of alternative materials, their advantages in specific high-demand scenarios are still difficult to completely replace.

1.3 Background of research and application

The development and application of thorium tungsten electrodes began in the early 20th century and gradually developed with the rise of arc welding technology. Tungsten is an ideal choice for electrode materials due to its high melting point and excellent electrical conductivity, but the difficulty of arc initiation and arc instability of pure tungsten electrodes at high currents limit its application. In the 30s of the 20th century, researchers found that the performance of tungsten electrodes could be significantly improved by doping a small amount of thorium oxide. The discovery that the low electron work of thorium oxide reduces the energy required for arc initiation while improving the durability of the electrode at high temperatures, which has led to the widespread application of thorium tungsten electrodes.

In the decades that followed, the preparation process of thorium tungsten electrodes continued to improve. The introduction of powder metallurgy technology has made it possible to have a uniform distribution of thorium oxide, which improves the quality and consistency of the electrodes. In the 80s of the 20th century, with the popularization of TIG welding technology, thorium tungsten electrodes became the mainstream materials in the welding industry, and international standards (such as ISO 6848 and AWS A5.12) were also formulated to regulate their production and use.

However, the radioactivity of thorium tungsten electrodes has gradually attracted attention.

Thorium-232 in thorium oxide is a naturally occurring radioactive element, and its decay releases α particles and small amounts of β and γ radiation. Despite its low levels of radioactivity, it can still pose a potential risk to worker health and the environment during production and use, such as dust generated during electrode grinding. Since the 90s of the 20th century, European and American countries have begun to promote the research and development of non-radioactive electrodes, and cerium tungsten electrodes (WC20) and lanthanum tungsten electrodes (WL20) have gradually entered the market. These alternative electrodes are close to thorium tungsten electrodes in terms of performance and have no radioactive risk, so they are gradually replacing thorium tungsten electrodes in some areas.

Despite this, thorium tungsten electrodes still have unique advantages in some demanding areas. For example, in the nuclear industry and aerospace, thorium tungsten electrodes are still the material of choice due to their excellent arc stability and high temperature resistance. In recent years, the focus of research has shifted to optimizing the production process of thorium tungsten electrodes to reduce radioactive contamination, while exploring new doping materials to further improve performance. In addition, with increasingly stringent environmental regulations, the production and use of thorium tungsten electrodes are more restricted, prompting the industry to develop safer and environmentally friendly alternatives.

Globally, the application and research of thorium tungsten electrodes continues. As a major country in tungsten resources, China occupies an important position in the production and export of thorium tungsten electrodes, and related enterprises continue to improve their production processes to meet international standards. At the same time, the demand for thorium tungsten electrodes in the international welding industry remains strong, especially in developing countries and in specific industrial sectors. In the future, with the advancement of new materials and processes, the role of thorium tungsten electrodes may change, but its important position in the history of welding technology is undeniable.

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1. Overview of Thorium Tungsten Electrode

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2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

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Chapter 2 Types of Thorium Tungsten Electrode

As the core consumables in tungsten inert gas shielded welding (TIG welding) and plasma welding, there are many types of thorium tungsten electrodes, which can be carefully classified according to the different thorium oxide content and application scenarios. The classification of thorium tungsten electrodes not only reflects the differences in their chemical composition and physical properties, but also reflects their applicability in different welding processes and industrial scenarios. This chapter will discuss in detail the classification of thorium tungsten electrodes by thorium oxide content, classification by application scenario, and comparison with other types of tungsten electrodes.

2.1 Thorium tungsten electrodes are classified according to thorium oxide content

The main characteristics of thorium tungsten electrode are derived from the doped thorium oxide (ThO_2) in the tungsten matrix, and its content directly affects the electron work of the electrode, arc stability, burn-out rate and applicable current range. International standards (e.g., ISO 6848:2015 and AWS A5.12/A5.12M) classify thorium tungsten electrodes into multiple models based on their thorium oxide content and identify them with different color applicators for easy differentiation in production and use. Here are four common models: WT10, WT20, WT30, and WT40, each with significant differences in performance and application scenarios.

2.1.1 WT10 (Yellow Paint)

WT10 thorium tungsten electrode contains 0.8-1.2% thorium tungsten electrode, which is the type of thorium tungsten electrode with the lowest thorium oxide content, and is identified with a yellow coating head. Its low thorium oxide content provides a balance between electron work and welding performance, making it suitable for low to medium current welding tasks.

Performance characteristics:

The electron work of the WT10 electrode is about 2.63 eV, which is lower than that of the pure tungsten electrode (about 4.5 eV), which significantly reduces the energy required for arc starting, making it have good arc initiation performance at low current conditions (typically 50-150 A). The arc stability is better, especially in DC negative electrode (DCEN) welding, where the arc is concentrated and there is less spatter. Due to the low thorium oxide content, WT10 has a relatively high burnout rate, especially at high currents or for long periods of continuous welding, where the electrode tip may be slightly melted or thorium depleted.

The radioactivity level of WT10 is the lowest of all thorium tungsten electrodes, and the activity concentration of thorium-232 is close to the exemption standard (1 Bq/g), so the radiation protection requirements in production and use are relatively relaxed. This makes it the preferred electrode for radioactive industrial applications, such as medical device manufacturing.

Application scenarios

WT10 is mainly used for thin plate welding and low-current precision welding, and is suitable for materials such as carbon steel, stainless steel, and copper alloys. For example, in bicycle frame manufacturing, WT10 electrodes are able to provide a stable arc, reduce weld overheating, and ensure high-quality joints. In addition, WT10 can also be used in micro TIG welding processes, such as precision welding of electronic components.

Pros and cons:

Advantages: low radioactivity, good arc initiation performance, suitable for low-current welding, relatively low cost.

Disadvantages: High burnout rate at high current, not suitable for heavy load or long-term continuous welding.

Precautions for production and use

In the production of WT10 electrodes, it is necessary to ensure a uniform distribution of thorium oxide to avoid local uneven performance. When used, it is recommended to use an appropriate grinding angle (typically 15°-30°) to optimize the arc concentration. In addition, special grinders and dust removal equipment are required during the grinding process to reduce the risk of thorium dust inhalation.

2.1.2 WT20 (red paint)

WT20 is currently the most widely used type of thorium tungsten electrode, with a thorium oxide content of 1.7-2.2%, and is identified by a red coat. Its moderate thorium oxide content allows it to achieve the best balance between performance, cost and applicability, and is widely used in industrial welding.

Performance characteristics:

The electron work of the WT20 electrode is similar to that of the WT10, but its arc stability is further improved due to the higher thorium oxide content, making it suitable for the medium to high current range (100-300 A). In DC anode welding, WT20 is able to maintain a concentrated and stable arc, reducing weld defects. Compared with WT10, WT20 has a lower burn-out rate, and the electrode tip is more durable at high temperatures, making it suitable for continuous welding for longer periods of time.

WT20 has a slightly higher level of radioactivity than WT10, but is still within a safe range. Protective measures in production and use must strictly follow relevant standards (such as GB 18871-2002), including wearing protective masks and using ventilation equipment.

Application scenarios

WT20 is an "all-rounder" electrode in TIG welding, which is widely used in the welding of stainless steel, carbon steel, nickel alloys and titanium alloys. In the aerospace sector, WT20 is commonly used for the welding of titanium alloy components, such as the manufacture of aircraft engine blades, where its stable arc and low burnout rate ensure high-quality welds. In the petrochemical industry, WT20 is also commonly used for pipe welding, especially for joining corrosion-resistant materials in harsh environments.

Pros and cons:

Advantages: strong arc stability, low burn-out rate, wide range of applicable current, suitable for a variety of materials.

Disadvantages: Slightly higher radioactivity, strict protection is required; The cost is higher than WT10.

Precautions for production and use

The production of WT20 requires precise control of the doping ratio of thorium oxide to ensure consistent performance. When using, it is recommended to use a grinding angle of 20°-35°, and regularly check the state of the electrode tip when welding at high current to avoid thorium loss affecting the welding quality. Grinding dust needs to be properly collected and disposed of to prevent environmental pollution.

2.1.3 WT30 (Purple Paint)

The WT30 electrode contains 2.8-3.2% thorium oxide and is identified with a purple coated head, making it suitable for high-current and heavy-duty soldering applications. Its high thorium oxide content significantly enhances the high temperature resistance and arc stability of the electrode.

Performance characteristics:

The electron work of WT30 is slightly lower than that of WT20, which further reduces the difficulty of arcing, and the arc remains stable at high currents (200-400 A). Its burn-off rate is the lowest among thorium tungsten electrodes, and the electrode tip is not easy to melt or deform under high temperature and high pressure, which is suitable for long-term continuous welding. The WT30's excellent conductivity and thermal stability make it excellent in heavy industrial scenarios.

However, the high thorium oxide content results in higher levels of radioactivity and stricter protection requirements in production and use. Operators are required to wear protective equipment and ensure that the working environment is well ventilated.

Application scenarios

WT30 is mainly used for the welding of thick plates and the manufacture of heavy structural parts, such as steel plate welding in shipbuilding, welding of pressure vessels in nuclear power plants, and assembly of large machinery and equipment. Its ability to maintain a stable arc at high currents makes it suitable for welding materials with high melting points, such as titanium alloys and nickel-based alloys. In addition, WT30 can also be used for plasma welding and arc cutting, where electrodes are required to maintain performance under extreme conditions.

Pros and cons:

Advantages: excellent arc stability, very low burn-out rate, suitable for high-current and heavy-duty welding.

Disadvantages: high radioactivity, high cost of protection; The cost is higher than WT10 and WT20.

Precautions for production and use

The production of WT30 requires a high-precision powder metallurgy process that ensures uniform distribution of thorium oxide to avoid localized defects. When in use, it is recommended to have a grinding angle of 25°-40° to optimize arc concentration and durability. During grinding and use, it is necessary to strictly comply with the radioactive protection specifications, and be equipped with a special collection device to deal with thorium dust.

2.1.4 WT40 (Orange Paint)

The WT40 electrode contains 3.8-4.2% thorium oxide, identified with an orange-yellow coating head, and is the model of the highest thorium oxide tungsten electrode with the highest thorium oxide content, designed for extremely high current and heavy-duty welding.

Performance characteristics:

The WT40 has the lowest electron power (approx. 2.6 eV) and excellent arc initiation performance, maintaining a stable arc even at ultra-high currents (300-500 A). Its burn-out rate is extremely low, and the electrode tip has almost no obvious loss during long-term high-temperature operation, which is suitable for extreme industrial scenarios. The WT40 is extremely thermally stable and mechanically strong, and is able to withstand high-intensity arc impacts.

However, WT40 has the highest level of radioactivity, and the activity concentration of thorium-232 is close to or slightly above the exemption standard, and the radiation protection requirements in production and use are the most stringent. Operators need to be fully equipped with protective equipment, and workplaces need to be equipped with efficient ventilation and dust collection systems.

Application scenarios

WT40 is mainly used for ultra-thick plate welding and industrial applications with extreme conditions, such as the welding of nuclear reactor pressure vessels, the joining of large titanium alloy structures in aerospace, and the manufacture of heavy machinery. In plasma cutting, the WT40 can also provide a high-strength arc to ensure cutting efficiency and precision. Its durability in high-load scenarios makes it the first choice for special industrial applications.

Pros and cons:

Advantages: Optimum arc stability, lowest burn-out rate, suitable for ultra-high currents and extreme conditions.

Disadvantages: highest radioactivity, extremely high cost of protection; High production and use costs.

Precautions for production and use

The production of WT40 requires the use of high-precision equipment to control the doping and distribution of thorium oxide, and the sintering process needs to be carried out in a high-temperature vacuum environment to ensure quality. When in use, the recommended grinding angle is 30°-45° to accommodate high current demands. Strict compliance with radioactive safety norms during grinding and welding processes and regular monitoring of ambient radiation levels.

2.2 Thorium tungsten electrodes are classified according to application scenarios

The application scenarios of thorium tungsten electrodes are mainly based on the difference in their performance in direct current (DC) and alternating current (AC) welding. Because the work of electronic evolution and arc stability of thorium tungsten electrodes is better than that of pure tungsten electrodes, it is mainly used for DC anode welding, but it also has applications in specific AC welding scenarios.

2.2.1 Thorium tungsten electrode for DC welding

DC anode (DCEN) welding is the most common application scenario for thorium tungsten electrodes. In DCEN welding, the electrode is connected to the negative electrode of the power supply, the workpiece is connected to the positive electrode, and electrons flow from the electrode to the workpiece, resulting in a concentrated and stable arc. In this mode, the low electron escape work and excellent thermal stability of the thorium tungsten electrode make it perform well.

Performance characteristics:

In DCEN mode, the thorium tungsten electrode can easily initiate arcing, and the arc is concentrated, and the heat is mainly concentrated on the workpiece, reducing the heat load of the electrode. This gives thorium tungsten electrodes significant advantages when welding carbon steels, stainless steels, nickel alloys, and titanium alloys. Different types of thorium tungsten electrodes are suitable for different current ranges:

WT10: suitable for low currents (50-150 A) for thin sheet and precision welding.
WT20: suitable for medium to high currents (100-300 A) and widely used in industrial welding.
WT30 and WT40: suitable for high to ultra-high currents (200-500 A) for thick plate and heavy-duty welding.

Thorium tungsten electrodes have a low burn-out rate in DCEN welding and a long electrode life, especially at high currents, which can still maintain the tip shape, reducing the need for frequent replacement. In addition, its high arc stability, excellent weld quality, and low spatter make it suitable for high-precision welding.

Application scenarios

Aerospace: Welding of titanium and nickel alloy components, such as aircraft fuselage and engine components.
Nuclear industry: Welding of pressure vessels and pipes, requiring high-strength and defect-free welds.
Petrochemical industry: welding of pipes and equipment with corrosion-resistant materials such as stainless steel and nickel-based alloys.
Automotive manufacturing: welding of high-strength steels and aluminum alloys, such as body and suspension components.

Precautions

In DCEN welding, it is necessary to select the appropriate electrode type and grinding angle according to the material thickness and welding current. The electrode tip needs to be checked and reground regularly to maintain arc concentration. Grinding requires the use of a dedicated grinder and a dust collection device to reduce the risk of radioactivity.

2.2.2 Thorium tungsten electrode for AC welding (special scene)

Although thorium tungsten electrodes are primarily used for DCEN welding, they also have applications in specific alternating current (AC) welding scenarios, especially when welding light metals such as aluminum and magnesium. In AC welding, the current is periodically switched between the positive and negative electrodes, and the electrodes are subjected to higher thermal loads.

Performance characteristics:

In AC welding, thorium tungsten electrodes do not perform as well as lanthanum-tungsten or zirconium-tungsten electrodes, but they can still be used in specific scenarios. WT20 and WT30 provide good arc stability in AC mode due to their higher thorium oxide content, but the electrode tip is prone to overheating during the positive electrode cycle (DCEP), resulting in thorium loss and electrode burnout. As a result, thorium tungsten electrodes often require higher maintenance frequencies in AC welding, such as frequent grinding to restore tip shape.

Application scenarios

Aluminum alloy welding: In marine and aerospace manufacturing, thorium tungsten electrodes (usually WT20) can be used for AC-TIG welding of aluminum sheets, especially when DC power is not available.
Magnesium alloy welding: In the automotive and aerospace fields, thorium tungsten electrodes can be used for precision welding of magnesium alloys, which require high arc control.
Repair welding: In some field repair scenarios, thorium tungsten electrodes can be used as a temporary replacement for AC welding of light metals.

Precautions

In AC welding, it is recommended to use a large electrode diameter (2.4-4.0 mm) to withstand the thermal load, and the grinding angle should be 30°-45°, and the tip can be slightly rounded to reduce overheating. Special attention should be paid to the protection of radioactive dust and an efficient ventilation system should be equipped.
2.3 Comparison of thorium tungsten electrode with other tungsten electrodes

Thorium tungsten electrodes occupy an important position in TIG welding due to their excellent welding performance, but with the development of non-radioactive electrodes, pure tungsten electrodes, cerium tungsten electrodes, lanthanum tungsten electrodes, zirconium tungsten electrodes and yttrium tungsten electrodes have gradually become alternative options. The following is a detailed comparison between these electrodes and thorium tungsten electrodes.

2.3.1 Pure tungsten electrode

overview

Pure tungsten electrode (WP, green coating head) is made of more than 99.5% pure tungsten without any oxide doping, which is the earliest type of tungsten electrode used.

Performance comparison

Electron work of electron evolution: The electron work of pure tungsten electrode is high (about 4.5 eV), which is difficult to start arcing and requires higher voltage.
Arc stability: Arc stability is poor, especially at high currents, the arc is prone to drift.
Burn-out rate: The burn-out rate is high, the electrode tip is easy to melt, and the life is short.
Radioactivity: Non-radioactive, safe and environmentally friendly better than thorium tungsten electrode.
Applicable scenario: It is mainly used for AC welding of aluminum and magnesium alloys, because it can form a stable oxide layer during the cathode cycle.

Pros and cons:

Advantages: non-radioactive, low cost, suitable for AC welding of light metals.
Disadvantages: Difficult arc starting, poor arc stability, not suitable for high current or DCEN welding.

Application scenarios

Pure tungsten electrodes are mainly used for low-requirement AC welding, such as aluminum plate welding, but have been gradually replaced by rare earth doped electrodes in modern industry.

2.3.2 Cerium tungsten electrodes

overview

Cerium-tungsten electrodes (WC20, grey coated tips) contain 1.8-2.2% cerium oxide (CeO_2) and are the main non-radioactive alternative to thorium tungsten electrodes.

Performance comparison

Electron work outcome: about 2.7 eV, slightly higher than thorium tungsten electrode, but good arc initiation.
Arc stability: The arc stability is close to WT20, suitable for DCEN and AC welding.
Burn rate: The burn loss rate is lower than that of pure tungsten electrode, but slightly higher than WT20.
Radioactivity: non-radioactive, high safety, in line with environmental protection requirements.
Applicable scenarios: Widely used in the welding of stainless steel, carbon steel and aluminum alloys, especially in radioactive sensitive industries.

Pros and cons:

Advantages: non-radioactive, good arc initiation performance, suitable for a variety of welding scenarios.
Disadvantages: The burnout rate is slightly higher at high current, and the durability is not as good

as WT20.

Application scenarios

Cerium tungsten electrodes are widely used in welding in medical devices, food processing equipment, and electronics industries, and are gradually replacing thorium tungsten electrodes due to their lack of radioactivity risk.

2.3.3 Lanthanum tungsten electrode

overview

Lanthanum tungsten electrodes (WL10, WL15, WL20, black, gold, and blue coated heads, respectively) contain 0.8-2.0% lanthanum oxide (La_2O_3) and are another non-radioactive alternative electrode.

Performance comparison

Electron work of evolution: about 2.6-2.8 eV, excellent arc initiation performance, close to thorium tungsten electrode.
Arc Stability: Excellent arc stability, especially in high current and AC welding.
Burn-out rate: Low burn-out rate, long electrode life, close to or better than WT20.
Radioactivity: Non-radioactive, high safety and environmental protection.
Applicable Scenarios: Suitable for DCEN and AC welding, widely used in high-precision and heavy-duty scenarios.

Pros and cons:

Advantages: non-radioactive, strong arc stability, long life, suitable for a variety of currents and materials.
Disadvantages: the cost is slightly higher, and the production process is strict.

Application scenarios

Lanthanum tungsten electrodes are widely used in aerospace, nuclear industry, and automotive manufacturing, especially in scenarios where high accuracy and long life are required.

2.3.4 Zirconium tungsten electrodes

overview

Zirconium tungsten electrodes (WZ3, WZ8, brown and white coated heads, respectively) contain 0.3-0.8% zirconia (ZrO_2) and are designed for AC welding.

Performance comparison

Electronic work of evolution: high (about 4.0 eV), average arc starting.
Arc Stability: Excellent performance in AC welding, especially in aluminum and magnesium alloy welding.
Burnout rate: The burnout rate is low, which is suitable for the positive electrode cycle of AC welding.
Radioactivity: non-radioactive, safe and environmentally friendly.

Applicable scenarios: Specially designed for AC welding of light metals, not suitable for high-current DCEN welding.

Pros and cons:
Advantages: Non-radioactive, suitable for AC welding of aluminum and magnesium alloys.
Disadvantages: Poor arc initiation performance, not suitable for DCEN welding.

Application scenarios
Zirconium tungsten electrodes are mainly used for AC-TIG welding of aluminum alloys and magnesium alloys, such as in marine and aerospace manufacturing.

2.3.5 Yttrium-tungsten electrodes

overview
Yttrium-tungsten electrodes (WY20, blue coated tip) contain 1.8-2.2% yttrium oxide (Y_2O_3) and are a newer non-radioactive electrode.

Performance comparison
Electronic work output: about 2.7 eV, good arc initiation performance.
Arc stability: The arc stability is better than that of cerium tungsten electrode and close to that of lanthanum tungsten electrode.
Burnout rate: Low burn loss rate and long life.
Radioactivity: non-radioactive, safe and environmentally friendly.
Applicable scenarios: suitable for DCEN and AC welding, especially in high-precision scenarios.

Pros and cons:
Advantages: non-radioactive, good arc stability, long life.
Disadvantages: Higher cost and low market popularity.

Application scenarios
Yttrium tungsten electrodes are suitable for high-precision welding, such as aerospace and electronics industries, but their application in industry has not yet been fully popularized.

CTIA GROUP LTD WT20 electrode

Chapter 3 Characteristics of Thorium Tungsten Electrode

As the core material of tungsten inert gas shielded welding (TIG welding) and plasma welding, thorium tungsten electrode occupies an important position in industrial applications due to its unique physical, chemical, welding properties and radioactive properties. This chapter will discuss in detail the physical properties (including high melting point, work of electron evolution, electrical conductivity and mechanical properties), chemical properties (oxidation resistance and chemical stability), welding properties (arc initiation performance, arc stability, burn-out rate, and high load behavior) and radioactivity (trace radioactivity of thorium oxide, health and environmental impacts, and comparison with non-radioactive electrodes). Through a comprehensive analysis, the aim is to reveal the advantages and limitations of thorium tungsten electrodes in the welding process.

3.1 Physical properties of thorium tungsten electrodes

The physical properties of thorium tungsten electrodes are the basis for their excellent performance in high-temperature, high-current welding environments. These properties include high melting point and thermal stability, low electron escape work, and excellent conductivity and mechanical properties that allow it to withstand the extreme conditions of arc welding.

3.1.1 High melting point and thermal stability of thorium tungsten electrode

Thorium tungsten electrodes are based on tungsten (W), one of the materials with the highest melting point of any known metal, with a melting point of about 3422 °C (6192 °F). This property allows the thorium tungsten electrode to maintain structural integrity in the high-temperature environment of arc welding (arc temperature up to 6000-7000°C) and avoid melting or significant deformation. The doping of thorium oxide (ThO_2) (typically in the range of 0.8-4.2%) further enhances the thermal stability of the electrode. Thorium oxide has a high melting point (about

3300°C) and a high heat capacity, which can effectively disperse the heat generated by the arc and reduce local overheating at the electrode tip.

In actual welding, the high melting point and thermal stability of thorium tungsten electrodes make them suitable for long-term continuous welding, especially in high-current DC anode (DCEN) welding. For example, when welding materials with high melting points, such as titanium alloys or stainless steel, the electrode tip maintains a stable shape and reduces burn and thorium loss. Compared with pure tungsten electrode (WP), thorium tungsten electrode has better performance at high temperatures, and the tip is not easy to form molten balls or cracks, thus prolonging the service life.

In addition, a uniform distribution of thorium oxide is essential for thermal stability. In the production process, powder metallurgy technology is used to ensure the uniform dispersion of thorium oxide particles in the tungsten matrix, so as to avoid the performance degradation caused by local high temperature. Thermal stability is also closely related to the grain structure of the electrode, and appropriate heat treatment processes such as high-temperature sintering and annealing can optimize the grain size and improve the electrode's resistance to thermal shock.

3.1.2 Electron work of thorium tungsten electrode (2.63 eV)

The work function is the minimum energy required for electrons to escape from the surface of the material, which directly affects the arc initiation performance of the electrode. The electron work of the thoriated tungsten electrode is about 2.63 eV, which is significantly lower than that of the pure tungsten electrode of 4.5 eV. This is mainly due to the doping of thorium oxide, whose low electron work degradation reduces the voltage requirement caused by the arc, so that the thorium tungsten electrode can easily start arcing at low currents.

The physical mechanism of low electron work is the thermal electron emission capacity of thorium oxide. Thorium oxide is able to release a large number of free electrons at high temperatures (arc environment), creating a stable flow of electrons, which initiates and sustains the arc. This feature is particularly important in DC negative electrode (DCEN) welding, as electrons flow from the electrode to the workpiece, and the lower work of escape reduces energy consumption during arc starting, increasing welding efficiency.

Different types of thorium tungsten electrodes (such as WT10, WT20, WT30, WT40) have slightly different electron escape work due to different thorium oxide content. WT40 (3.8-4.2% ThO_2) has the lowest electron work (close to 2.6 eV) and the best arc initiation performance, which is suitable for high-current welding. WT10 (0.8-1.2% ThO_2) has slightly higher electron escape work, but it is still much better than pure tungsten electrode. This difference allows the thorium tungsten electrode to be adapted to a wide range of scenarios, from low-current precision welding to high-current, heavy-duty welding.

In practical applications, the low electron work also reduces the thermal load at the electrode tip and reduces the burnout rate. For example, in the welding of titanium alloys in the aerospace industry, the WT20 electrode is able to start the arc quickly at low voltages, ensuring the uniformity and precision of the weld. However, the advantages of electron work need to be fully exploited by the appropriate electrode grinding angle (typically 15°-45°), and the sharp tip can further concentrate the electron flow and improve the arc initiation efficiency.

3.1.3 Conductivity and mechanical properties of thorium tungsten electrodes

The conductivity of the thorium tungsten electrode is due to the high electrical conductivity of the tungsten substrate (about 30% of copper), which enables it to efficiently transmit welding current and reduce resistive heat loss. The doping of thorium oxide has little effect on the conductivity, but at high currents, the conductivity of the thorium tungsten electrode is still better than that of the pure tungsten electrode, because the thorium oxide particles improve the electron migration efficiency. The stability of the conductivity ensures the continuity and consistency of the arc, especially in high-frequency arc initiation or pulse welding.

In terms of mechanical properties, thorium tungsten electrodes have high hardness (Vickers hardness of about 400-450 HV) and excellent tensile strength (about 1000 MPa). These properties are due to the BCC (body-centered cube) crystal structure and high density (19.25 g/cm³) of tungsten. The doping of thorium oxide further improves the fracture resistance and wear resistance of the electrode by refining the grains and strengthening the matrix. This allows the thorium tungsten electrode to maintain structural integrity under high-intensity arc impact, making it suitable for heavy-duty welding applications.

In the production process, the optimization of mechanical properties relies on the powder metallurgy process and subsequent heat treatment. The pressing and sintering process controls the grain size and reduces internal defects; The calendering and grinding processes, on the other hand, improve the surface quality and reduce the stress concentration points. In practice, the mechanical properties of the electrode directly affect its durability. For example, in the welding of pressure vessels in the nuclear industry, WT30 or WT40 electrodes are subjected to high currents and long operating periods, and their high hardness and fracture resistance ensure the reliability of the electrodes.

3.2 Chemical properties of thorium tungsten electrodes

The chemical properties of thorium tungsten electrodes are mainly reflected in their oxidation resistance and chemical stability, which determine the performance of the electrode in high temperature and complex environments.

3.2.1 Oxidation resistance of thorium tungsten electrodes

Thorium tungsten electrodes are protected by inert gases (such as argon or helium) in a high-temperature arc environment (6000-7000°C), and their oxidation resistance is mainly dependent on the chemical inertness of the tungsten matrix. Tungsten is extremely reactive to oxygen at room and high temperatures, and only forms volatile oxides (e.g. WO_3) at very high temperatures (>1000°C). The oxidation resistance of the electrode is further enhanced by the doping of thorium oxide, as thorium oxide itself is a stable oxide that does not easily react further with oxygen.

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In TIG welding, the inert gas protection effectively isolates oxygen and prevents oxidation of the electrode surface. However, during electrode grinding or storage, if exposed to moisture or oxygen, trace oxide layers may form on the surface, affecting arc initiation performance. Therefore, it is necessary to ensure that the surface of the electrode is clean during production and storage, and it is often stored in vacuum packaging or in a dry environment.

Another key factor in oxidation resistance is the thermal stability of the electrode tip. Thorium oxide particles can exist stably at high temperatures to avoid oxidative volatilization of tungsten matrix. Compared with pure tungsten electrodes, thorium tungsten electrodes are more resistant to oxidation and burning loss in high-current welding and prolong their service life. For example, in stainless steel pipe welding, the WT20 electrode is able to maintain surface integrity over long periods of operation and reduce oxide contamination of the weld.

3.2.2 Chemical stability of thorium tungsten electrodes

The chemical stability of thorium tungsten electrodes is reflected in their resistance to common chemicals such as acids, alkalis, and molten metals. The tungsten matrix has extremely high corrosion resistance to most acid-base solutions (such as hydrochloric acid, sulfuric acid and sodium hydroxide) at room temperature, and only minor corrosion may occur in strong oxidizing environments (such as concentrated nitric acid or high-temperature oxidizing atmospheres). As a stable ceramic material, thorium oxide further enhances the chemical stability of the electrode, making it less prone to chemical reactions with metals or gases in the molten pool during the welding process.

In practical applications, the chemical stability of the thorium tungsten electrode ensures the purity of the weld. For example, in titanium alloy welding, impurities will not be released on the electrode surface to contaminate the weld pool, maintaining the mechanical properties and corrosion resistance of the weld. In addition, the thorium tungsten electrode is non-reactive to inert shielding gases (e.g., argon, helium) and is suitable for use in a variety of welding environments.

However, the limitation of chemical stability lies in the thorium oxide dust that can be released during electrode grinding or high-temperature operation. Thorium oxide can volatilize at high temperatures or be released as dust, and although chemically stable, its radioactivity requires strict precautions. Special equipment (e.g. closed grinders and ventilation systems) is required in production and use to reduce dust diffusion.

3.3 Welding performance of thorium tungsten electrodes

The welding performance of thorium tungsten electrode is the core advantage of its wide application in TIG welding and plasma welding, which is embodied in the arc initiation performance, arc stability, burn-out rate and performance under high load current.

3.3.1 Arc initiation performance of thorium tungsten electrode

The arc initiation performance is a key indicator to measure the difficulty of the electrode to initiate the arc, and the thorium tungsten electrode has excellent arc initiation performance due to its low electron escape work (2.63 eV). In DC negative electrode (DCEN) welding, electrons flow from the electrode to the workpiece, and the low work of escape reduces the voltage required for arc initiation (typically 10-15 V), allowing the arc to be rapidly initiated at low currents. This is particularly important for precision welding, such as thin sheet stainless steel or electronic components, as it reduces heat input at arc initiation and prevents the material from overheating.

Different types of thorium tungsten electrodes have slightly different arc initiation performance. WT40 has the highest thorium oxide content (3.8-4.2%) and the best arc initiation performance, which is suitable for high-current scenarios. WT10 is more suitable for low-current precision welding. Arc initiation performance is also affected by the electrode grinding angle and surface quality. The sharp grinding angle (15°-30°) can concentrate the flow of electrons and improve the arc starting efficiency; Surface polishing reduces surface defects and reduces the arcing voltage.

In practical application, the arc initiation performance of thorium tungsten electrode is significantly better than that of pure tungsten electrode. For example, in the welding of titanium alloys in the aerospace sector, the WT20 electrode is able to start the arc quickly at low voltages, ensuring the quality of the start of the weld. In pulsed TIG welding, the rapid arc initiation ability of thorium tungsten electrode further improves the welding efficiency and accuracy.

3.3.2 Arc stability of thorium tungsten electrodes

Arc stability is the core advantage of thorium tungsten electrodes, which directly affects the quality of the weld and the welding efficiency. The arc stability of thorium tungsten electrodes is due to the thermal electron emission ability of thorium oxide and the high conductivity of tungsten matrix. In DCEN welding, the arc is concentrated and continuous, with small fluctuations and less spatter, which is suitable for high-precision welding. Thorium oxide particles release a steady flow of electrons at high temperatures, maintaining the uniformity of the arc and not drifting or interrupting the arc even at high currents or during long runs.

Different types of electrodes differ in arc stability. WT20 and WT30 are widely used in industrial welding due to their moderate thorium oxide content (1.7-3.2%) and best arc stability at medium to high currents (100-400 A). The WT40 maintains arc stability at ultra-high currents (300-500 A) and is suitable for heavy-duty applications such as the welding of pressure vessels in nuclear power plants.

Arc stability is also affected by the state of the shielding gas and electrodes. Argon protection provides a stable arc environment, while helium or argon-helium mixtures are suitable for high heat input welding. Proper grinding of the electrode tip (e.g. 20°-35° cone angle) can further optimize the arc concentration. For example, in pipe welding in the petrochemical industry, the WT20 electrode provides a stable arc to ensure uniform weld seam and corrosion resistance.

3.3.3 Electrode burn-out rate of thorium tungsten electrodes

The electrode burn-out rate is an important indicator to measure the durability of the electrode, which refers to the quality loss of the electrode due to high temperature, arc shock or thorium oxide loss during the welding process. The burn-off rate of thorium tungsten electrodes is significantly lower than that of pure tungsten electrodes, mainly due to the thermal stability of thorium oxide and the high melting point of tungsten matrix. Thorium oxide forms a stable electron emission layer at high temperatures, reducing the volatilization and melting of the tungsten matrix.

The burnout rate of different types of thorium tungsten electrodes decreases with the increase of thorium oxide content. WT10 (0.8-1.2% ThO_2) has a low burnout rate at low currents, but thorium loss may occur at high currents. WT40 (3.8-4.2% ThO_2) has the lowest burn-out rate and is suitable for ultra-high current and long-term continuous welding. For example, in the welding of thick plates in shipbuilding, the WT40 electrode is able to operate for hours at high currents with little change in tip shape.

The burn-out rate is also affected by welding parameters and operating conditions. Proper current control, shielding gas flow (8-15 L/min) and electrode grinding angles can significantly reduce the burnout rate. In practice, regular inspection and regrinding of the electrode tip can extend the service life while reducing the release of thorium dust.

3.3.4 Performance of thorium tungsten electrodes at high load currents

The performance of thorium tungsten electrodes at high load currents (200-500 A) is a key advantage in heavy industry. Due to the high thorium oxide content, the WT30 and WT40 electrodes can withstand the arc impact of high current and high temperature, maintaining arc stability and low burn-out rate. This property makes it suitable for welding thick plates and materials with high melting points, such as pressure vessels in the nuclear industry, large titanium alloy structures in aerospace, and corrosion-resistant pipes in the petrochemical industry.

The thermal stability and mechanical strength of the thorium tungsten electrode ensure the durability of the electrode tip at high load currents. For example, in pressure vessel welding in a nuclear power plant, the WT40 electrode is capable of continuous operation at 400 A, with a concentrated and stable arc and a high weld quality. In addition, the low electron work of the thorium tungsten electrode at high current reduces the energy consumption of arc initiation and arc maintenance, and improves the welding efficiency.

However, at high load currents, attention needs to be paid to the thermal load management of the electrodes. Excessive currents may cause thorium loss to accelerate and release trace amounts of radioactive dust. Therefore, it is advisable to use a large electrode diameter (3.2-6.4 mm) and an appropriate grinding angle (30°-45°) with an efficient cooling system (e.g. a water-cooled welding gun) to reduce the electrode temperature.

3.4 Radioactive properties of thorium tungsten electrodes

Thorium tungsten electrodes are slightly radioactive due to the presence of thorium oxide (ThO_2), a property that is both a source of its performance advantage and a major limitation in its application. This section will explore the radioactive characteristics of thorium oxide, its health and environmental impacts, and its comparison with non-radioactive electrodes.

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Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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3.4.1 Trace radioactivity of thorium oxide

Thorium-232 (Th-232) in thorium oxide is a naturally occurring radioactive element with a half-life of about 14 billion years and mainly releases α particles (4.01-4.08 MeV) accompanied by small amounts of β particles and γ rays. The radioactivity level of the thorium tungsten electrode is directly related to the thorium oxide content, with WT10 (0.8-1.2% ThO_2) having the lowest activity concentration (close to 1 Bq/g, meeting the exemption criteria) and WT40 (3.8-4.2% ThO_2) having the highest activity concentration, close to or slightly above the exemption standard.

Under normal conditions of use (e.g. TIG welding), the radioactivity of the electrodes has less direct radiation effect on the operator because of the low penetration of α particles (which can be blocked by a few centimeters of air or skin). However, dust and volatile thorium oxides at high temperatures during electrode grinding can enter the body through inhalation or contact, posing a risk of internal radiation. The dose rate of γ radiation is low (typically < 0.1 μSv/h), but long-term exposure is a concern.

During the production process, the radioactivity management of thorium tungsten electrodes is strictly regulated. International standards (e.g., ICRP Publication 103) and Chinese standards (e.g., GB 18871-2002) specify exempt activity concentrations and protection requirements for thorium-232. The production workshop needs to be equipped with X-γ radiation dose rate detector and α and β surface pollution detector to regularly monitor the environmental radiation level.

3.4.2 Health and environmental impacts

The health effects of thorium tungsten electrodes are mainly due to the radioactive dust released during grinding and welding. α particles that enter the lungs through inhalation can pose long-term health risks, such as lung cancer or tissue damage. Studies have shown that workers who are chronically exposed to thorium dust may face higher radiation doses (about 0.1-1 mSv per year, well below the public annual value of 1 mSv). Therefore, operators need to wear protective masks, use special grinders and efficient ventilation equipment.

In terms of environmental impact, waste materials from the production and use of thorium tungsten electrodes (including grinding dust, waste water and waste electrodes) need to be properly disposed of. The radioactive waste of thorium-232 shall be stored and disposed of in accordance with the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises for the Development and Utilization of Associated Radioactive Mines (Trial) to avoid polluting soil and water bodies. Businesses need to have dedicated waste treatment facilities, such as closed collection systems and radioactive waste repositories.

In practice, European and American countries have gradually restricted the use of thorium tungsten electrodes and promoted non-radioactive electrodes to reduce health and environmental risks. As a major producer of tungsten electrodes, China has also strengthened radioactive protection measures in recent years, and some enterprises have adopted automated grinding equipment and closed production workshops, which have significantly reduced dust emissions.

3.4.3 Comparison of thorium tungsten electrodes with non-radioactive electrodes

Non-radioactive electrodes (such as cerium-tungsten, lanthanum-tungsten, zirconium-tungsten and yttrium-tungsten electrodes) are the main alternatives to thorium tungsten electrodes, and their main advantage is that there is no risk of radioactivity. Here's a detailed comparison:

Cerium tungsten electrode (WC20): contains 1.8-2.2% cerium oxide, the electron work is about 2.7 eV, the arc initiation performance and arc stability are close to WT20, the burning rate is slightly higher, and it is non-radioactive, which is widely used in the medical and food industries.
Lanthanum tungsten electrode (WL20): contains 1.8-2.0% lanthanum oxide, electron work is about 2.6-2.8 eV, arc stability and lifetime are better than cerium tungsten electrode, suitable for high-precision and heavy-duty welding, non-radioactive.
Zirconium tungsten electrode (WZ8): contains 0.8% zirconia, specially designed for AC welding aluminum and magnesium alloy, good arc stability, but the arc initiation performance and DCEN welding performance are not as good as thorium tungsten electrode, non-radioactive.
Yttrium-tungsten electrode (WY20): contains 1.8-2.2% yttrium oxide, the performance is close to that of lanthanum tungsten electrode, suitable for high-precision welding, but the cost is high, the market popularity is low, and it is non-radioactive.

The advantages of thorium tungsten electrodes are their excellent arc initiation performance, arc stability, and low burn-out rate, especially in high-current and heavy-duty scenarios. However, its radioactivity problem has gradually led to its replacement in industries with high environmental and health requirements. For example, in Europe, lanthanum tungsten electrodes have replaced thorium tungsten electrodes as the mainstream, while in China, thorium tungsten electrodes are still widely used in heavy industry due to their cost advantages and excellent performance.

3.5 Thorium Tungsten Electrode MSDS from CTIA GROUP LTD

Material Safety Data Sheet (MSDS) for Thorium-Tungsten Electrode

1. Chemical Identification
Chemical Name: Thorium-Tungsten Electrode
Common Name: Thorium-Tungsten Rod, Thorium-Tungsten Welding Electrode
CAS Number:
Tungsten (W): 7440-33-7
Thorium Dioxide (ThO_2): 1314-20-1

2. Composition/Information on Ingredients
Tungsten (W): 95.8-99.2%
Thorium Dioxide (ThO_2): 0.8-4.2%
Impurities (Fe, Ni, O, C, etc.): <0.05%

3. Hazards Overview
Hazard Category: Low specific activity radioactive material (LSA-I), with low radioactive risk; dust may cause irritation.

Fire and Explosion Hazard: Non-flammable, no explosion risk.
Health Hazards:
Inhalation: Dust generated during grinding or processing may irritate the respiratory tract. Long-term low-dose exposure may increase lung health risks.
Skin Contact: May cause mild irritation.
Eye Contact: Dust may cause eye discomfort or inflammation.
Ingestion: Accidental ingestion may lead to gastrointestinal discomfort, requiring immediate medical attention.

Environmental Hazards: Improper disposal of thorium-containing waste may contaminate soil and water, requiring management as radioactive waste.
Regulatory Basis: GB 18871-2002, ICRP Publication 103, IAEA SSR-6.

4. First-Aid Measures
Skin Contact:
Immediately remove contaminated clothing and rinse the skin with soap and plenty of water for at least 15 minutes.
Seek medical attention if irritation or discomfort persists.

Eye Contact:
Lift eyelids and flush with running water or saline for at least 15 minutes.
Seek medical attention if discomfort persists.

Inhalation:
Move the affected person to fresh air immediately, ensuring clear airways.
Administer oxygen if breathing is difficult; perform artificial respiration if breathing stops.
Seek medical attention immediately, informing medical personnel of potential thorium dust exposure.

Ingestion:
Drink plenty of warm water to induce vomiting (if the patient is conscious).
Seek medical attention immediately, providing this MSDS to medical personnel.

Note: First-aid personnel must wear protective equipment (e.g., dust masks, gloves) to avoid secondary exposure.

5. Fire-Fighting Measures
Hazard Characteristics: Non-flammable, no explosion risk.
Extinguishing Methods: Not applicable. If a fire occurs nearby, use dry powder, foam, or carbon dioxide extinguishers.
Fire-Fighting Precautions:
Firefighters must wear protective clothing and positive-pressure respirators.
Prevent thorium-containing dust from spreading due to fire, which may cause environmental

contamination.

6. Accidental Release Measures

Spill Handling:

Isolate the spill area, restrict reason: Restrict access to unauthorized personnel and display a “Radioactive Material” warning sign.

Emergency personnel must wear protective clothing, dust masks, and gloves, using wet cleaning methods to collect spilled electrodes or dust into sealed containers.

Assess the spill area using an X-γ radiation dose rate detector (e.g., AT1123) and α, β surface contamination detector (e.g., XH-3206). Report to nuclear safety authorities if the dose rate exceeds 0.1 μSv/h or surface contamination exceeds 0.4 Bq/cm^2.

Waste Disposal:

Treat spilled material as low specific activity radioactive waste (LSA-I), store in dedicated sealed containers, and solidify waste with activity concentration >1 Bq/g (e.g., mixed with cement matrix) for transfer to professional disposal facilities.

Clean contaminated areas with water; wastewater activity must be <0.1 Bq/L before discharge.

Reporting: Report spills to local environmental and nuclear safety authorities within 24 hours, providing details and disposal measures.

7. Handling and Storage

Handling Precautions:

Protective Measures: Personnel must wear protective clothing, dust masks, and gloves. Work areas must be equipped with local exhaust hoods (air velocity 0.5-1 m/s) and HEPA filters (capture efficiency >99.9%).

Grinding Requirements: Use dedicated grinding machines with negative pressure dust collection systems to prevent thorium dust dispersion.

Environmental Monitoring: Regularly measure X-γ dose rate (<0.05 μSv/h) and α, β surface contamination (<0.4 Bq/cm^2) in work areas, in compliance with GB 18871-2002.

Training: Operators must receive radiation safety training to understand thorium-232 health risks.

Storage Precautions:

Store in a dry (humidity <60%), well-ventilated dedicated warehouse at 10-30°C.

Use sealed stainless steel or plastic containers marked with radioactive warning labels.

Store different electrode models separately; store discarded electrodes in dedicated radioactive waste containers.

Regularly check storage area radiation levels, with records archived for at least 5 years.

8. Exposure Controls/Personal Protection

Occupational Exposure Limits:

Public: Annual effective dose <1 mSv (ICRP 103).

Occupational: Annual effective dose <20 mSv, 5-year average <4 mSv (GB 18871-2002).

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Environmental Limits: Work area dose rate <0.05 μSv/h, surface contamination <0.4 Bq/cm².

Engineering Controls:
Production and use areas must have sealed hoods, HEPA filters, and negative pressure ventilation systems.
Grinding equipment must be connected to dust collection systems with >99.9% capture efficiency.

Personal Protective Equipment:
Respiratory Protection: Wear KN95 or FFP2 dust masks to prevent inhalation of thorium dust.
Eye Protection: Use safety goggles to prevent dust entry into eyes.
Skin Protection: Wear long-sleeved protective clothing and gloves to avoid skin contact.
Monitoring: Operators must wear personal dosimeters, with annual health checks and dose records.

Hygiene Measures:
Wash hands with soap after handling; prohibit eating or smoking in work areas.
Store work clothing separately from daily clothing and wash regularly.

9. Physical and Chemical Properties
Appearance and Characteristics: Silver-gray metal rod with color-coded ends (WT10 yellow, WT20 red, WT30 purple, WT40 orange-yellow).
Melting Point: 3422° C (tungsten matrix).
Density: 18.5-19.0 g/cm³ (95-98% of theoretical density).
Hardness: 350-450 HV.
Solubility: Insoluble in water, soluble in strong acids (e.g., nitric acid-hydrofluoric acid mixture).
Radioactivity: Contains thorium-232, emits α particles (4.01-4.08 MeV) and minor β, γ rays, with activity concentration of 1-4 Bq/g.

10. Stability and Reactivity
Stability: Stable at room temperature; may release trace thorium dioxide particles at high temperatures (>2000° C).
Reactivity: Reacts with strong acids (e.g., nitric acid, hydrofluoric acid) to form thorium compounds; may cause mild reactions with strong oxidants.
Incompatible Materials: Avoid contact with acidic substances and flammables.

11. Toxicological Information
Acute Toxicity: No significant acute toxicity; LD50 data unavailable.
Chronic Toxicity: Long-term inhalation of thorium dust may increase lung health risks (annual effective dose <1 mSv is safe).
Carcinogenicity: Thorium-232 is classified as a Group 1 carcinogen by IARC; long-term low-dose exposure may increase lung cancer risk, requiring strict protection.
Reproductive Toxicity: No clear evidence of reproductive toxicity.
Target Organs: Respiratory system, skin, eyes.

12. Ecological Information

Environmental Impact: Improper disposal of thorium-containing waste may contaminate soil and water, affecting ecosystems.

Bioaccumulation: Thorium compounds may enter the food chain via water, requiring strict emission control (wastewater activity <0.1 Bq/L).

Disposal Requirements: Handle as per the "Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Utilizing Associated Radioactive Minerals (Trial)."

13. Disposal Considerations

Waste Classification: Discarded thorium-tungsten electrodes and dust are low specific activity radioactive waste (LSA-I).

Disposal Methods:

Collect in dedicated sealed containers marked "Radioactive Waste."

Waste with activity concentration >1 Bq/g must be solidified (e.g., mixed with cement matrix) and sent to professional disposal facilities (e.g., China National Nuclear Corporation).

Waste with activity concentration <1 Bq/g may be treated as ordinary waste with nuclear safety authority approval.

Emission Control: Wastewater must be treated via sedimentation and ion exchange, with activity <0.1 Bq/L before discharge.

Records: Document batch, quantity, activity concentration, and disposal date, archiving for at least 5 years.

14. Transport Information

Transport Classification: Low specific activity radioactive material (LSA-I), compliant with IAEA SSR-6 and GB 11806-2004.

Packaging Requirements:

Use Type A packaging (stainless steel or high-strength plastic boxes, thickness >2 mm) marked with radioactive warning labels.

Package surface dose rate <0.1 μSv/h, surface contamination <0.4 Bq/cm^2.

Transport Precautions:

Use dedicated trucks or cargo holds with shockproof fixtures and radiation detectors (e.g., RadEye PRD).

Transport personnel must receive radiation safety training and wear personal dosimeters.

Transport routes should avoid densely populated areas, with prior declaration to nuclear safety authorities.

International Transport: Provide English-language radioactive material transport certificates, compliant with IATA or IMDG regulations.

15. Regulatory Information

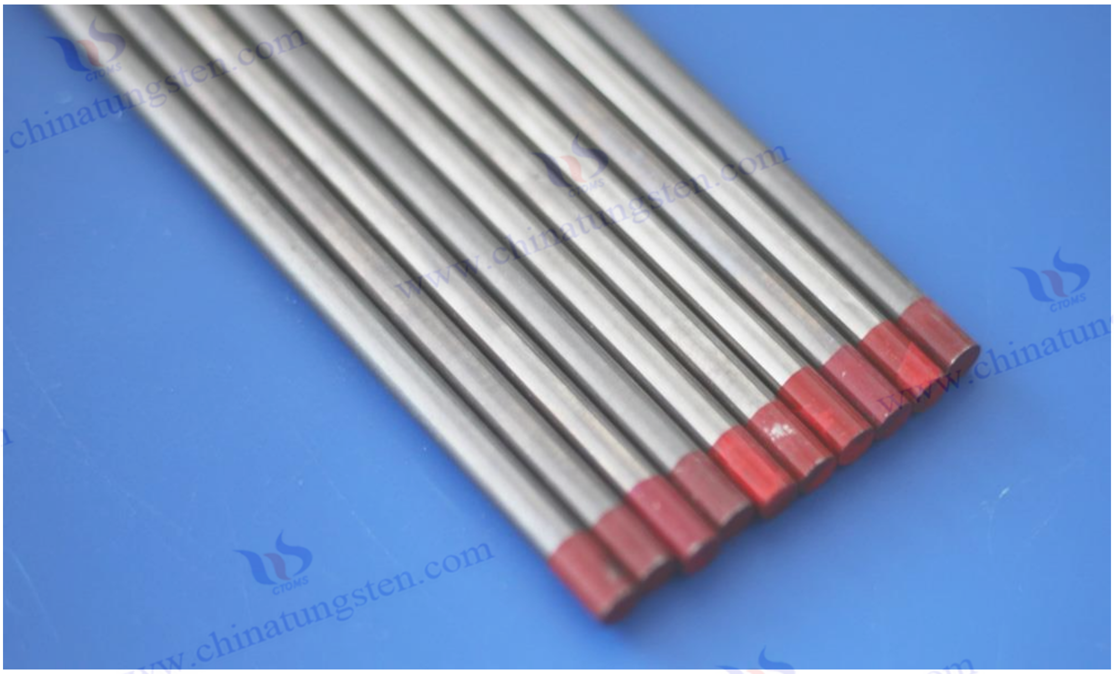
International Regulations:

ICRP Publication 103 (2007): Public annual effective dose <1 mSv, occupational exposure <20 mSv.
IAEA SSR-6 (2018): Requirements for radioactive material transport packaging and limits.
EU 2013/59/Euratom: Production and use environment dose rate <0.1 μ Sv/h, surface contamination <0.4 Bq/cm² .

Domestic Regulations:
GB 18871-2002: Basic Standards for Protection Against Ionizing Radiation, environment dose rate <0.05 μ Sv/h, waste activity <1 Bq/g.
GB/T 4187-2017: Tungsten Electrodes for Inert Gas Shielded Arc Welding and Plasma Welding, specifying composition and performance.
Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Utilizing Associated Radioactive Minerals (Trial): Requires annual radiation monitoring reports and public disclosure.

Corporate Compliance:
Register with the National Nuclear Safety Administration to obtain radioactive material handling permits.
Obtain ISO 14001 (Environmental Management) and ISO 45001 (Occupational Health and Safety) certifications.

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


CTIA GROUP LTD WT20 electrode

Chapter 4 Preparation and Production Technology of Thorium Tungsten Electrode

The preparation of thorium tungsten electrodes is a complex process that involves the selection of high-purity raw materials, precision powder metallurgy technology, molding processing, and strict quality control and radioactive protection measures. The production process directly determines the performance of the electrode, including arc stability, burn-out rate and service life. This chapter will discuss in detail the preparation and production technology of thorium tungsten electrodes, covering raw material preparation, powder metallurgy process, rolling and grinding process, quality control, and radioactive contamination prevention and control.

4.1 Preparation of raw materials for thorium tungsten electrodes

The performance of thorium tungsten electrodes is highly dependent on the quality and purity of the raw material. Tungsten powder and thorium oxide (ThO_2) are the main raw materials for the preparation of thorium tungsten electrodes, and their selection, purification and doping processes are crucial to the chemical composition, microstructure and final properties of the electrodes.

4.1.1 Selection and purification of tungsten powder

Tungsten powder is the main component of thorium tungsten electrode, accounting for 95.8%-99.2% of the electrode mass. Tungsten is a refractory metal with a high melting point (3422°C) and a high density (19.25 g/cm^3), and its powder morphology directly affects the formability of the subsequent powder metallurgy process and the performance of the electrode.

Selection of tungsten powder

The selection of tungsten powder should consider particle size, purity and morphology. Tungsten powders commonly used in industry range from 1 to 10 μm, and powders that are too fine (<1 μm) may cause excessive shrinkage during sintering, while powders that are too coarse (>10 μm) may reduce the density and uniformity of the electrode. Uniform particle size distribution is usually required to ensure good flowability of the powder during pressing and sintering.

Purity is the key indicator for the selection of tungsten powder. The purity of tungsten powder is required to reach more than 99.95% to reduce the influence of impurities (such as iron, nickel, oxygen, carbon, etc.) on the conductivity and welding performance of the electrode. High levels of impurities can lead to arc instability or increased electrode burning. For example, oxygen levels above 0.02% may form volatile oxides (WO_3) at high temperatures, reducing electrode lifetime.

The morphology of tungsten powder should also be considered. Tungsten powder with near-spherical or polyhedral morphology is usually selected because of its high bulk density and fluidity, which is conducive to the uniformity of press forming. Chemical vapor deposition (CVD) or hydrogen reduction are commonly used in production to prepare high-purity tungsten powder to ensure that the powder quality meets international standards (e.g. ISO 6848:2015).

Purification of tungsten powder

The purification process of tungsten powder is designed to remove impurities from the raw material and improve purity and performance. Common purification methods include:

Hydrogen reduction method: tungstic acid (H_2WO_4) or tungsten oxide (WO_3) is reduced to tungsten metal powder under a high temperature (800-1000°C) hydrogen atmosphere. This method can effectively remove oxygen and some volatile impurities to obtain high-purity tungsten powder.
Pickling process: use dilute hydrochloric acid or nitric acid solution to clean tungsten powder to remove metal impurities such as iron and nickel adsorbed on the surface. After pickling, rinse repeatedly with deionized water to avoid acid residues.
High Temperature Vacuum Treatment: Tungsten powder is treated at high temperature (1200-1500°C) in a vacuum environment (10^{-4} Pa) to further remove residual oxygen and carbon to ensure a purity of 99.99%.

The purified tungsten powder is subjected to particle size sieving (usually by vibrating screen or airflow classifier) to ensure that the particle size distribution meets the requirements. After screening, tungsten powder needs to be stored in a dry, vacuum, or inert gas environment to prevent oxidation or moisture absorption.

4.1.2 Thorium oxide doping process

Thorium oxide (ThO_2) is the key dopan of thorium tungsten electrodes, and its content (0.8-4.2%) directly affects the electron work and arc stability of the electrodes. The thorium oxide doping process needs to ensure its uniform distribution in the tungsten matrix while controlling its radioactivity risk.

Selection of thorium oxide

Thorium oxide powders need to be of high purity (>99.9%) and appropriate particle size (0.5-2 μm). Thorium oxide particles that are too fine may agglomerate during the sintering process, resulting in uneven distribution; Particles that are too coarse may reduce the mechanical strength of the electrode. Thorium oxide is usually prepared by thermal decomposition or precipitation of thorium salts (such as thorium nitrate), and the content of impurities (such as uranium, iron, etc.) needs to be strictly controlled to avoid affecting the performance of the electrode.

Due to the trace radioactivity of thorium oxide (thorium-232, half-life 14 billion years), its procurement and storage must comply with the regulations on the management of radioactive substances (e.g., GB 18871-2002). Suppliers are required to provide a radioactivity test report to ensure that the activity concentration is below the exempted standard (1 Bq/g).

Doping process

The thorium oxide doping process is usually carried out in the mixing stage, and the main methods include:

Dry mixing: tungsten powder and thorium oxide powder are mixed in a high-speed mixer (such as a V-type mixer or a three-dimensional mixer), and the mixing time is usually 4-8 hours. A small amount of organic binders (such as polyvinyl alcohol, PVA) should be added during the mixing

process to improve the fluidity of the powder and avoid the agglomeration of thorium oxide particles.
Wet mixing: Tungsten powder and thorium oxide powder are dispersed in deionized water or ethanol and wet mixed by means of a ball mill (usually using zirconia balls). Wet mixing improves homogeneity, but subsequent drying (100-150°C, vacuum or inert atmosphere) is required to remove solvents.
Chemical co-precipitation method: thorium nitrate is added to the tungstate solution, and a tungsten-thorium complex is formed through co-precipitation, and then doped powder is prepared by high-temperature reduction. This method can achieve uniform doping at the atomic level, but it is expensive and is often used in high-end electrode production.

The content of thorium oxide should be strictly controlled during the doping process, and the proportions of WT10 (0.8-1.2%), WT20 (1.7-2.2%), WT30 (2.8-3.2%) and WT40 (3.8-4.2%) should be accurately weighed (accuracy ± 0.01%). The mixed powder is detected by X-ray fluorescence spectroscopy (XRF) or inductively coupled plasma spectroscopy (ICP) to ensure homogeneity.

Radiological protection
Strict radioactive protection measures are required in the process of thorium oxide doping. Operators need to wear protective clothing and masks, and the mixing equipment needs to be equipped with an airtight cover and ventilation system to prevent the spread of dust. The mixed powder should be stored in an airtight container with a radioactive warning label.

4.2 Powder metallurgy process of thorium tungsten electrode

Powder metallurgy is the core process of thorium tungsten electrode preparation, which converts tungsten powder and thorium oxide powder into high-performance electrode rods through mixing, pressing, sintering and heat treatment. This process requires precise control of the parameters at each stage to ensure consistent density, grain structure, and performance of the electrode.

4.2.1 Mixing and pressing

Mixture
Compounding is the first step in powder metallurgy and is designed to ensure a uniform distribution of tungsten powder and thorium oxide. The mixing equipment is usually a high-speed mixer or ball mill, and the mixing time and speed need to be adjusted according to the powder particle size and ratio. For example, the WT20 electrode (1.7-2.2% ThO_2) needs to be mixed for 6-8 hours at 200-300 rpm to avoid the agglomeration of thorium oxide particles.

A small amount of binder (e.g. PVA or polyethylene glycol, PEG, 0.5-1% mass ratio) is added during the mixing process to improve the flow of the powder. After the mixing is complete, the particle size distribution of the powder is checked by a laser particle size analyzer to ensure that the D50 (median particle size) is in the range of 2-5 μm.

suppress
The pressing process forms the mixed powder into a blank, usually by cold isostatic pressing (CIP)

or compression. Cold isostatic pressing is the mainstream method, in which the powder is pressed into rod or plate billets by high pressure (100-200 MPa). During the pressing process, the pressure and holding time (1-3 minutes) need to be controlled to ensure that the density of the primary blank is uniform (about 60-70% of the theoretical density).

Pressing equipment is equipped with precision molds, usually made of carbide or stainless steel, to withstand high pressures and ensure dimensional accuracy. The diameter and length of the blank are based on the final electrode specification (e.g. 1.6 mm, 2.4 mm, 3.2 mm). After pressing, the blank undergoes a preliminary inspection (e.g. visual inspection and density test) to remove cracks or defects.

4.2.2 Sintering process

Sintering is a key step in powder metallurgy, where the primary blank is densified and a stable microstructure is formed by high-temperature treatment. The sintering of thorium tungsten electrodes is usually carried out under hydrogen or vacuum atmosphere to prevent oxidation.

Sintering equipment and conditions

The sintering furnace is usually a high-temperature resistance furnace or induction furnace with an operating temperature range of 2000-2800°C. The sintering process is divided into three stages:

Low temperature pre-sintering (800-1200°C): Remove binders and volatile impurities, and the shrinkage of the primary blank is about 5-10%.
High temperature sintering (2200-2800°C): Tungsten particles diffuse and combine, and the thorium oxide particles are evenly distributed in the tungsten matrix, and the density of the blank reaches 95-98% of the theoretical density.
Insulation and cooling (1800-1000°C): By controlling the holding time (2-4 hours) and cooling rate (10-20°C/min), the grain structure is optimized and the internal stress is reduced.

The sintering atmosphere needs to be strictly controlled, and the purity of hydrogen is required to be > 99.999% to avoid oxygen or nitrogen pollution. Vacuum sintering (10^{-4} Pa) further reduces the impurity content and is suitable for high-end electrode production.

Microstructure control

During the sintering process, the distribution of thorium oxide particles in the tungsten matrix and the grain size are key. Proper sintering temperature and time can result in uniform distribution of thorium oxide particles (0.5-2 μm particle size) and avoid agglomeration or segregation. The grain size of tungsten matrix is usually controlled at 10-50 μm, and too large grains may reduce the mechanical strength, while too small grains may affect the electrical conductivity.

The sintered blank is analyzed by metallurgical microscopy and scanning electron microscopy (SEM) to ensure that there are no cracks, pores, or thorium oxide segregation. Density tests (Archimedes) confirm that the density of the blank is 18.5-19.0 g/cm³.

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Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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

4.2.3 Heat treatment and grain control

Heat treatment is an important step after sintering to optimize the grain structure, mechanical properties, and welding properties of the electrode. Heat treatment typically consists of two stages: annealing and grain control.

anneal

Annealing is carried out in a hydrogen or vacuum atmosphere at a temperature of 1200-1600 ° C and a holding time of 1-2 hours. Annealing relieves the internal stresses generated during the sintering process and improves the ductility and fracture resistance of the electrode. After annealing, the hardness of the electrode decreases slightly (about 350-400 HV), but the toughness is significantly improved, making it suitable for subsequent calendering.

Grain control

Grain control adjusts the grain size of the tungsten matrix through a precise heat treatment process. Smaller grains (10-20 μm) increase the mechanical strength of the electrode and are suitable for high-current welding; Larger grains (30-50 μm) are beneficial for conductivity and arc stability. Grain size control depends on:

Sintering temperature: high temperature (>2600°C) promotes grain growth, low temperature (<2200°C) inhibits grain growth.
Doping effect: thorium oxide particles can nail grain boundaries, inhibit grain overgrowth, and ensure uniform microstructure.
Cooling rate: Rapid cooling (20-30°C/min) fixes fine grains, and slow cooling (5-10°C/min) results in larger grains.

After heat treatment, the grain structure of the blank is verified by X-ray diffraction (XRD) and metallographic analysis to ensure that it meets the performance requirements of WT10, WT20, WT30 or WT40.

4.3 Rolling and grinding process of thorium tungsten electrode

The calendering and grinding process processes the sintered blank into an on-spec electrode rod to ensure dimensional accuracy, surface quality, and consistent performance.

4.3.1 Forming of electrode rods

Calendering is the main process of electrode rod forming, in which the sintered blank is processed into the desired diameter (0.5-10 mm) by multi-pass hot or cold calendering. Hot calendering is usually carried out at 1400-1800°C, using a multi-roll calender to gradually reduce the diameter of the blank. The amount of deformation is controlled at 10-20% per calendering to avoid cracks or internal stress concentrations.

Calendering process

Equipment: Multi-roll calender or rotary forging machine, equipped with precision dies and heating systems.

Process parameters: temperature 1400-1800°C, calendering speed 0.5-2 m/min, deformation 10-20%/pass.
Atmosphere control: hydrogen or vacuum atmosphere to prevent oxidation.

After calendering, the electrode rod is straightened (by means of a straightener) and a preliminary dimensional inspection. Diameter tolerances are typically controlled at ±0.05 mm and length tolerances of ±1 mm. Different types of electrodes (e.g. WT20, WT40) need to be selected according to the appropriate diameter for the end application, e.g. 1.6 mm for low-current welding and 4.8 mm for high-current welding.

Cutting and pre-processing

The calendered long bars are cut to standard lengths (e.g. 150 mm or 175 mm) using a diamond or laser cutter to ensure a flat cut. After cutting, the electrode rod undergoes a preliminary grinding to remove the surface oxide layer and burrs in preparation for the subsequent grinding process.

4.3.2 Surface polishing and precision control

Surface polishing is the final step in the preparation of thorium tungsten electrodes and is designed to improve surface quality and dimensional accuracy, and reduce arc drift and burn-out in welding.

Grinding and polishing

Coarse grinding: A diamond grinding wheel (grit size 80-120 mesh) is used to remove surface defects, and the surface roughness reaches Ra 1.6-3.2 μm.
Fine grinding: Fine-grained grinding wheels (200-400 mesh) are used to further smooth the surface with a roughness of Ra 0.8-1.6 μm.
Polishing: Use polishing paste and a high-speed rotating cloth wheel to reduce the surface roughness to Ra 0.2-0.4 μm to ensure a mirror effect.

During the polishing process, special grinding equipment is used, equipped with a water cooling system to reduce the temperature and prevent thermal damage to the tungsten matrix and thorium oxide. Grinding dust is collected through an enclosure and a high-efficiency filtration system to prevent radioactive contamination.

Precision control

Diameter accuracy: The diameter is detected with a laser caliper with a tolerance of ±0.02 mm.
Straightness: Detected by an optical projector or laser scanner to ensure that the straightness deviation < 0.1 mm/m.
Surface quality: The surface is inspected by microscopy with no cracks, scratches or oxide residues.

After polishing, the electrodes undergo a final cleaning (ultrasonic or chemical) to remove oil and dust from the surface, followed by vacuum packaging to prevent oxidation.

4.4 Quality control of thorium tungsten electrodes

Quality control runs through every step of thorium tungsten electrode preparation, covering composition uniformity, dimensional accuracy, and surface quality to ensure that the electrode meets international standards (e.g. ISO 6848:2015) and customer requirements.

4.4.1 Ingredient uniformity testing

The homogeneity of the composition directly affects the welding performance and consistency of the electrode. Assays include:

X-ray fluorescence spectroscopy (XRF): non-destructive detection of tungsten and thorium oxide with an accuracy of ±0.01%. For example, the WT20 electrode needs to ensure that the thorium oxide content is in the range of 1.7-2.2%.
Inductively Coupled Plasma Spectroscopy (ICP-OES): High-precision analysis of impurity elements (e.g., Fe, Ni, O, C) ensures a total impurity content of <0.05%.
Scanning electron microscopy (SEM-EDS): Analyze the distribution and particle size of thorium oxide particles to confirm no agglomeration or segregation.

The frequency of testing is usually 10-20% sampling per batch, and unqualified batches need to be remixed or sintered.

4.4.2 Dimensional and surface quality inspection

Dimensional and surface quality inspections ensure the geometric accuracy and welding performance of the electrodes. Assays include:

Dimensional inspection: Diameter and length are measured using laser calipers and micrometers, and the tolerances meet the standards (such as GB/T 4187-2017).
Straightness detection: Measured by a laser scanner or optical projector to ensure a deviation of < 0.1 mm/m.
Surface quality inspection: Inspect the surface with a light microscope or surface roughness meter with a roughness of Ra<0.4 μm and no cracks, scratches or oxides.

Non-conforming electrodes need to be reworked (re-ground or polished) or scrapped, and inspection records are archived to trace quality issues.

4.5 Prevention and control of radioactive contamination of thorium tungsten electrodes

The trace amount of radioactivity of thorium oxide (thorium-232) is a major challenge in the production of thorium tungsten electrodes, which requires strict waste management, protective measures and waste disposal to reduce health and environmental risks.

4.5.1 Radioactive waste management in the production process

Radioactive waste generated during the production process includes dust, waste and wastewater. Management measures include:

Dust collection: Mixing, grinding and polishing equipment requires a containment hood and a high-efficiency filtration system (e.g. HEPA filter) with a capture rate of > 99.9%.

Waste classification: Waste from sintering and cutting is collected separately and stored in sealed containers marked with a radioactive warning.
Waste monitoring: Waste activity is regularly monitored using the X-γ Radiation Dose Rate Detector (AT1123) and the α and β Surface Contamination Detector (XH-3206) to ensure that it is below the exemption standard (1 Bq/g).

Wastes shall be registered and reported in accordance with the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises for the Development and Utilization of Associated Radioactive Mines (for Trial Implementation).

4.5.2 Protective measures and equipment requirements

Protective measures are designed to protect operators and the environment from radiation hazards:

Personal protection: Operators are required to wear protective clothing, dust masks, and gloves, and receive regular radiation dose monitoring (effective dose < 1 mSv per year).
Equipment requirements: Mixers, sintering furnaces and grinding equipment need to be equipped with closed hoods and ventilation systems, and exhaust gas emissions need to be treated through activated carbon filters.
Working environment: Radiation monitors need to be installed in the production workshop to monitor the X-γ dose rate (<0.1 μSv/h) and α and β surface contamination in real time.

4.5.3 Treatment of wastewater and solid waste

Wastewater treatment: The wastewater produced by mixing and cleaning needs to be treated by sedimentation, filtration and ion exchange to remove thorium compounds, and the wastewater activity needs to be less than 0.1 Bq/L before discharge.
Solid waste treatment: Dust and waste materials need to be solidified (e.g. mixed with cement matrix) and stored in a dedicated radioactive waste repository, which is regularly handed over to professional institutions for disposal.
Documentation and supervision: Waste disposal is subject to regular inspections by environmental protection authorities that record activity, weight, and disposal methods.

CTIA GROUP LTD WT20 electrode

Chapter 5 Uses of Thorium Tungsten Electrode

Due to its excellent physical, chemical and welding properties, thorium tungsten electrodes have a wide range of applications in industrial fields, especially in tungsten argon arc welding (TIG welding), plasma welding and other special industrial scenarios. The low electron escape work, high arc stability and low burn-out rate of thorium tungsten electrodes make them the material of choice for high-precision and high-load welding. However, due to the trace amount of radioactivity brought by thorium oxide (ThO_2), the application scenarios are limited, which promotes the development and substitution of non-radioactive electrodes. This chapter will discuss in detail the application of thorium tungsten electrodes in the field of welding, other industrial uses, and the limitations of their application scenarios.

5.1 Application of thorium tungsten electrode in the field of welding

The application of thorium tungsten electrode in the welding field is mainly concentrated in tungsten argon arc welding (TIG welding), plasma welding and direct current negative electrode (DCEN) welding process. Its excellent arc initiation performance and arc stability make it an ideal choice for welding high melting points and refractory metals, and are widely used in aerospace, nuclear industry, petrochemical, automotive manufacturing and shipbuilding industries.

5.1.1 Tungsten inert gas welding

Tungsten Inert Gas Welding (TIG) is a welding method that uses tungsten electrodes to generate an arc under the protection of an inert gas (such as argon or helium), and is widely used in a variety of industrial scenarios because of its high precision and high quality welds. Thorium tungsten electrodes dominate TIG welding, especially in direct current anode (DCEN) and certain alternating current (AC) welding processes.

Performance Benefits

The low electron work of the thorium tungsten electrode (approx. 2.63 eV) makes it easy to initiate arcing at low voltages, reducing heat input during arc initiation, making it suitable for precision welding. Its high arc stability allows it to maintain a concentrated and continuous arc over a wide current range (50-500 A), reducing spatter and weld defects. In addition, the low burn-out rate of thorium tungsten electrodes prolongs the service life and reduces production costs. Different types of thorium tungsten electrodes (e.g. WT10, WT20, WT30, WT40) can be selected according to current and material requirements:

WT10 (0.8-1.2% ThO_2): suitable for low-current (50-150 A) precision welding, such as thin sheet stainless steel or copper alloys.
WT20 (1.7-2.2% ThO_2): suitable for medium to high currents (100-300 A) and is the most commonly used model in TIG welding.
WT30/WT40 (2.8-4.2% ThO_2): Suitable for high-current (200-500 A) heavy-duty welding, such as thick plate titanium or nickel alloys.

Application scenarios

Aerospace: TIG welding uses thorium tungsten electrodes (typically WT20 or WT30) to weld titanium alloys (e.g., Ti-6Al-4V) and nickel-based alloys (e.g., Inconel 718) for the manufacture of aircraft fuselages, engine blades, and turbine components. These components require high strength, no defects and excellent corrosion resistance of the weld, and the stable arc and low burn-out rate of the thorium tungsten electrode ensure the quality of the weld. For example, in the manufacture of Boeing 787 aircraft, WT20 electrodes are used for TIG welding of titanium alloy fuselage structures to ensure the mechanical properties and fatigue life of the welds.

Nuclear industry: Thorium tungsten electrodes are widely used in TIG welding of pressure vessels and pipelines in nuclear power plants. The WT30 or WT40 electrodes are capable of providing a stable arc at high currents, welding thick-walled stainless steels (e.g., 316L) or nickel alloys, ensuring that the weld is free of porosity and cracks. For example, in the manufacture of the AP1000 reactor pressure vessel of the Chinese nuclear industry, thorium tungsten electrodes are used for the welding of key components.

Petrochemical industry: Thorium tungsten electrodes are used to weld corrosion-resistant pipes and vessels, such as stainless steel (304, 316) and nickel-based alloys (Hastelloy). The arc stability of the WT20 electrode at medium and high currents ensures the uniformity and corrosion resistance of the weld seam to meet the needs of harsh chemical environments.

Automobile manufacturing: Thorium tungsten electrodes are used for TIG welding of high-strength steel and aluminum alloys, such as the manufacture of automobile suspension and exhaust systems. The WT10 electrode is suitable for welding thin-walled parts at low currents, reducing thermal distortion and material damage.

Operational precautions

When using thorium tungsten electrodes in TIG welding, it is necessary to select the appropriate electrode diameter (1.6-6.4 mm) and grinding angle (15°-45°) depending on the material and current. Sharp grinding angles (20°-30°) can concentrate the arc and improve accuracy; The large angle (30°-45°) is suitable for high-current welding and enhances durability. The shielding gas flow rate (8-15 L/min) needs to be tightly controlled to avoid arc drift or electrode oxidation. Grinding electrodes requires the use of a dedicated grinder and a dust collection device to reduce the risk of radioactivity.

5.1.2 Plasma welding

Plasma arc welding (PAW) is a welding method that uses confined arc to generate high-temperature plasma flow, which has higher energy density and welding accuracy, and is suitable for precision welding of materials with high melting points. Thorium tungsten electrodes excel in plasma welding because of their ability to maintain a stable arc in a high-temperature and high-pressure plasma environment.

Performance Benefits

The arc temperature of plasma welding can reach 15000-20000°C, which requires extremely high thermal stability and burn resistance of the electrode. The high melting point (3422°C) of the thorium tungsten electrode and the thermal electron emission capability of thorium oxide allow it to withstand such extreme conditions. WT20 and WT30 electrodes are the first choice for plasma welding due to their moderate thorium oxide content (1.7-3.2%) and low burn-out rate. The low electron work of the electrodes ensures fast arcing in high-frequency arc initiation or pulse mode, while arc stability ensures uniformity and depth of the weld.

Application scenarios

Aerospace: Plasma welding uses thorium tungsten electrodes to weld titanium and nickel alloy components, such as rocket engine nozzles and aerospace turbine blades. The WT20 electrode is capable of providing a stable plasma arc at high energy densities, ensuring weld depth and strength. For example, thorium tungsten electrodes are used for precision plasma welding in SpaceX's Falcon rocket fuel tank welding.

Medical devices: Plasma welding is used to make stainless steel or titanium alloy medical devices, such as surgical instruments and implants. The WT10 electrode is suitable for thin-walled materials in low-current plasma welding, reducing the heat-affected zone (HAZ) and ensuring surface quality.

Electronics industry: Thorium tungsten electrodes are used in miniature plasma welding for the connection of electronic components such as semiconductor packages and miniature circuit boards. The WT10 or WT20 electrodes provide fine arc control for high accuracy.

Operational precautions

In plasma welding, thorium tungsten electrodes need to use a smaller diameter (1.0-2.4 mm) to accommodate the plasma arc with high energy density. The electrode tip needs to be ground at a

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sharp angle (15°-25°) to concentrate the arc, and the flow rate of the shielding gas (argon or argon-helium mixture) needs to be precisely controlled (2-5 L/min). Due to the high temperature environment of plasma welding, the electrodes need to be equipped with water-cooled welding guns to reduce the heat load and prolong the service life.

5.1.3 DC anode welding (carbon steel, stainless steel, nickel alloy, titanium alloy, etc.)

Direct current anode (DCEN) welding is the most common application mode of thorium tungsten electrodes, where electrons flow from the electrode to the workpiece, and the heat is mainly concentrated on the workpiece, reducing the thermal load of the electrode. This mode is suitable for welding a wide range of metal materials, including carbon steel, stainless steel, nickel alloys, and titanium alloys.

Performance Benefits

In DCEN mode, the low electron work and arc stability of the thorium tungsten electrode enable it to rapidly initiate an arc and maintain a concentrated, continuous arc flow. Different types of electrodes are suitable for different currents and materials:

Carbon steel: WT10 or WT20 electrodes are suitable for welding carbon steel structural parts such as bridges and building frames at low to medium currents (50-200 A).

Stainless steel: The WT20 electrode provides a stable arc at a current of 100-300 A, which is suitable for welding stainless steel such as 304, 316, etc., and is widely used in petrochemical pipelines and food processing equipment.

Nickel alloys: WT30 or WT40 electrodes are suitable for welding Inconel or Hastelloy at high currents (200-400 A) for corrosion-resistant components in aerospace and chemical equipment.

Titanium alloys: WT20 or WT30 electrodes are suitable for welding titanium alloys (e.g., Ti-6Al-4V) at medium to high currents for use in aerospace and medical fields where high precision and oxygen-free environments are required.

The low burn-out rate of the thorium tungsten electrode ensures reliability for long-term welding, especially in the welding of thick plates or materials with high melting points. For example, the WT40 electrode is capable of continuous operation for several hours at 400 A with virtually no change in the shape of the electrode tip.

Application scenarios

Aerospace: Thorium tungsten electrodes are used for DCEN-TIG welding of titanium and nickel alloys, such as aircraft fuselages, engine components, and rocket fuel tanks. The WT20 electrode provides a stable arc at 150-250 A, ensuring high strength and corrosion resistance of the weld.

Nuclear industry: WT30 or WT40 electrodes are used for the welding of stainless steel and nickel alloy pressure vessels, such as the cooling pipes of nuclear reactors. The arc stability is high, the weld is defect-free, and it meets strict safety standards.

Petrochemical industry: Thorium tungsten electrodes are used for the welding of carbon steel and stainless steel pipes, such as oil pipelines in oil refineries. The WT20 electrode ensures corrosion resistance and mechanical properties of the weld at medium to high currents.

Marine industry: WT30 electrodes are used to weld high-strength steel plates, such as hull and deck structures, and the arc stability ensures the depth and quality of thick plate welding.

Operational precautions

In DCEN welding, the electrode diameter needs to be selected according to the current (1.6-6.4 mm) and the grinding angle (20°-35°) needs to be optimized to concentrate the arc. The shielding gas (argon or helium) flow rate should be maintained at 8-12 L/min to prevent electrode oxidation or melt pool contamination. Regularly check the condition of the electrode tip and re-grind if necessary to restore performance.

5.2 Application of thorium tungsten electrode in other industries

In addition to welding, thorium tungsten electrodes also have important applications in other industrial scenarios, especially in vacuum electronics and arc cutting, where their high melting point and thermal electron emission capabilities make them key materials.

5.2.1 Cathode materials in vacuum electronics

Thorium tungsten electrodes are used as cathode materials for vacuum electronic devices such as microwave tubes, X-ray tubes, and cathode ray tubes due to their low electron escape work and high thermal stability. The cathode is the core component of emitting electrons in electronic devices, and the material is required to be able to work stably in a high temperature and high vacuum environment.

Performance Benefits

The thorium oxide doping of the thorium tungsten electrode significantly reduces the electron escape work (2.63 eV), making it emit a large number of electrons at a lower temperature (about 1500-2000°C), which is better than that of pure tungsten cathode (above 2500°C). Its high melting point and resistance to burnout ensure the durability of the cathode in high-power operation. WT20 and WT30 electrodes are often used in such applications due to their moderate thorium oxide content.

Application scenarios

Microwave tubes: Thorium tungsten electrodes are used as cathodes in microwave tubes for radar and communication equipment, such as magnetrons and traveling wave tubes. Its stable electron emission capability ensures high-frequency performance and long life of the device. For example, in military radar systems, the WT20 electrode cathode is capable of thousands of hours of continuous operation at high power.

X-ray tubes: Thorium tungsten electrodes are used in the cathodes of medical and industrial X-ray tubes to produce a stable electron beam to excite X-rays. The low electron work and high thermal stability of the WT20 electrode are suitable for high-intensity X-ray equipment such as CT scanners.

Cathode ray tube (CRT): Although CRT technology is gradually being phased out, thorium tungsten electrodes are still used as cathode materials in some special display devices, providing stable electron emission.

Operational precautions

In vacuum electronics, thorium tungsten electrodes need to operate in a high vacuum (10^{-6} Pa) environment to prevent oxidation or contamination. The electrode surface is precision polished (Ra<0.2 μm) to ensure uniform electron emission. Radioactive dust needs to be strictly controlled during production and installation, and operators need to wear protective equipment.

5.2.2 Arc cutting and arc initiation

Thorium tungsten electrodes are suitable for industrial scenarios with high energy density due to their high arc stability and high temperature resistance in arc cutting and arc initiation applications.

Performance Benefits

Arc cutting requires the electrode to maintain a stable arc in a high-temperature and high-pressure plasma environment, and the low electron work and high melting point of the thorium tungsten electrode allow it to quickly initiate high-intensity arcs and withstand extreme conditions. WT30 and WT40 electrodes are commonly used for arc cutting and arcing due to their low burn-out rate and high current tolerance.

Application scenarios

Plasma cutting: Thorium tungsten electrodes are used in plasma cutting machines to cut materials such as carbon steel, stainless steel, and aluminum alloys. The WT30 electrode provides a stable plasma arc at 200-400 A currents, ensuring cutting speed and precision. For example, in shipbuilding, WT30 electrodes are used to cut thick steel plates with flat cuts and a small heat-affected zone.
Electric arc furnaces: Thorium tungsten electrodes are used for arc initiation in small electric arc furnaces, especially in metallurgical laboratories, for melting alloys with high melting points. The WT40 electrode is capable of rapidly initiating arcing and maintaining stable operation at high currents.
Ignition device: Thorium tungsten electrodes are used in industrial ignition systems, such as those of gas turbines or boilers, and their fast arcing ability ensures reliable ignition performance.

Operational precautions

In arc cutting, the electrode needs to be equipped with an efficient cooling system (such as a water-cooled nozzle) to reduce the heat load and prolong the life. The electrode diameter (3.2-6.4 mm) and grinding angle (30°-45°) need to be optimized according to the cutting current. The thorium dust generated during the cutting process is collected by a high-efficiency filtration system to prevent radioactive contamination.

5.3 Limitations of thorium tungsten electrode application scenarios

Although thorium tungsten electrodes have significant advantages in welding and other industrial applications, their trace amounts of radioactivity and the development of alternative electrodes pose certain limitations to their application scenarios.

5.3.1 Radioactive use scenarios

Thorium oxide (ThO_2) in thorium tungsten electrodes contains thorium-232, which is a naturally occurring radioactive element that releases α particles and small amounts of β and γ rays. Although its activity concentration is low (WT10 is close to 1 Bq/g, WT40 is slightly above the exemption standard), it still requires strict radiological protection measures during production, storage and use, which limits its application in some scenarios.

Radiological risk

Production: Thorium dust generated during mixing, sintering and grinding can enter the human body through inhalation or contact, increasing the risk of internal radiation. Long-term exposure may cause lung or tissue damage, although the risk is low (annual effective dose of about 0.1 to 1 mSv).

Application: Electrode grinding in welding and cutting generates radioactive dust, which requires the use of special grinders and efficient ventilation systems. Operators are required to wear protective masks, and the workplace is required to regularly monitor radiation levels (X-γ dose rate< 0.1 μSv/h).

Environmental impact: Waste materials in production and use (such as dust, waste water and waste electrodes) should be disposed of in accordance with the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises for the Development and Utilization of Associated Radioactive Mines (Trial) to avoid polluting soil and water bodies.

Restricted scenes

Medical and food industries: Thorium tungsten electrodes are limited in the welding of medical devices and food processing equipment due to the risk of radioactivity. For example, Europe and North America have banned the use of thorium tungsten electrodes in food-grade stainless steel welding, switching to cerium tungsten or lanthanum tungsten electrodes.

Areas with high environmental requirements: The European Union and some states in the United States (such as California) have strict regulations on the use of radioactive materials, and thorium tungsten electrodes require special permits, which increases the cost of use.

High-precision electronics industry: In semiconductor and microelectronics manufacturing, the radioactivity of thorium tungsten electrodes can contaminate the cleanroom environment, limiting its application.

Response

To reduce the risk of radioactivity, companies need to be equipped with special equipment (such as closed grinders and HEPA filtration systems) and operators need to be trained in radiation protection. Waste treatment needs to comply with international and national standards (e.g. ICRP Publication 103 and GB 18871-2002) to ensure that activity concentrations and emissions are met.

5.3.2 Application trends of alternative electrodes

With the strengthening of environmental protection regulations and the research and development of non-radioactive electrodes, thorium tungsten electrodes are gradually replaced by cerium tungsten, lanthanum tungsten, zirconium tungsten and yttrium-tungsten electrodes in some application scenarios. These alternative electrodes are close to thorium tungsten electrodes in terms of performance and have no risk of radioactivity, which meets the environmental requirements of modern industry.

Performance of alternative electrodes

Cerium tungsten electrode (WC20): contains 1.8-2.2% cerium oxide, the electron work is about 2.7 eV, the arc initiation performance and arc stability are close to WT20, suitable for DCEN and AC welding, non-radioactive, widely used in medical and electronics industries.

Lanthanum tungsten electrode (WL20): containing 1.8-2.0% lanthanum oxide, arc stability and lifetime are better than cerium tungsten electrode, suitable for high-precision and heavy-duty welding, and has replaced thorium tungsten electrode in aerospace and nuclear industries.

Zirconium tungsten electrode (WZ8): containing 0.8% zirconia, specially designed for AC welding of aluminum and magnesium alloys, with good arc stability, suitable for light metal welding.

Yttrium-tungsten electrode (WY20): containing 1.8-2.2% yttrium oxide, the performance is close to that of lanthanum tungsten electrode, which is suitable for high-precision welding, but the cost is high and the market popularity is low.

Alternative trends

European and American markets: The European Union and the United States have phased out thorium tungsten electrodes, and lanthanum tungsten electrodes (WL20) have become the mainstream, accounting for more than 60% of the TIG welding electrode market. Cerium tungsten electrode (WC20) is also widely used in cost-sensitive scenarios.

Chinese market: As a large country of tungsten resources, thorium tungsten electrodes are still used in heavy industry due to cost advantages, but the share of lanthanum-tungsten and cerium-tungsten electrodes is increasing year by year, especially in the field of export products and high-end manufacturing.

Technology-driven: Advances in new doped materials (e.g., composite rare earth oxides) and production processes have further improved the performance of non-radioactive electrodes. For example, the burn-out rate of lanthanum tungsten electrodes at high currents is close to WT40, and the cost is gradually decreasing.

Future outlook

Although thorium tungsten electrodes still have performance advantages in high-current and heavy-duty welding, their radioactivity concerns have prompted the industry to accelerate the transition to non-radioactive electrodes. In the future, with the further tightening of environmental regulations and the maturity of alternative electrode technologies, thorium tungsten electrodes may gradually be limited to specific high-demand scenarios (such as the nuclear industry and aerospace), while non-radioactive electrodes will dominate more fields.

CTIA GROUP LTD WT20 electrode

Chapter 6 Production Equipment for Thorium Tungsten Electrode

The preparation of thorium tungsten electrodes involves multiple complex process steps from raw material handling to finished product processing, each of which requires high-precision, high-reliability special equipment to ensure the performance and quality of the electrode. At the same time, due to the trace radioactivity of thorium oxide (ThO_2), production equipment also needs to be equipped with strict protection and detection systems to protect operators and the environment. This chapter will discuss in detail the raw material handling equipment, powder metallurgy equipment, molding and processing equipment, radioactive protection equipment, and testing equipment used in the production of thorium tungsten electrodes.

6.1 Raw material processing equipment for thorium tungsten electrodes

Raw material processing is the first step in the production of thorium tungsten electrodes, which involves the grinding and sieving of tungsten powder and the doping process of thorium oxide. Special equipment needs to ensure high purity, uniform particle size and precise proportioning of raw materials, while controlling the diffusion of radioactive dust.

6.1.1 Tungsten powder grinding and screening equipment

Tungsten powder is the main raw material of thorium tungsten electrode, and its particle size, purity and morphology directly affect the density and welding performance of the electrode. Grinding and screening equipment is used to prepare high-purity tungsten powder with uniform particle size.

Grinding equipment

Equipment type: planetary ball mill or jet mill

Function: Grind crude tungsten powder (particle size 10-50 μm) to fine powder (1-10 μm) to improve the fluidity and bulk density of powder.

Key Parameters:
Speed: 200-600 rpm
Grinding medium: zirconia or carbide balls (2-10 mm diameter)
Grinding time: 4-12 hours
Atmosphere: Inert gas (e.g. argon) or vacuum to prevent oxidation

Features: The planetary ball mill has high efficiency and uniform grinding capacity, and is equipped with a cooling system to control the temperature and prevent the tungsten powder from overheating and oxidizing. The jet mill achieves contamination-free grinding through high-speed airflow collision, which is suitable for high purity requirements.
Typical models: Fritsch Pulverisette 5 (planetary ball mill), Hosokawa Alpine AFG (jet mill)
Maintenance requirements: Regularly clean the grinding jar and media, check the tightness, and prevent contamination by impurities.

Screening equipment
Equipment type: vibrating screen or ultrasonic screening machine
Function: The ground tungsten powder is graded according to the particle size, and the particle size range that meets the requirements (D50 is about 2-5 μm) is screened.
Key Parameters:
Mesh pore size: 1-10 μm
Vibration frequency: 20-50 Hz
Sieving time: 10-30 minutes

Features: The ultrasonic screening machine prevents fine powder from clogging the screen through high-frequency vibration and improves the screening efficiency. The equipment needs to be equipped with an airtight cover to prevent dust leakage.
Typical models: Russell Finex Compact Sieve， Retsch AS 200
Maintenance requirements: Replace the screen regularly and clean the screening chamber to ensure that there is no residual powder contamination.

Protective measures
The grinding and screening process is equipped with a local exhaust system and a high-efficiency filter (HEPA) to trap tungsten dust and prevent the risk of inhalation. Operators are required to wear dust masks and protective gloves, and the work area needs to be cleaned regularly.

6.1.2 Thorium oxide doping equipment
Thorium oxide (ThO_2) is a key dopan of thorium tungsten electrodes, and its uniform distribution is crucial for the electron work and arc stability of the electrodes. Doping equipment needs to ensure the precise ratio and mixing of tungsten powder and thorium oxide, as well as the control of radioactive dust.

Device type

Dry mixer: V-type mixer or three-dimensional mixer
Wet mixers: planetary ball mills or agitated ball mills
Chemical co-precipitation equipment: reactors and centrifuges (for high-end production)

Dry process mixer

Function: Tungsten powder and thorium oxide powder (particle size 0.5-2 μm) are evenly mixed with an accurate ratio of ±0.01%.
Key Parameters:
Speed: 50-200 rpm
Mixing time: 4-8 hours
Binder: Polyvinyl alcohol (PVA, 0.5-1%)

Features: The V-type mixer achieves efficient mixing through a double cone chamber, and the three-dimensional mixer improves uniformity through multi-axis movement. The equipment is lined with stainless steel or ceramic to prevent contamination.
Typical models: Hosokawa Nauta Mixer， WAB Turbula T2F
Protective measures: The equipment should be equipped with a closed cover and a negative pressure exhaust system to prevent the spread of thorium oxide dust. Operators are required to wear protective clothing and masks.

Wet mixer

Function: Tungsten powder and thorium oxide are mixed in deionized water or ethanol medium to improve uniformity, followed by drying to prepare doped powder.
Key Parameters:
Speed: 100-300 rpm
Grinding medium: zirconia balls
Mixing time: 6-12 hours
Drying temperature: 100-150°C (vacuum or inert atmosphere)

Features: Wet mixing reduces dust flying, suitable for high-precision doping. The drying equipment needs to be equipped with a condensation recovery system to prevent solvent discharge.
Typical models: Netzsch PMH/PML， Fritsch Pulverisette 7
Protective measures: The ball mill needs to be operated in a closed manner, and the waste liquid needs to be treated by precipitation and filtration to prevent the leakage of thorium compounds.

Chemical co-precipitation equipment

Function: Preparation of atomic-level homogeneous doped powder by co-precipitation of tungstate and thorium nitrate solution, suitable for high-end electrodes.
Key Parameters:
Reaction temperature: 60-80°C
pH: 7-9
Centrifugal speed: 5000-10000 rpm

Features: The reactor is equipped with a stirring and temperature control system, and the centrifuge realizes solid-liquid separation. The process is complex but extremely homogeneous.
Typical models: IKA RW 20 (reactor), Beckman Coulter Avanti J-26
Protective measures: Wastewater needs to be treated by ion exchange, and the exhaust gas of the reactor needs to be discharged through the activated carbon filter.

6.2 Powder metallurgy equipment for thorium tungsten electrodes

Powder metallurgy is the core process of thorium tungsten electrode preparation, which involves mixing, pressing and sintering steps to transform the doped powder into a highly dense electrode body. The equipment needs to be highly accurate and consistent.

6.2.1 Mixers

Function: Tungsten powder, thorium oxide and binder are homogeneously mixed to provide high-quality raw materials for pressing.
Equipment type: V-type mixer, three-dimensional mixer, double cone mixer
Key Parameters:
Volume: 5-100 L
Speed: 50-150 rpm
Mixing time: 4-8 hours

Features: The mixer needs to be equipped with frequency conversion speed regulation and timing function, and is lined with wear-resistant ceramic or stainless steel to prevent pollution. Some high-end models support online particle size monitoring.
Typical models: Hosokawa Micron Vrieco-Nauta，Shuanglong V-500
Maintenance requirements: Regularly inspect the seals, clean the inner cavity, and prevent cross-contamination.
Protective measures: Equipped with an airtight hood and a HEPA filter, the operating area should be isolated to prevent the spread of radioactive dust.

6.2.2 Presses

Function: The mixed powder is pressed into a primary billet (rod or plate) to provide the basis for sintering.
Equipment type: cold isostatic press (CIP), hydraulic molding machine
Key Parameters:
Pressure: 100-200 MPa
Holding time: 1-3 minutes
Mold material: tungsten carbide or stainless steel

Features: The cold isostatic press applies uniform pressure through the liquid medium, and the density of the primary blank reaches 60-70%. The hydraulic molding machine is suitable for small batch production and has a lower cost.
Typical models: EPSI CIP 400，Dorst TPA 50
Maintenance requirements: Regularly check the hydraulic system and mold wear to ensure that the

pressure is stable.

Protective measures: The press needs to be equipped with a dust cover, and the operator needs to wear protective gloves.

6.2.3 High temperature sintering furnace

Function: Densification of the primary blank through high temperature treatment to form a high-density electrode body.

Equipment type: resistance sintering furnace, induction sintering furnace, vacuum sintering furnace

Key Parameters:

Temperature: 2000-2800°C

Atmosphere: Hydrogen (purity> 99.999%) or vacuum (10^{-4} Pa).

Keep warm: 2-4 hours

Cooling rate: 10-20°C/min

Features: Resistance sintering furnace is suitable for mass production, induction sintering furnace heating speed is fast, vacuum sintering furnace is suitable for high-end electrodes. The furnace material is molybdenum or graphite, which is resistant to high temperatures.

Typical models: Nabertherm HTK，ALD Vacuum Technologies VIM

Maintenance requirements: Regularly check the furnace tightness and heating elements, and clean the residue.

Protective measures: The sintering furnace needs to be equipped with an exhaust gas treatment system to prevent hydrogen leakage or volatilization of thorium compounds.

6.3 Forming and processing equipment for thorium tungsten electrode

Forming and processing equipment is used to process sintered bodies into electrode rods that meet specifications, ensuring dimensional accuracy and surface quality.

6.3.1 Calenders

Function: Machining of the sintered body to the required diameter (0.5-10 mm) by means of multi-pass hot or cold rolling.

Equipment type: multi-roll calender, rotary forging machine

Key Parameters:

Temperature: 1400-1800°C (hot calendered)

Calendering speed: 0.5-2 m/min

Deformation: 10-20%/pass

Features: The multi-roll calender is equipped with precision molds and a heating system to ensure a diameter tolerance of ±0.05 mm. The rotary forging machine is suitable for small diameter electrodes and has high efficiency.

Typical models: SMS Group 4-Hi Mill，Daniel & C. Swaging Machine

Maintenance requirements: Regularly check the wear of the roller surface and the heating system, lubricate the transmission parts.

Protective measures: The calender needs to be equipped with a high-temperature protective cover to prevent the operator from being burned.

6.3.2 Grinding and polishing equipment

Function: Improve electrode surface quality by coarse grinding, fine grinding and polishing with a roughness of Ra 0.2-0.4 μm.
Equipment type: centerless grinder, special polishing machine
Key Parameters:
Grinding wheel size: 80-400 mesh
Speed: 2000-5000 rpm
Cooling method: water cooling

Features: Centerless grinding machine realizes continuous grinding and high efficiency; The polishing machine uses diamond polishing paste and cloth wheels to achieve a mirror effect.
Typical models: Glebar GT-610,Struers Tegramin
Maintenance requirements: Replace the grinding wheel and polishing cloth regularly, and check the cooling system.
Protective measures: Equipped with a closed cover and an efficient dust removal system to prevent the spread of thorium dust.

6.4 Radioprotective equipment for thorium tungsten electrodes

The trace radioactivity of thorium oxide (thorium-232) requires production equipment to be equipped with special protection systems to reduce health and environmental risks.

6.4.1 Special grinder and dust removal system

Function: Collects radioactive dust when grinding electrodes to prevent inhalation or diffusion.
Equipment type: closed grinder, high-efficiency dust collector
Key Parameters:
Grinding wheel material: diamond
Dust collection efficiency: >99.9% (HEPA filter)
Air flow: 500-1000 m^3/h

Features: The grinder is equipped with a transparent protective cover and a negative pressure suction port, and the dust collector uses multi-stage filtration (coarse filtration + HEPA).
Typical models: Weldcraft Dedicated Grinder， Donaldson Torit DFO
Maintenance requirements: Replace the filter regularly and clean the vacuum pipe.
Protective measures: Operators need to wear dust masks, and dust needs to be sealed and stored.

6.4.2 Enclosures and ventilation equipment

Function: Isolate radioactive dust and keep the working environment clean.
Equipment type: local exhaust hood, central ventilation system
Key Parameters:
Wind speed: 0.5-1 m/s
Filtration efficiency: >99.9%

Noise: <70 dB

Features: Containment covers mixing, grinding and sintering equipment, ventilation system with activated carbon and HEPA filters.
Typical models: Nederman Fume Extractor，Camfil APC Farr Gold Series
Maintenance requirements: Regularly check the air duct tightness and filter saturation.
Protective measures: The ventilation system needs to regularly check the activity of the exhaust gas to ensure that it meets the standard.

6.4.3 Radioactive waste disposal equipment

Function: Treatment of radioactive waste (dust, wastewater, solid waste) in production.
Type of equipment: Wastewater treatment system, solidification equipment, sealed storage container
Key Parameters:
Wastewater activity: <0.1 Bq/L (after treatment)
Curing material: cement or resin
Storage container: stainless steel, thickness > 2 mm

Features: Wastewater treatment system removes thorium compounds through sedimentation, filtration, and ion exchange; The curing equipment mixes the dust into the cement matrix; Storage containers are marked with a radioactive warning.
Typical models: Veolia Water Technologies RO，Orano Waste Containers
Maintenance requirements: Regularly check the wastewater discharge and solidification strength, and update the storage records.
Protective measures: Waste disposal should be carried out in a segregated area, and operators should be trained in radiation protection.

6.5 Testing equipment for thorium tungsten electrode

Testing equipment is used to monitor electrode quality and radioactivity levels to ensure that products meet standards such as ISO 6848:2015 and safety requirements.

6.5.1 X-γ radiation dose rate detector

Function: Measure X-ray and γ-ray dose rates in the production environment and on the electrode surface.
Device type: Portable radiation dosimeter
Key Parameters:
Measuring range: 0.01-100 μSv/h
Accuracy: ±5%
Detector: GM counter tube or NaI crystal

Features: Real-time display of dose rate, support data recording, suitable for workshop inspection.
Typical models: RadEye PRD（Thermo Scientific），AT1123（Atomtex）
Maintenance requirements: Regular calibration (once a year) to check detector sensitivity.
Scenario of use: Detection of radiation levels in mixing, grinding and storage areas to ensure < 0.1

μSv/h.

6.5.2 α, β surface contamination detector

Function: Measure α, β particle contamination on the electrode surface and the surface of the device.
Device Type: Portable Surface Contamination Meter
Key Parameters:
Measuring range: 0.1-1000 Bq/cm²
Detection efficiency: >30%(a),>40%(b)
Detector: ZnS scintillator or gas proportional counting tube

Features: High sensitivity, suitable for detecting trace amounts of thorium-232 contamination, supporting fast scanning.
Typical models: Ludlum Model 43-93, XH-3206 (China Nuclear Instruments)
Maintenance Requirements: Calibrate regularly and check the integrity of the detector window.
Usage scenario: Detection of contamination of electrode surfaces, equipment walls, and waste containers after grinding.


CTIA GROUP LTD WT10 electrode

CTIA GROUP LTD

Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

Email: sales@chinatungsten.com

Phone: +86 592 5129595; 592 5129696

Website: www.tungsten.com.cn

Chapter 7 Domestic and Foreign Standards for Thorium Tungsten Electrode

As a key material for tungsten inert gas shielded welding (TIG welding) and plasma welding, the production and use of thorium tungsten electrode are subject to strict international and domestic standards. These standards cover the classification of electrodes, performance requirements, quality control, and radiological safety management, ensuring their consistency and safety in industrial applications. Since the thorium tungsten electrode contains trace amounts of radioactive thorium oxide (ThO_2), the relevant standards also include specific requirements for radiation protection and environmental management. This chapter will discuss in detail the international and domestic standards for thorium tungsten electrodes, as well as the radiological safety standards.

7.1 International standards for thorium tungsten electrodes

The international standard provides a unified technical specification for the production, classification and use of thorium tungsten electrodes, which are widely used in the global welding industry. Major international standards include ISO 6848:2015, AWS A5.12/A5.12M, and EN 26848, which specify in detail the chemical composition, physical properties, dimensional specifications, and identification methods of thorium tungsten electrodes.

7.1.1 ISO 6848:2015 (Classification and requirements for tungsten electrodes)

ISO 6848:2015 "Arc welding and cutting — Nonconsumable tungsten electrodes — Classification" is a classification standard for tungsten electrodes developed by the International Organization for Standardization (ISO) for non-consumable tungsten electrodes, including thorium tungsten electrodes, in TIG welding and plasma welding.

Standard content

Classification: The standard divides thorium tungsten electrodes into four types according to the thorium oxide (ThO_2) content:
WT10: 0.8-1.2% ThO_2, yellow applied
WT20: 1.7-2.2% ThO_2, red applicator
WT30:2.8-3.2% ThO_2, purple coating
WT40: 3.8-4.2% ThO_2, orange-yellow applicator

Chemical composition: The purity of the tungsten matrix ≥ 99.5%, and the total content of impurities (such as Fe, Ni, C) < 0.05%. The thorium oxide content needs to be precisely controlled, and the deviation is ± 0.1%.
Dimensions: Electrode diameter range of 0.5-10 mm, tolerance ± 0.05 mm; Lengths are typically 50 mm, 75 mm, 150 mm or 175 mm with tolerances ± 1 mm.
Surface quality: The surface of the electrode should be smooth, free of cracks, oxides or oils, and the roughness should be Ra≤0.4 μm.
Performance requirements: The electrode needs to meet specific arc stability, arc initiation performance, and burn-out rate requirements. For example, the WT20 needs to maintain a stable arc at 100-300 A with a burn-out rate of < 0.1 mm/h.
Labeling: The upper part of the electrode should be color-coded (e.g. red for WT20) and the model,

batch and manufacturer information should be indicated on the packaging.

Scope of application

ISO 6848:2015 applies to the global welding industry and is the basis for international trade and quality certification. The standard also classifies non-radioactive electrodes (e.g., cerium tungsten, lanthanum tungsten), reflecting the trend towards replacing thorium tungsten electrodes.

Features and significance

Uniformity: Provide a unified classification and performance standard for global thorium tungsten electrode manufacturers and users, which is convenient for quality control and international trade.
Safety: The standard mentions the radioactive risk of thorium oxide and recommends protective measures during production and use, such as ventilation systems and dust collection devices.
Update: The 2015 edition updates the 1992 edition with additional requirements for environmental protection and radiological protection, reflecting the development trend of non-radioactive electrodes.

Implementation requirements

Manufacturers are required to pass the audit of the ISO certification body to ensure that the production process and product quality meet the standards. Detection methods include X-ray fluorescence spectroscopy (XRF) analysis of compositions, laser diameter measurement for size detection, and metallographic microscopy for microstructure.

7.1.2 AWS A5.12/A5.12M (American Welding Institute Tungsten Electrode Specification)

AWS A5.12/A5.12M:2009 "Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting" is a tungsten electrode specification developed by the American Welding Society (AWS) and widely used in the welding industry in North America and other regions.

Standard content

Classification: Similar to ISO 6848, thorium tungsten electrodes are divided into WT10, WT20, WT30 and WT40, and the color labeling is consistent.
Chemical composition: Specified thorium oxide content (0.8-4.2%) and impurity limits (e.g. O<0.02%, Fe <0.01%). The purity of tungsten powder is required to be ≥ 99.95%.
Physical properties: The electrode needs to meet specific conductivity (>30% IACS) and hardness (350-450 HV). The burn-off rate needs to be < 0.08 mm/h at 200 A.
Dimensions & Tolerances: Diameter 0.5-6.4 mm, Tolerance±0.03 mm; Length 75-300 mm with ± tolerance of 1.5 mm.
Test methods: including chemical analysis (ICP-OES), arc stability test (performed under argon protection) and surface quality inspection (microscopic observation).
Radioactive Warning: The standard clearly requires that the radioactive risk of thorium oxide be marked in the packaging and instructions, and special grinding equipment and protective measures are recommended.

Scope of application

AWS A5.12 is suitable for TIG welding, plasma welding, and arc cutting, especially in the aerospace, automotive, and petrochemical industries. This standard is widely followed by welding equipment manufacturers and users in the United States and Canada.

Features and significance

Detail: The standard provides detailed test methods and performance indicators, such as arc starting voltage (<15 V) and burn-out rate, suitable for industrial applications.

Safety: Emphasis on radiological protection, the use of closed grinders and high-efficiency filters is recommended to reduce thorium dust exposure.

Compatibility: Highly compatible with ISO 6848 for easy coordination in international markets.

Implementation requirements

Manufacturers need to be certified by AWS, and testing equipment must comply with ASTM standards (e.g., ASTM E1476). Users need to calibrate their welding equipment regularly to ensure that the electrode performance meets specifications.

7.1.3 EN 26848 (European standard for tungsten electrodes)

EN 26848:1991 "Welding — Tungsten electrodes for inert gas shielded arc welding and for plasma welding" is a tungsten electrode standard developed by the European Committee for Standardization (CEN) for the welding industry in EU countries.

Standard content

Classification: Consistent with ISO 6848, thorium tungsten electrodes are divided into WT10, WT20, WT30 and WT40, and the color mark is the same.

Chemical composition: Thorium oxide content requirements are consistent with ISO 6848, and impurity limits are stricter (e.g., C<0.005%, S<0.002%).

Dimensions: diameter 0.5-10 mm, tolerance ± 0.04 mm; Length 50-300 mm, tolerance ± 1 mm.

Performance requirements: The electrode needs to pass the arc stability test (100-400 A) and the burn rate test (<0.1 mm/h). The surface roughness is Ra≤0.3 μm.

Radiological management: Requires compliance with the EU Radiation Protection Directive (2013/59/Euratom) in production and use, including dust control and waste disposal.

Scope of application

EN 26848 applies to TIG welding and plasma welding in EU countries, especially in the aerospace, nuclear industry and shipbuilding. Due to the strict regulation of radioactive materials in the European Union, this standard promotes the application of non-radioactive electrodes such as lanthanum tungsten and cerium tungsten.

Features and significance

Environmental protection: Emphasis on radioactive protection and waste management, in line with EU environmental regulations.

Regional: Primarily serving the European market, it is compatible with ISO 6848 and AWS A5.12, but with a greater focus on environmental protection and safety.

Limitations: The 1991 version is older and does not fully reflect the trend of non-radioactive electrodes.

Implementation requirements

EU companies are required to pass CE certification, and production workshops need to be equipped with radiation monitoring equipment and waste treatment facilities. Users are required to comply with local radiation protection regulations and regularly check the radiation level of the working environment.

7.2 Domestic standards for thorium tungsten electrodes

As the world's largest tungsten resource and producer of thorium tungsten electrodes, China has formulated a series of national standards covering the performance, quality and radioactive safety management of electrodes. These standards include GB/T 4187-2017, GB 18871-2002 and Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises in the Development and Utilization of Associated Radioactive Mines (for Trial Implementation).

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

GB/T 4187-2017 "Tungsten electrodes for tungsten inert gas arc welding and plasma welding" is a Chinese national standard, which stipulates the classification, performance and testing methods of tungsten electrodes, and is suitable for TIG welding and plasma welding.

Standard content

Classification: Thorium tungsten electrodes are divided into WT10, WT20, WT30 and WT40, which are consistent with international standards and have the same color marking.
Chemical composition: thorium oxide content requirements: WT10 (0.8-1.2%), WT20 (1.7-2.2%), WT30 (2.8-3.2%), WT40 (3.8-4.2%). Tungsten purity ≥ 99.95%, impurity limits (e.g. Fe<0.01%, O<0.015%).
Dimensions: diameter 0.5-10 mm, tolerance ± 0.05 mm; Length 50-300 mm, tolerance ± 1 mm.
Performance requirements: The electrode needs to meet the requirements of arc starting voltage (<15 V), arc stability (no drift at 100-400 A) and burn-out rate (<0.1 mm/h).
Inspection methods: including chemical analysis (ICP-OES), dimensional measurement (laser caliper), surface quality inspection (microscope) and arc performance testing.
Identification and packaging: The electrode part shall be colored, and the packaging shall be marked with the model, specification, batch and radioactive warning.

Scope of application

GB/T 4187-2017 is the basic standard for China's welding industry, which is widely used in aerospace, petrochemical, nuclear industry and shipbuilding. The standard supports the export electrode to meet the requirements of the international market.
Features and significance

Localization: Combined with the advantages of China's tungsten resources, the production process requirements are optimized and the cost is reduced.

Compatibility: Highly consistent with ISO 6848 and AWS A5.12 for easy international trade.
Safety: Emphasis on radioactive protection, requiring production enterprises to equip with dust collection and waste disposal facilities.

Implementation requirements

The manufacturer needs to pass the national quality certification (such as CNAS), and the testing equipment must meet the accuracy requirements specified in the standard. The user needs to calibrate the welding equipment regularly to ensure the performance of the electrodes.

7.2.2 GB 18871-2002 (Basic Standard for Protection against Ionizing Radiation and Safety of Radiation Sources)

GB 18871-2002 "Basic Standard for Protection against Ionizing Radiation and Safety of Radiation Sources" is a national standard for ionizing radiation protection in China, which is applicable to the production and use of radioactive materials including thorium tungsten electrodes.

Standard content

Principles of radiation protection: optimal protection, dose limitation, and justification. The annual effective dose is required < 1 mSv (public) and < 20 mSv (occupational exposure).
Radiation monitoring: The production workshop should be equipped with X-γ radiation dose rate detector (measurement range 0.01-100 μSv/h) and α and β surface pollution detector (measurement range 0.1-1000 Bq/cm^2).
Waste management: Radioactive waste (dust, wastewater, waste electrodes) needs to be collected, solidified and stored in a dedicated facility with an activity concentration of <1 Bq/g.
Protective measures: Operators need to wear protective clothing and dust masks, and the working area needs to be equipped with ventilation and dust removal systems.

Scope of application

The standard applies to the production, storage and use of thorium tungsten electrodes, especially in mixing, grinding and waste disposal. Enterprises are required to report radiation monitoring data to the environmental protection authorities on a regular basis.

Features and significance

Comprehensive: Covers all aspects of radiation protection to ensure the safety of operators and the environment.
Mandatory: As a national mandatory standard, enterprises must comply with it or face penalties.
Guidance: Provides clear guidance for radioactive waste disposal and the configuration of protective equipment.

Implementation requirements

Enterprises need to establish a radiation safety management system, and assign professionals to be responsible for monitoring and recording. The environmental protection department conducts regular inspections to ensure that the standard requirements are met.

7.2.3 Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises for the Development and Utilization of Associated Radioactive Minerals (for Trial Implementation)

The Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises for the Development and Utilization of Associated Radioactive Minerals (for Trial Implementation) (hereinafter referred to as the "Measures") is a regulation formulated by the Ministry of Environmental Protection of the People's Republic of China for the management of associated radioactive materials, including the production of thorium tungsten electrodes.

Standard content

Monitoring requirements: Enterprises need to monitor the X-γ dose rate (<0.1 μSv/h) and α and β surface contamination (<0.4 Bq/cm²) in the production environment. The wastewater activity should be <0.1 Bq/L.

Information disclosure: Enterprises are required to submit radiation monitoring reports to the environmental protection department every year, and disclose waste treatment and emission data.

Waste disposal: Radioactive waste needs to be cured (e.g. cement) or buried deep to prevent environmental pollution.

Protective facilities: The production hall needs to be equipped with an airtight hood, a HEPA filter and a dedicated waste repository.

Scope of application

The Measures apply to all industrial activities involving thorium-232 in China, including thorium tungsten electrode manufacturers. Especially in the dust and wastewater treatment process, there are strict requirements.

Features and significance

Environmental protection orientation: Promote enterprises to adopt green production technology and reduce radioactive pollution.

Transparency: Require information disclosure and enhance public scrutiny.

Regional: Combined with the characteristics of China's tungsten resources and electrode production, the protective measures have been refined.

Implementation requirements

Enterprises need to establish an environmental radiation monitoring system, equipped with professional testing equipment (such as AT1123, XH-3206), and accept the annual inspection of the environmental protection department. Non-compliant enterprises need to rectify or stop production.

7.3 Radioactive safety standards for thorium tungsten electrodes

The radioactivity safety standard for thorium tungsten electrodes is mainly for thorium-232 (Th-232) in thorium oxide, and covers exemption from activity concentrations, protective requirements in production and use, and waste management.

7.3.1 Thorium-232 exempt activity concentration (1 Bq/g)

Thorium-232 is the main radionuclide in the thoriated tungsten electrode with a half-life of about 14 billion years, releasing α particles (4.01-4.08 MeV) as well as small amounts of β and γ rays. International and domestic standards specify the exempt activity concentrations of thorium-232.

Standard content

International Standard (ICRP Publication 103):

The exempt activity concentration of thorium-232 is 1 Bq/g, below which no special supervision is required.

WT10 (0.8-1.2% ThO_2) activity concentrations close to 1 Bq/g are generally exempt; WT40 (3.8-4.2% ThO_2) may be slightly higher than the exemption standard and needs to be strictly managed.

Chinese Standard (GB 18871-2002):

The exempt activity concentration was consistent with ICRP, 1 Bq/g.

Waste activity concentrations of <1 Bq/g can be treated as ordinary waste, otherwise they need to be managed as radioactive waste.

Detection method: The activity concentration was measured using a high-purity germanium γ spectrometer or a liquid scintillation counter with an accuracy of ±5%.

significance

The exemption from the activity concentration setting reduces the regulatory cost of low-radioactive electrodes (e.g., WT10), but requires stricter protection and waste disposal measures for electrodes with high thorium oxide content (e.g., WT40).

Implementation requirements

Manufacturers need to regularly check the activity concentration of electrodes and waste, record the data and archive it. The frequency of testing is 5-10% sampling per batch, and unqualified batches need to be reprocessed.

7.3.2 Protection requirements in production and use

The production and use of thorium tungsten electrodes involves mixing, sintering, grinding and welding, which may produce radioactive dust or exhaust gas, and strict protective measures need to be taken.

Protective measures

Production links:

Equipment protection: Mixers, sintering furnaces and grinding equipment need to be equipped with closed hoods and HEPA filters, and the capture efficiency is > 99.9%.

Personal protection: Operators are required to wear protective clothing, dust masks, and gloves, and receive regular radiation dose monitoring (effective dose < 1 mSv per year).

Environmental monitoring: The workshop needs to install X-γ radiation dose rate detector and α and β surface pollution detector to monitor the radiation level in real time.

Links:
Grinding protection: Use a special grinder, equipped with a negative pressure dust suction system, to prevent thorium dust from being inhaled.
Ventilation system: The welding station needs to be equipped with a local exhaust hood with a wind speed of 0.5-1 m/s, and the exhaust gas is treated through activated carbon and HEPA filters.
Specifications: Welders are trained in radiation safety and regularly inspected for electrode surface contamination.

Standard basis
International: ICRP Publication 103 and the EU Directive 2013/59/Euratom require the production and use of an ambient radiation dose rate of < 0.1 μSv/h and a surface contamination < 0.4 Bq/cm².
Domestic: GB 18871-2002 has the same requirements as the "Measures", the wastewater activity is < 0.1 Bq/L, and the exhaust gas emission must meet environmental protection standards.

Implementation requirements
Enterprises need to develop a radiation safety management system, and assign professionals to be responsible for monitoring and recording. Protective equipment needs to be calibrated regularly, and waste disposal needs to meet the requirements of the Measures.

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Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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Chapter 8 Detection Methods of Thorium Tungsten Electrode

The performance of thorium tungsten electrodes directly affects its performance in industrial applications such as tungsten argon arc welding (TIG welding) and plasma welding, so the detection of its chemical composition, physical properties, radioactivity level and welding performance is crucial. The detection method needs to ensure that the electrode complies with international and national standards (e.g., ISO 6848:2015, GB/T 4187-2017) and pay attention to the trace radioactivity risk posed by thorium oxide (ThO_2). This chapter will discuss in detail the chemical composition testing, physical property testing, radioactivity testing, welding performance testing, and testing equipment and calibration requirements of thorium tungsten electrodes.

8.1 Chemical composition detection of thorium tungsten electrodes

Chemical composition testing is used to verify the compliance of thorium oxide content and impurity elements in thorium tungsten electrodes to ensure that their performance meets the requirements of the standard (e.g., WT20 has a thorium oxide content of 1.7-2.2%).

8.1.1 Thorium oxide content analysis

Thorium oxide (ThO_2) is the key dopane of thorium tungsten electrodes, and its content directly affects the work of electron evolution and arc stability. Accurate detection of thorium oxide content is at the heart of quality control.

Detection method

X-ray fluorescence spectroscopy (XRF):
Principle: X-rays are used to excite sample atoms, analyze the characteristic fluorescence spectrum of their emission, and determine the thorium oxide content.
Device: Handheld or benchtop XRF analyzer.

Steps:
Sampling: 5-10 electrodes were randomly selected from the electrode batch and cut into thin sections (1-2 mm thick).
Surface treatment: Wash the sample with ethanol to remove oil and oxides.
Detection: The sample is placed in the XRF instrument, the analysis time is set (30-60 seconds), and the thorium (Th) signal is recorded.
Quantitative analysis: The thorium oxide content was calculated by calibration curve with an accuracy of ±0.01%.

Advantages: non-destructive, fast, suitable for batch inspection.
Limitations: The accuracy of the analysis of light elements (such as O) is low, and it needs to be verified in combination with other methods.

Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES):
Principle: The sample is dissolved and excited by plasma, and the emission spectrum is analyzed to determine the thorium content.

Device: ICP-OES instrument.

Steps:
Sample preparation: The electrode sample is dissolved in a nitric acid-hydrofluoric acid mixture solution (1:1) and heated until completely dissolved.
Dilution: Dilute with deionized water to the appropriate concentration (1-10 ppm).
Detection: The solution is introduced into the ICP-OES and the characteristic spectral lines of thorium (e.g., 401.91 nm) are determined.
Quantitative: Calibration with a standard solution was used to calculate the thorium oxide content with an accuracy of ± 0.005%.

Advantages: High precision, suitable for micro-analysis.
Limitations: Sample destructiveness, complex operation, and high cost.

Neutron Activation Analysis (NAA):
Principle: Irradiate the sample with neutrons, activate thorium-232 to generate radioisotopes, and measure γ rays to determine the content.
Equipment: nuclear reactor and γ spectrometer.

Steps:
Sample preparation: Cut electrode sample (mass 0.1-1 g).
Irradiation: 1-2 hours in a reactor with a neutron flux of 10^{13} n/cm²·s.
Measurements: Characteristic γ rays (e.g., 311.9 keV) of thorium-232 were analyzed with a γ spectrometer after cooling.
Quantitative: Calibrated by standard samples with an accuracy of ±0.01%.

Advantages: Extremely high accuracy, suitable for trace analysis.
Limitations: The equipment is expensive, requires the support of nuclear facilities, and is only used for scientific research or high-end testing.

Standard requirements:
According to ISO 6848:2015 and GB/T 4187-2017, the thorium oxide content should be controlled within the specified range (e.g. 1.7-2.2% for WT20) with a deviation of ±0.1%.
Detection frequency: 5-10% sampling per batch, no less than 3 electrodes.

Precautions
Samples need to be homogeneously representative of the batch to avoid segregation affecting the results.
Testing equipment needs to be calibrated regularly to ensure accuracy using standard samples such as NIST SRM 610.
The testing environment needs to be dustproof, and the operator needs to wear protective equipment to prevent radioactive dust from being inhaled.

8.1.2 Impurity content detection

Impurities (such as Fe, Ni, O, C) will affect the conductivity, mechanical properties and welding stability of thorium tungsten electrodes, and their content needs to be strictly controlled.

Detection method

Inductively Coupled Plasma Mass Spectrometry (ICP-MS):

Principle: The sample is dissolved and ionized by plasma, and the ion mass spectrometry is analyzed to determine the impurity element content.

Device: ICP-MS instrument.

Steps:

Sample preparation: Same as ICP-OES, dissolved in nitric acid-hydrofluoric acid mixed solution.

Dilution: Dilute to 0.1-1 ppm and add an internal standard (e.g., indium).

Detection: Determination of characteristic ions of Fe, Ni, O, C and other elements (such as Fe^{56}, Ni^{60}).

Quantitative: Calibrated with multi-element standard solution with a detection limit of <0.001%.

Advantages: High sensitivity, simultaneous analysis of multiple elements.

Limitations: Sample destructive and costly.

Glow Discharge Mass Spectrometry (GD-MS):

Principle: Ion mass spectrometry is analyzed by atomizing the sample surface by glow discharge.

Device: GD-MS instrument.

Steps:

Sample preparation: Cut the electrode and polish to Ra<0.4 μm.

Detection: Place the sample in the glow discharge chamber and set the discharge voltage (800-1000 V).

Analysis: Determine the signal intensity of impurity elements and analyze them quantitatively.

Advantages: Semi-non-destructive, suitable for surface analysis.

Limitations: Expensive equipment and limited depth of analysis.

Oxygen and nitrogen analyzers:

Principle: The oxygen and nitrogen content released is measured by melting the sample at high temperatures.

Equipment: Oxygen and nitrogen analyzer.

Steps:

Sample preparation: Cut the electrode into small pieces (0.1-0.5 g).

Detection: Heated to 2500°C in a helium atmosphere, the released gas is analyzed.

Quantitative: Calibrated by standard gas, accuracy ± 0.002%.

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Advantages: Dedicated to oxygen and nitrogen analysis, easy to operate.
Limitations: Limited to gaseous elements.

Standard requirements:
According to GB/T 4187-2017, impurity limits are: Fe<0.01%, Ni<0.005%, O<0.015%, C<0.005%.
Testing frequency: 5% sampling per batch, focusing on the detection of key impurities.

Precautions
Samples should be cleaned to avoid surface contamination.
The testing equipment needs to be calibrated regularly and use high-purity tungsten standard samples.
The test records need to be archived to facilitate quality traceability.

8.2 Testing of physical properties of thorium tungsten electrodes

Physical property testing is used to evaluate the density, hardness and grain structure of thorium tungsten electrodes to ensure that their mechanical properties and welding properties meet the requirements.

8.2.1 Density and hardness testing

Density test
Objective: To verify the density of the electrode and ensure the sintering quality (theoretical density of 19.25 g/cm³).
Method: Archimedes' method
Equipment: Precision electronic balance (accuracy ± 0.001 g) and density tester.

Steps:
Weighing: Measuring the dry weight of the electrode (m_1).
Immersion: The electrode is immersed in deionized water and the wet weight (m_2) and suspended weight (m_3) are measured.
Calculation: Density $\rho = m_1 / (m_1 - m_3) \times \rho_0$ (ρ_0 is the density of water, 1 g/cm³).
Standard requirements: density 18.5-19.0 g/cm³ (95-98% theoretical density).
Pros: Simple, accurate.
Limitations: Only suitable for regular-shaped samples.

Hardness test
Purpose: To evaluate the mechanical strength of the electrode and prevent fracture during welding.
Method: Vickers hardness test
Device: Vickers hardness tester.

Steps:
Sample preparation: Cut the electrode and polish to Ra<0.2 μm.
Test: Apply a load of 5-10 kgf, hold for 15 seconds, measure the indentation diagonal length.
Calculation: Hardness (HV) is calculated based on the indentation area.

Standard requirements: hardness 350-450 HV.
Advantages: high precision, suitable for hard materials.
Limitations: The sample needs to be destroyed, and the test points need to be evenly distributed.

Precautions
Deionized water is used for density testing to avoid air bubbles affecting the results.
The hardness test involves selecting multiple test points, with the average value representing the hardness of the sample.
Test frequency: 3-5 samples per batch, at least 3 locations are tested.

8.2.2 Grain structure analysis

The grain structure affects the mechanical properties and arc stability of the electrode and needs to be analyzed by microscopy and X-ray techniques.

Detection method
Metallurgical microscope:
Principle: Observe the grain morphology and thorium oxide distribution of the electrode cross-section by optical microscope.
Device: Metallurgical microscope.

Steps:
Sample preparation: Cutting electrodes, polishing and corrosion with acids (e.g., nitric-hydrofluoric acid).
Observation: 100-1000x magnification to analyze grain size and thorium oxide particle distribution.
Measurement: Calculate the grain size (10-50 μm) using image analysis software such as ImageJ.

Pros: Intuitive and suitable for quick analysis.
Limitations: Samples need to be destroyed and the depth of analysis is limited.

Scanning Electron Microscopy (SEM-EDS):
Principle: The sample is scanned by an electron beam, and the distribution of thorium oxide particles is analyzed by energy spectroscopy.
Device: SEM-EDS instrument.

Steps:
Sample preparation: Cutting, polishing, and plating of carbon or gold conductive layers.
Scanning: Set the accelerating voltage (15-20 kV) and observe the grains and thorium oxide particles (0.5-2 μm).
Analysis: Quantitative analysis of thorium distribution by EDS.

Advantages: High resolution, microstructure analysis.
Limitations: The equipment is expensive and the operation is complex.

X-ray diffraction (XRD):

Principle: Analyze the crystal structure and grain orientation of a sample.

Device: XRD instrument (e.g., Bruker D8 Advance).

Steps:

Sample preparation: Cut the electrode and polish it to a flat surface.

Detection: Cu Kα ray is set, and the scanning angle is 2θ (20°-80°).

Analysis: Determination of tungsten and thorium oxide phases by peak position and intensity, calculation of grain size (Scherrer formula).

Advantages: Non-destructive, crystal structure can be analyzed.

Limitations: Low precision for the analysis of fine grains.

Standard requirements:

Grain size: 10-50 μm, thorium oxide particles are uniformly distributed without agglomeration.

Detection frequency: 3 samples per batch, cross-section and longitudinal section are analyzed.

Precautions

Sample preparation needs to avoid the introduction of artificial defects.

SEM and XRD analyses need to be combined with metallurgical microscopy results to ensure data consistency.

Operators are required to wear protective equipment to prevent exposure to radioactive dust.

8.3 Radioactivity detection of thorium tungsten electrodes

Since thorium oxide contains thorium-232 (half-life of 14 billion years, emitting α, β, and γ rays), the radioactivity level of the electrode and production environment needs to be rigorously tested to ensure compliance with international and domestic standards (e.g., ICRP Publication 103, GB 18871-2002).

8.3.1 X-γ Radiation Dose Rate Detection (AT1123 Instrument)

objective

X-ray and γ-ray dose rates are measured on the electrode surface and in the production environment to ensure that the radiation level is below the safe limit (<0.1 μSv/h).

Detection method

Device: AT1123 X-γ Radiation Dose Rate Detector

Key Parameters:

Measuring range: 0.01-100 μSv/h

Accuracy: ±5%

Detector: NaI scintillation crystal

Steps:

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Calibration: Calibrate the instrument using the Cs-137 standard source.
Detection: Place the probe on the electrode surface (1 cm away) or in the working area (e.g., mixing, grinding area) and record the dose rate.
Data processing: Take the average of multiple measurements, record the time and location.

Standard requirements: electrode surface dose rate < 0.1 μSv/h, environmental dose rate < 0.05 μSv/h (GB 18871-2002).
Advantages: portable, real-time, suitable for on-site monitoring.
Limitations: Insensitive to α particles, requires a combination of other methods.

Precautions
Testing frequency: 5-10 pieces per batch, environmental monitoring once a day.
Electromagnetic interference is avoided to ensure instrument sensitivity.
The operator wears a personal dosimeter to record the cumulative dose.

8.3.2 α. β surface contamination detection (XH-3206 instrument)
objective
Detect α, β particle contamination on electrode surfaces and equipment to ensure that they are below the safe limit (<0.4 Bq/cm²).

Detection method
Equipment: XH-3206 α, β surface pollution detector
Key Parameters:
Measuring range: 0.1-1000 Bq/cm²
Detection efficiency: A>30%,B>40%
Detector: ZnS scintillator

Steps:
Calibration: Calibration using Am-241 (α) and Sr-90 (β) standard sources.
Detection: Place the probe close to the electrode surface or the surface of the device (<2 mm away), scan slowly, and record the count rate.
Calculation: Convert the surface contamination level (Bq/cm²) based on the detection efficiency.

Standard requirements: surface contamination < 0.4 Bq/cm² (GB 18871-2002).
Advantages: High sensitivity, suitable for trace contamination detection.
Limitations: Insensitive to γ-ray, combined with X-γ detection.

Precautions
Detection frequency: 3-5 pieces per batch, and the surface of the equipment is inspected weekly.
The surface of the sample should be cleaned to avoid oil or dust.
The testing area should be isolated to prevent cross-contamination.

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Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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8.3.3 Environmental radiation monitoring

objective

Monitor radiation levels on the production floor to ensure the safety of operators and the environment.

Detection method

Stationary Monitoring:

Equipment: Environmental radiation monitoring station.

Operation: Fixed probes are installed in mixing, sintering, grinding, and storage areas to record X-γ dose rates in real time.

Standard requirements: Ambient dose rate < 0.05 μSv/h.

Portable Monitoring:

Device: AT1123 or similar.

Operation: Inspect all areas of the workshop, and record the dose rate and contamination level on a daily basis.

Waste Monitoring:

Device: γ spectrometer.

Operation: Detect the activity concentration of waste materials (dust, wastewater, waste electrodes), <1 Bq/g can be treated as ordinary waste.

Precautions

Monitoring data should be archived and reported to the environmental protection department on a regular basis.

The workshop needs to be equipped with ventilation and dust removal systems to reduce dust concentration.

Monitoring frequency: stationary monitoring real-time recording, portable monitoring once a day, waste monitoring once per batch.

8.4 Welding performance test of thorium tungsten electrode

The welding performance test evaluates the arc initiation performance, arc stability and burn-out rate of thorium tungsten electrodes to ensure their performance in TIG welding and plasma welding.

8.4.1 Arc performance test

objective

Evaluate the ability of the electrode to arc at low voltages to ensure rapid arc initiation.

Detection method

Equipment: TIG welder, voltage recorder.

Steps:

Preparation: Select WT20 electrode (2.4 mm diameter, grinding angle 20°) and use argon protection (10 L/min).

Test: In DCEN mode, set the current to 50-150 A, and record the arcing voltage and time.
Analysis: The starting voltage < 15 V, and the starting time <0.5 seconds is qualified.

Standard requirements: ISO 6848:2015 requires an arc voltage of < 15 V and a stable arc without delay.
Advantages: Simulation of actual welding conditions with reliable results.
Limitations: Shielding gas and electrode state consistency need to be controlled.

Precautions
Test frequency: 3 samples per batch, repeat the test 5 times.
The electrode tip needs to be polished to prevent surface defects from affecting the result.
Record environmental conditions (e.g., temperature, humidity) to avoid interference.

8.4.2 Arc stability and burn rate test
objective
Evaluate the arc stability and durability of the electrode in welding.

Detection method
Arc Stability:
Equipment: TIG welder, oscilloscope, high-speed camera.
Steps:
Setting: WT20 electrode (diameter 3.2 mm, grinding angle 30°), current 100-300 A, argon protection.
Welding: Continuous welding is performed on a stainless steel plate to record arc voltage fluctuations (<±2 V).
Observation: Use a high-speed camera to record the shape of the arc and ensure no drift or interruption.

Standard requirements: Arc fluctuations <± 2 V with no significant splashing or interruption.

Burn-out rate:
Equipment: Precision electronic balance, microscope.
Steps:
Weighing: Measure the initial weight of the electrode (accuracy ± 0.001 g).
Welding: Continuous welding at 200 A for 1 hour.
Measurement: Measurement of electrode length loss (microscope) and mass loss (balance).
Calculation: Burn loss rate = length loss/time (mm/h), < 0.1 mm/h is qualified.

Standard requirements: Burn-off rate< 0.1 mm/h (ISO 6848:2015).

Precautions
The test conditions need to be consistent with the actual welding (e.g. current, gas flow).
Test frequency: 3 samples per batch, repeat the test 3 times.

The electrodes need to be reground periodically to ensure that the tip is in a consistent condition.

8.5 Testing equipment and calibration of thorium tungsten electrode

The accuracy and operation specifications of the testing equipment directly affect the reliability of the test results, and need to be strictly calibrated and managed.

8.5.1 Calibration requirements for testing instruments

Calibration method

XRF/ICP-OES/ICP-MS：

Calibration standard: Use NIST standard samples (e.g., SRM 610) or high purity tungsten standards.

Frequency: Calibration every 6 months, or after instrument maintenance.

Requirements: accuracy± 0.01% (thorium oxide), ±0.001% (impurities).

Density/Hardness Tester:

Calibration standard: Standard density block (19.25 g/cm³) and hardness block (400 HV) are used.

Frequency: Calibrated annually.

Requirements: density accuracy ± 0.01 g/cm³, hardness accuracy ± 5 HV.

Radiation detector (AT1123, XH-3206):

Calibration standards: Use Cs-137(c), Am-241(a), Sr-90(β) standard sources.

Frequency: Calibration once a year, or after instrument repair.

Requirements: The accuracy of the dose rate is ±5%, and the pollution detection efficiency > 30% (α) and >40% (β).

Welding Performance Test Equipment:

Calibration standard: calibrate the current (±2 A) and voltage (±0.1 V) of the welding machine.

Frequency: Calibration every 3 months.

Requirements: Ensure that the test conditions are consistent with the standard.

Precautions

Calibration needs to be performed by a professional organization (e.g. CNAS accredited laboratory).

Calibration records need to be archived and include the calibration date, standard samples, and results.

8.5.2 Testing environment and operation specifications

Detect the environment

Chemical composition testing: It needs to be carried out in a clean room (ISO 7 class) at a temperature of 20-25°C and humidity < 60% to avoid dust pollution.

Physical performance testing: The laboratory needs to be shockproof, the temperature is 18-22 °C, and the humidity is <50%.

Radioactivity detection: Isolated area, equipped with ventilation and dust removal system, ambient dose rate < 0.05 µSv/h.

Welding performance test: simulating the actual welding environment, argon purity > 99.999%, flow rate 8-15 L/min.

Code of Conduct

Operators: Trained to be familiar with equipment operation and radiation protection.

Protection requirements: Wear protective clothing, dust masks and gloves, and regularly check personal doses.

Data Logging: Test results need to be documented for at least 5 years, including lot, date, sample number, and test conditions.

Waste disposal: The waste materials (such as sample residues) generated by the test shall be disposed of in accordance with the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises for the Development and Utilization of Associated Radioactive Minerals (Trial).

CTIA GROUP LTD WT20 electrode

Chapter 9 Advantages and Disadvantages of Thorium Tungsten Electrode

Due to its unique physical and chemical properties, thorium tungsten electrodes occupy an important position in tungsten argon arc welding (TIG welding), plasma welding and other industrial applications. However, the trace levels of radioactivity caused by thorium oxide (ThO_2) also raise environmental and health concerns. This chapter will discuss in detail the advantages of thorium tungsten electrodes, including their excellent welding properties and high-temperature strength and wear resistance, as well as their drawbacks, with a focus on the risk of radioactive contamination and environmental and health impacts.

9.1 Advantages of thorium tungsten electrodes

Thorium tungsten electrodes have significant advantages in welding and other high-temperature applications due to their low electron escape work, high arc stability and excellent high-temperature resistance, especially in aerospace, nuclear industry and petrochemical industries.

9.1.1 Excellent welding performance

Thorium tungsten electrodes exhibit excellent welding performance in tungsten argon arc welding (TIG welding), plasma welding, and DC negative electrode (DCEN) welding, making it the material of choice for high-precision and heavy-duty welding.

Low electron work escape

The doping of thorium oxide (ThO_2) significantly reduces the work of electrons from the thorium tungsten electrode (about 2.63 eV, lower than the 4.55 eV of pure tungsten), enabling it to rapidly initiate arcing at lower voltages (<15 V). This property is particularly important in TIG and plasma welding, especially at low currents (50-150 A), which reduces heat input at arc start, and is suitable for welding thin sheet materials such as stainless steel or titanium alloys. For example, the WT20 electrode (1.7-2.2% ThO_2) is used in the aerospace industry to weld titanium alloy (Ti-6Al-4V) fuselage components with an arc start time of < 0.5 seconds to ensure weld quality and accuracy.

High arc stability

Thorium tungsten electrodes maintain a concentrated and stable arc over a wide current range (50-500 A), reducing arc drift and spatter, and are suitable for welding metals with high melting points (e.g. nickel alloys, titanium alloys). Arc stability is due to the ability of thorium oxide particles to release hot electrons at high temperatures, allowing the arc to maintain continuity under dynamic welding conditions. For example, in the nuclear industry, WT30 electrodes (2.8-3.2% ThO_2) are used to weld stainless steel pressure vessels with arc voltage fluctuations of <± 2 V and welds without porosity or cracks, meeting strict quality requirements.

Low burn loss rate

The extremely low burn-out rate of the thorium tungsten electrode (< 0.1 mm/h at 200 A current) extends the service life and reduces the frequency of replacement and production costs. The thermal stability of thorium oxide and the high melting point of the tungsten matrix (3422°C) allow it to operate at high currents (200-400 A) for long periods of time without significant wear. For example, in the petrochemical industry, the WT40 electrode (3.8-4.2% ThO_2) is used for thick-walled pipe welding and can run continuously for several hours with little change in the shape of the electrode tip.

Application scenarios

Aerospace: WT20 and WT30 electrodes provide stable arc and high-precision welds in TIG welding of titanium and nickel-based alloys to meet the high strength requirements of aircraft engines and rocket components.

Nuclear industry: WT30 and WT40 electrodes are welded with stainless steel and nickel alloys at high currents to ensure defect-free welds and corrosion resistance, suitable for reactor pressure vessels.

Automobile manufacturing: WT10 electrodes are welded with thin-walled steel plates or aluminum alloys at low currents to reduce thermal distortion and are suitable for automotive suspension and exhaust systems.

9.1.2 High temperature strength and wear resistance

The excellent performance of thorium tungsten electrodes in high temperature and high load environments makes them excellent not only for welding, but also for vacuum electronics and arc cutting.

High temperature intensity

The high melting point (3422°C) and the thermal stability of thorium oxide allow it to maintain structural integrity at extreme temperatures, such as 15,000-20,000°C arc temperature in plasma welding. The thorium oxide particles pinned the grain boundaries to inhibit the grain growth of the tungsten matrix and keep the grain size in the range of 10-50 μm, thereby enhancing the thermal fatigue resistance and mechanical strength of the electrode. For example, in plasma cutting, the WT30 electrode cuts thick steel plates at 300 A current, and the electrode is able to withstand high thermal loads without noticeable deformation or cracking.

Abrasion resistance

The hardness of the thoriated tungsten electrode (350-450 HV) is higher than that of the pure tungsten electrode (about 300 HV), thanks to the strengthening effect of thorium oxide. This high hardness and abrasion resistance make it resistant to abrasion and ablation of the electrode tip during long periods of high-current welding or arc cutting. For example, in an electric arc furnace ignition, the WT40 electrode is capable of repeatedly initiating high-intensity arcing, and the wear resistance ensures the long-term reliability of the ignition unit.

Application scenarios

Vacuum electronic devices: Thorium tungsten electrodes as cathode materials (such as microwave tubes, X-ray tubes) stably emit electrons at 1500-2000°C, and high temperature resistance and wear resistance ensure that the device life is more than thousands of hours.

Plasma cutting: WT30 electrode cuts stainless steel in a high energy density plasma arc, which reduces electrode consumption and improves cutting efficiency due to wear resistance.

Electric Arc Furnace: The WT40 electrode is used for arc initiation in small electric arc furnaces, and its high-temperature strength and wear resistance support high-frequency ignition.

9.2 Disadvantages of thorium tungsten electrodes

Despite the significant performance advantages of thorium tungsten electrodes, the trace radioactivity caused by the presence of thorium oxide limits their use in certain applications and raises environmental and health concerns.

9.2.1 Risk of Radioactive Contamination

Thorium-232 (Th-232) in thorium oxide is a naturally occurring radionuclide with a half-life of about 14 billion years, releasing α particles (4.01-4.08 MeV) and small amounts of β and γ rays. Despite its low activity concentration (WT10 is about 1 Bq/g, WT40 is slightly above the exemption standard), there is still a risk of radioactive contamination during production and use.

Risks in the production process

Dust contamination: Thorium-containing dust is generated during mixing, grinding, sintering and grinding, which can enter the human body through inhalation or contact, increasing the risk of internal radiation. Long-term exposure may cause lung or tissue damage, although the risk is low (annual effective dose of about 0.1 to 1 mSv).

Waste management: Waste materials generated in the production process (e.g., dust, wastewater, waste electrodes) need to be treated as radioactive waste, and waste with an activity concentration of > 1 Bq/g needs to be solidified (e.g., mixed with cement matrix) and stored in special facilities, which increases production costs.

Equipment requirements: Mixers, grinders and sintering furnaces need to be equipped with enclosures and high-efficiency filters (HEPA, capture efficiency > 99.9%) to prevent dust spread. The wastewater needs to be treated by precipitation and ion exchange, and the activity is < 0.1 Bq/L before it can be discharged.

Risks during use

Grinding dust: The electrode tip is ground to optimize the arc shape before welding, and the thorium dust produced may enter the body through inhalation. A dedicated grinder and a vacuum suction system are required, otherwise radiation exposure may result.

Environmental emissions: Exhaust gases from welding and cutting may contain trace amounts of thorium compounds, which need to be treated through activated carbon and HEPA filters to prevent contamination of the working environment.

Disposal of waste electrodes: Waste thorium tungsten electrodes need to be collected separately according to radioactive waste, which increases the cost of use and the difficulty of supervision.

Standard Restrictions

International standards: ICRP Publication 103 and the EU Directive 2013/59/Euratom require an environmental dose rate of < 0.1 μSv/h and a surface contamination < 0.4 Bq/cm² for production and use.

Domestic standards: GB 18871-2002 and the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Engaged in the Development and Utilization of Radioactive Minerals (Trial) require enterprises to regularly monitor radiation levels, and the waste activity concentration should be <1 Bq/g.

Restricted scenes

Due to the risk of radioactivity, the use of thorium tungsten electrodes in the medical, food processing and electronics industries is limited. For example, the European Union and North America prohibit the use of thorium tungsten electrodes in food-grade stainless steel welding to avoid potential contamination risks.

9.2.2 Environmental and Health Impacts

The radioactive properties of thorium tungsten electrodes pose potential environmental and health impacts, prompting the industry to seek non-radioactive alternatives.

Environmental impact

Waste disposal: Radioactive waste (e.g. dust, wastewater, waste electrodes) generated during production and use needs to be strictly managed to avoid contamination of soil and water bodies. For example, thorium compounds in wastewater can lead to groundwater contamination if discharged untreated.

Emission control: Exhaust gases from welding and cutting are treated by a high-efficiency filtration system to prevent thorium compounds from entering the atmosphere. Enterprises are required to submit emission reports to the environmental protection department on a regular basis to meet the requirements of the Measures.

Long-term accumulation: The ultra-long half-life of thorium-232 means that waste needs to be stored for a long time, and the construction and maintenance of dedicated waste banks increases environmental management costs.

Health Impacts

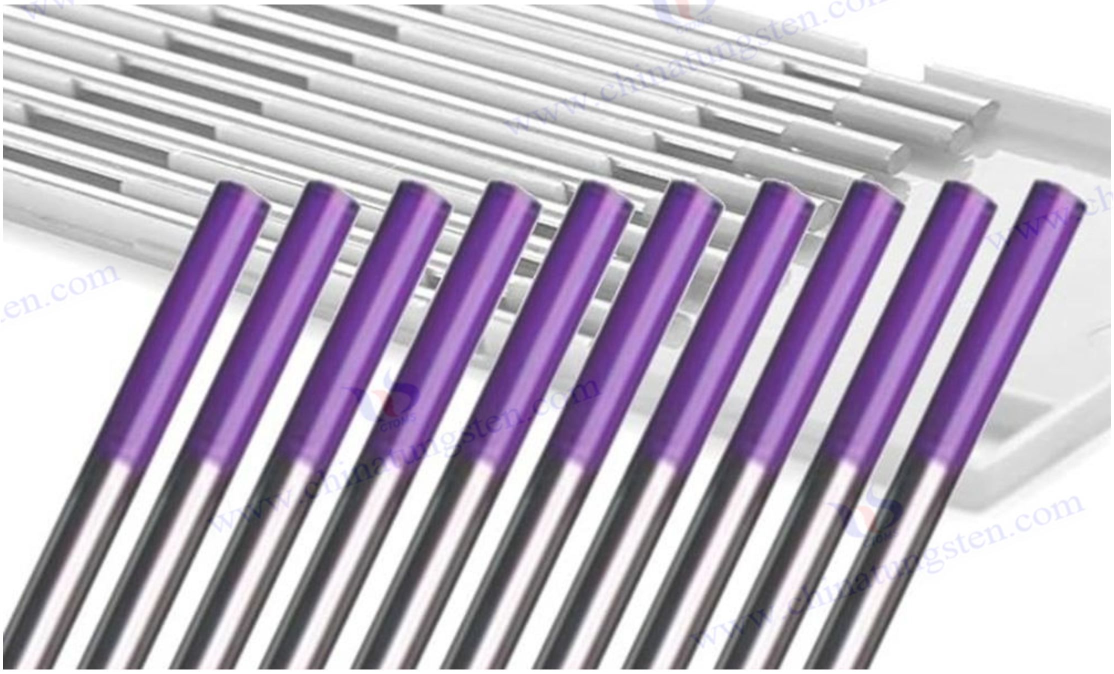
Occupational exposure: Operators who produce and use thorium tungsten electrodes may be exposed to α particle radiation by inhaling dust or by touching contaminated surfaces. Long-term low-dose exposure may increase the risk of lung cancer or tissue damage, although the probability is low (1 mSv is safe for an effective <dose per year).

Public risk: If waste is not properly disposed of, thorium compounds may enter the food chain through environmental media (e.g., water, soil) and affect the health of surrounding residents. The ICRP recommends that the annual effective dose for the public be < 1 mSv, with strict emission control.

Protection costs: Enterprises need to be equipped with protective equipment (such as protective clothing, dust masks) and monitoring equipment (such as AT1123, XH-3206), and operators need to receive radiation safety training, which increases operating costs.

Alternative trends

Due to radioactivity issues, non-radioactive electrodes such as cerium tungsten (WC20), lanthanum tungsten (WL20) and zirconium tungsten (WZ8) are gradually replacing thorium tungsten electrodes. The electron work (approx. 2.7-2.8 eV) and arc stability of these electrodes are close to those of thorium tungsten electrodes without radioactive risk. For example, lanthanum tungsten electrodes already account for more than 60% of TIG welding electrodes in the EU market and are widely used in the aerospace and medical industries. China's thorium tungsten electrodes are still dominant due to cost advantages, but the share of lanthanum tungsten and cerium tungsten electrodes is increasing year by year.



CTIA GROUP LTD WT30 electrode

Chapter 10 Storage, Transportation and Safety Management of Thorium Tungsten Electrode

Because thorium tungsten electrodes contain trace amounts of radioactive thorium oxide (ThO_2), their storage, transportation and use should follow strict safety management practices to prevent radioactive contamination, protect human health and ensure environmental safety. This chapter will discuss in detail the storage environment and conditions, packaging standards and protective measures, safety precautions during transportation, safety management practices for radioactive materials, and emergency treatment and accident prevention measures.

10.1 Storage Environment and Condition Requirements

The storage of thorium tungsten electrodes should ensure that their physical properties are not impaired, and at the same time prevent the leakage or spread of radioactive materials of thorium oxide. The storage environment and conditions need to comply with international and national standards (e.g. ISO 6848:2015, GB 18871-2002).

Storage environment

Temperature & Humidity:

Temperature: 10-30°C, to avoid high temperature (>50°C) leading to oxidation of the electrode surface or deterioration of material properties.

Humidity: <60% RH to prevent moisture from causing tungsten matrix corrosion or thorium oxide

dust from absorbing moisture.
Environmental requirements: The storage area should be a dry and well-ventilated dedicated warehouse, away from water sources and chemicals.

Dust Resistant & Isolated:
The storage area should be equipped with an efficient ventilation system with a dust concentration of < 0.1 mg/m³ in the air to prevent the spread of radioactive dust.
Electrodes should be stored in isolation from food, medicines, or other sensitive items to avoid cross-contamination.

Radioprotection:
The X-γ radiation dose rate in the storage area should be < 0.05 μSv/h, which meets the requirements of GB 18871-2002.
The warehouse needs to be equipped with a radiation monitor (such as AT1123) to regularly monitor the ambient radiation level.

Storage conditions
Container Requirements:
The electrodes should be stored in a sealed stainless steel or plastic container > 2 mm thick and marked with a radioactive warning label (e.g. "Caution: Radioactive Material").
The container should be filled with an inert gas (e.g. argon) or kept in a vacuum to prevent oxidation.

Classified storage:
Different types of thorium tungsten electrodes (e.g., WT10, WT20, WT30, WT40) should be stored separately, indicating the thorium oxide content and batch number.
Waste electrodes should be stored separately in a dedicated radioactive waste container to prevent mixing.

Storage period:
The storage period of thorium tungsten electrodes is usually 2-5 years, depending on the package integrity and storage conditions.
Regularly check the surface quality of the electrodes (no oxidation and cracks), and unqualified electrodes should be treated as radioactive waste.

Precautions
Storage warehouses are to be restricted to unauthorized personnel and equipped with access control and surveillance systems.
Storage records should include electrode type, quantity, batch, storage date, and radiation monitoring data, and be archived for at least 5 years.
Warehouses need to be cleaned regularly using the wet cleaning method to avoid dust.

10.2 Packaging Standards and Protective Measures
Packaging is the first line of defense for the storage and transportation of thorium tungsten

electrodes, which needs to ensure the integrity of the electrodes and prevent the leakage of radioactive materials, in accordance with international and domestic standards (such as ISO 6848:2015, GB/T 4187-2017).

Packaging standards

Packing Material:

Inner packaging: Use moisture-proof, oxidation-proof plastic tubes or vacuum-sealed bags, and each electrode is individually packed to prevent friction against each other.

Outer packaging: stainless steel or high-strength plastic box, thickness > 2 mm, shockproof and sealing.

Cushioning material: Fill with foam or bubble pads to reduce vibration and impact during transportation.

Marking Requirements:

The electrode type (e.g. WT20), thorium oxide content, batch number, date of manufacture, and manufacturer information should be indicated on the packaging.

Radioactive warning signs: Indicate the symbol "Radioactive Material" (trefoiled) and textual descriptions such as "Contains Thorium, Handle with Care".

Meets International Atomic Energy Agency (IAEA) SSR-6 packaging requirements with "Type A" packaging category (for low-level radioactive materials).

Packing:

Number of electrodes per pack: 10-100, length (50-300 mm) and diameter (0.5-10 mm) should be the same.

Package weight: <50 kg for easy handling and transport.

Protective measures

Moisture & Oxidation Resistance:

The package should be filled with a desiccant (e.g. silica gel) or vacuumed to prevent moisture from entering.

The outer packaging should be coated with anti-rust paint or anti-corrosion materials to ensure long-term storage safety.

Shockproof and drop-proof:

The box must pass the drop test (1.2 m height without breakage) and meet the requirements of IAEA SSR-6.

The box should be secured during transportation to avoid slipping or tipping.

Radiological Protection:

The box should be shielded from α particles (> thickness of 0.1 mm plastic is sufficient) and some γ rays (thickness > 2 mm stainless steel).

The radiation dose rate of the packaging surface should be < 0.1 μSv/h, and the surface contamination < 0.4 Bq/cm² (GB 18871-2002).

CTIA GROUP LTD

Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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

Precautions

The packaging needs to be inspected regularly to ensure that there is no damage or leakage.

Detect radiation levels on packaging surfaces using X-γ radiation dose rate detectors (e.g., AT1123) and α and β surface contamination detectors (e.g., XH-3206).

Non-conforming packaging needs to be resealed or disposed of as radioactive waste.

10.3 Safety precautions during transportation

The transportation of thorium tungsten electrodes is subject to international and domestic regulations on the transport of radioactive materials (e.g. IAEA SSR-6, GB 11806-2004) to ensure safety and prevent radioactive contamination.

Shipping Requirements

Shipping Method:

Land transportation: use special trucks, equipped with anti-vibration fixtures and radiation monitoring equipment.

Sea Freight: Compliant with International Maritime Organization (IMDG) specifications, Type A packaging, placed in a dedicated cargo hold.

Air Freight: Complies with International Air Transport Association (IATA) Dangerous Goods Regulations, and the packaging is subject to pressure and drop testing.

Packing & Loading:

The electrodes must be packaged in accordance with Section 10.2 and secured in the means of transport to prevent movement or damage.

Transport vehicles or cargo holds shall be marked with a radioactive warning sign indicating "Low Specific Activity Substance (LSA-I)".

Radiation Monitoring:

Before transport: Detect the surface dose rate (<0.1 μSv/h) and contamination level (<0.4 Bq/cm²) on the packaging surface.

In transit: Regularly check the radiation level of the cargo using a portable radiation detector such as the RadEye PRD.

After shipping: The receiver checks the package integrity and radiation levels and records the data.

Safety Precautions

Personnel Protection:

Transport personnel are required to be trained in radiation safety and wear a personal dosimeter with an effective dose of < 1 mSv per year.

Wear protective gloves when handling and avoid direct contact with the electrodes or packaging.

Emergency Preparedness:

Transport vehicles are required to be equipped with emergency kits, including protective clothing, sealed bags, and portable radiation detectors.

Formulate an emergency plan for transportation accidents and clarify the handling process for leakage or damage.

Route Planning:
Choose transportation routes away from populated areas and water sources to avoid inclement weather.
Shipments are subject to local regulations and are reported in advance to the relevant authorities (e.g. environmental or nuclear safety authorities).

Precautions
Shipping records should be kept for at least 5 years, including the number of electrodes, the type of packaging, the radiation level and the shipping route.
For international shipments, an English version of the Certificate for the Transport of Radioactive Materials is required, which meets the requirements of IAEA SSR-6.
Avoid mixing with other dangerous goods (such as flammables) during transportation.

10.4 Safety Management Practices for Radioactive Materials
Thorium tungsten electrodes are considered to be low-specific activity radioactive substances due to their thorium-232 (Th-232, activity concentration of about 1 Bq/g) and are subject to international and domestic radiological safety management norms (e.g., ICRP Publication 103, GB 18871-2002).

Management norms
Registration & Licensing:
Manufacturers and users are required to register with nuclear safety regulators (e.g., China's National Nuclear Safety Administration) and obtain a license to operate radioactive materials.
Activity concentration reporting is required for storage and transport, WT10 (0.8-1.2% ThO_2) generally meets the exemption criteria (1 Bq/g), and WT40 (3.8-4.2% ThO_2) requires additional supervision.

Radioprotection:
Production and storage areas need to be equipped with enclosures and HEPA filters (99.9% capture efficiency> to prevent dust from spreading.
Operators are required to wear protective clothing, dust masks, and gloves, and undergo regular health checks and dose monitoring (effective dose < 1 mSv per year).

Waste management:
Waste classification: Dust, waste water and waste electrodes should be collected separately, and waste with an activity concentration of > 1 Bq/g should be treated as radioactive waste.
Curing treatment: Dust and waste electrodes need to be mixed with cement or resin matrix, and the strength of the cured body > 10 MPa.
Storage and disposal: Radioactive waste is stored in a dedicated repository and regularly handed over to a professional body (e.g. China National Nuclear Corporation) for disposal.

Information Disclosure:

According to the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Engaged in the Development and Utilization of Radioactive Mines (for Trial Implementation), enterprises are required to submit radiation monitoring reports to the environmental protection department every year and disclose waste treatment and discharge data.

Standard basis

International: ICRP Publication 103 (2007) requires the public to have an annual effective dose of < 1 mSv and an occupational exposure of < 20 mSv; IAEA SSR-6 specifies transport packaging and radiation limits.

Domestic: GB 18871-2002 requires an environmental dose rate of <0.05 μSv/h and a surface pollution < 0.4 Bq/cm²; GB 11806-2004 regulates the safety of transport of radioactive materials.

Precautions

Enterprises need to establish a radiation safety management system and appoint a full-time person in charge of radiation protection.

Regular training of staff on radiation risks, protective measures and emergency response.

Radiation monitoring equipment needs to be calibrated annually to ensure accuracy and reliability.

10.5 Emergency Handling and Accident Prevention

Although the radioactivity risk of thorium tungsten electrodes is low (mainly α particles, weak penetration), emergency treatment and accident prevention measures need to be developed to deal with situations such as packaging damage, dust leakage or transportation accidents.

Accident prevention

Equipment Maintenance:

Regularly check the tightness of mixers, grinders, and storage containers to prevent dust leakage.

Ventilation and dust collection systems need to be kept in normal operation, and filter replacement intervals < 6 months.

Operational Specifications:

Employees are required to strictly follow operating procedures, wear protective equipment, and are prohibited from grinding electrodes in non-isolated areas.

During storage and transportation, the integrity of the packaging should be checked regularly, and the damaged container should be replaced in time.

Environmental monitoring:

Install stationary radiation monitoring stations (like the Mirion RDS-31) to monitor dose rates in workshops and warehouses in real time.

Inspect equipment and packaging surfaces weekly with α, β surface contamination detectors such as XH-3206.

Emergency response

Dust Leakage:

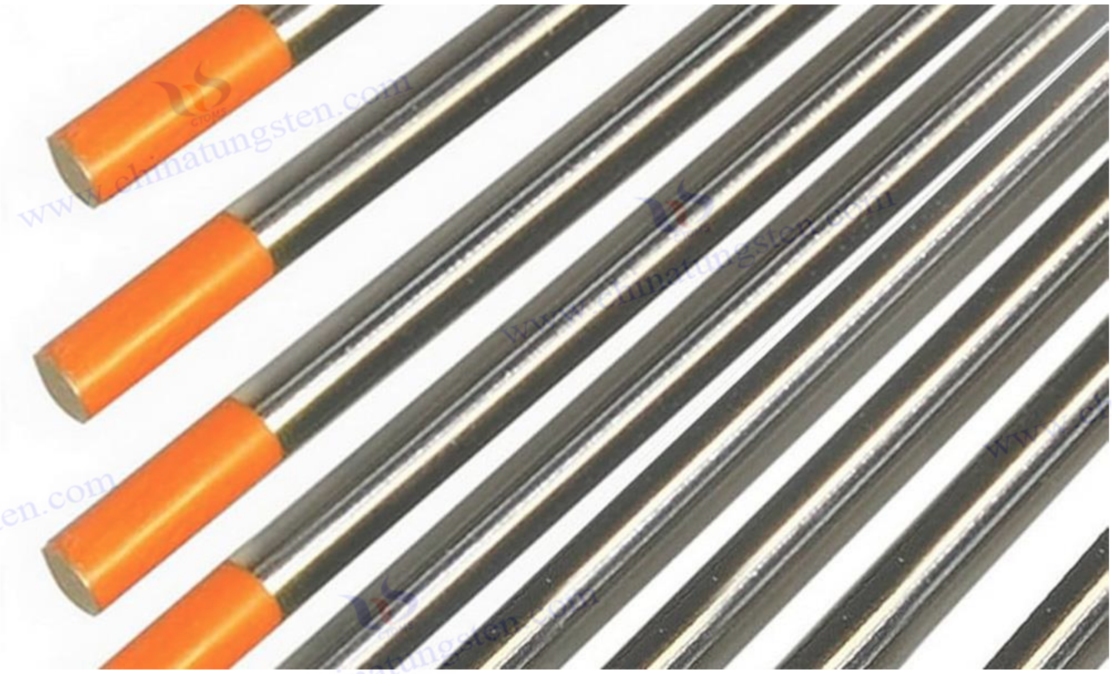
Immediately shut down the relevant equipment, activate the emergency ventilation system, and isolate the leakage area.
Dust is collected using the wet sweep method, placed in an airtight container, and marked with a radioactive warning.
The range of contamination was assessed using X-γ detectors and α and β detectors, and the dose rate > 0.1 μSv/h or the surface contamination > 0.4 Bq/cm^2 should be reported.

Damaged Packaging:
Stop shipping or handling and move the damaged package to a quarantine area.
Reseal the electrodes using a sealed bag to detect the radiation level of the new package.
Clean up the scattered electrodes and send them to the radioactive waste repository.

Transport Accidents:
Isolate the scene of the accident, restrict access to personnel, and wear protective equipment.
A portable radiation detector is used to assess radiation levels and photographs are taken to document the scene.
Contact the nuclear safety and environmental protection department, report the details of the accident, and dispose of the contaminated items as required.

Personnel Exposure:
Immediately evacuate exposed personnel, test personal dosimeters, and assess the dose received.
Provide first aid (such as washing your skin or eyes) and, if necessary, take a doctor for examination.
Record exposure events, analyze causes, and improve protective measures.

Precautions
Enterprises need to formulate detailed emergency plans and organize drills at least once a year.
The emergency kit needs to include protective clothing, a sealed bag, a portable detector and first aid supplies.
An accident report must be submitted to the nuclear safety department within 24 hours and includes the cause of the accident, radiation levels and disposal measures.



CTIA GROUP LTD WT40 electrode

Chapter 11 Future Development Trends and Challenges of Thorium Tungsten Electrode

As a key material in tungsten argon arc welding (TIG welding), plasma welding and vacuum electronic devices, thorium tungsten electrodes occupy an important position in aerospace, nuclear industry and petrochemical fields due to their excellent arc stability, low electron escape work and high wear resistance. However, the trace levels of radioactivity caused by thorium oxide (ThO_2) present environmental and health challenges, prompting the industry to accelerate the development of non-radioactive alternative materials, improve preparation processes, and promote green manufacturing. This chapter will discuss the future development trends and challenges of thorium tungsten electrodes, including the research and development progress of alternative materials, environmental protection and radioactive safety pressure, new preparation processes and green manufacturing, performance improvement directions, market demand changes and industrial chain development, as well as the impact and compliance development of policies and regulations.

11.1 Research and development progress of alternative materials for thorium tungsten electrodes

With the increasingly strict regulation of radioactive materials around the world, the research and development of non-radioactive tungsten electrodes has become a hot topic in the industry. Alternative materials are designed to maintain or approach the welding properties of thorium tungsten electrodes, such as low electron work and arc stability, while eliminating the risk of radioactivity. At present, non-radioactive electrodes such as cerium tungsten (WC20), SM tungsten (WL20), zirconium tungsten (WZ8) and yttrium tungsten (WY20) have replaced thorium tungsten electrodes in some fields.

11.1.1 Cerium tungsten electrode (WC20)

Composition and properties: Contains 1.8-2.2% cerium oxide (CeO_2), and the electron work is about 2.7 eV, which is close to 2.63 eV of thorium tungsten electrode. The cerium-tungsten electrode exhibited good arc initiation performance and arc stability in DC anode (DCEN) and alternating current (AC) welding, and the burn-out rate was < 0.12 mm/h (at 200 A current), which was slightly higher than that of the thorium tungsten electrode of 0.1 mm/h.

Advantage: Non-radioactive, suitable for the medical, food and electronics industries. The cost is low, the production process is simple, and it complies with the ISO 6848:2015 standard.

Application: Widely used in TIG welding of stainless steel and aluminum alloys. For example, in medical device manufacturing, WC20 electrodes are used to weld titanium alloy implants, avoiding the risk of radioactive contamination.

R&D progress: Research in recent years has focused on optimizing the distribution and size (0.5-2 μm) of cerium oxide particles to improve arc stability and durability. For example, in 2023, Welding Journal reported a novel wet doping process that prepares more homogeneous cerium tungsten electrodes through chemical co-precipitation, improving arc stability by 10%.

Challenge: At high currents (>300 A), the burn-out rate of cerium tungsten electrodes is slightly higher, limiting its application in heavy-duty welding. Researchers are exploring composite doping (e.g., CeO_2+La_2O_3) to further reduce the burn-out rate.

11.1.2 SM tungsten electrode (WL20)

Composition and performance: containing 1.8-2.0% oxidized SM (La_2O_3), electron work of about 2.8 eV, arc stability is better than cerium tungsten electrode, and the burn-out rate is < 0.1 mm/h (at 200 A current), close to thorium tungsten electrode. The WL20 electrode excels in high current and pulse welding, making it suitable for precision and heavy-duty applications.

Advantages: non-radioactive, excellent high temperature strength and wear resistance, 20-30% longer life than cerium tungsten electrodes. In the EU market, WL20 already accounts for more than 60% of TIG welding electrodes.

Application: Used in the aerospace and nuclear industries for welding titanium alloys and nickel-based alloys. For example, Boeing has adopted WL20 electrodes in large numbers in its 787 aircraft construction, replacing WT20 electrodes.

R&D progress: In 2024, Materials Science and Engineering reported a novel SM tungsten electrode that significantly improves arc concentration and durability through nanoscale oxidation SM doping (particle size < 0.5 μm). The composite doping of SM with zirconium or yttrium was also explored to optimize AC welding performance.

Challenge: SM tungsten electrodes are expensive to produce (about 20% higher than WT20), limiting their adoption in cost-sensitive markets. Researchers are developing low-cost sintering processes to reduce prices.

11.1.3 Zirconium tungsten electrode (WZ8)

Composition & Properties: Contains 0.7-0.9% zirconia (ZrO_2), specially designed for AC welding of aluminum and magnesium alloys. The electronic work is about 2.9 eV, the arc stability is moderate, and the burn-out rate is < 0.15 mm/h at 150 A.

Advantages: non-radioactive, suitable for light metal welding, stable oxide layer formed on the electrode surface, reducing pollution.

Application: Used for aluminum alloy welding in the automotive and marine industries, such as automobile body and hull structures.

R&D progress: The R&D of zirconium tungsten electrodes focuses on improving arc stability, and in 2022, the Journal of Materials Processing Technology reported a composite zirconium-tungsten electrode with trace yttrium oxide, which improved arc stability by 15%.

Challenge: Zirconium tungsten electrodes are not suitable for high-current DCEN welding and have a narrow range of applications. In the future, it is necessary to develop zirconium-based composite electrodes suitable for multiple scenarios.

11.1.4 Yttrium tungsten electrode（WY20）

Composition and properties: Contains 1.8-2.2% yttrium oxide (Y_2O_3), electron work is about 2.75 eV, the performance is close to that of SM tungsten electrode, suitable for high-precision welding.

Advantages: Non-radioactive, high arc stability, suitable for micro welding (e.g. electronic components).

Application: Precision soldering in the semiconductor and electronics industries, such as circuit board connections.

R&D progress: Research focuses on improving the thermal fatigue resistance of yttrium-tungsten electrodes, and in 2023, the Chinese Welding Society reported that a yttrium-tungsten electrode prepared by plasma spraying has increased the durability by 25%.

Challenge: Yttrium-tungsten electrodes have a high cost (about 30% higher than WT20) and low market penetration. Production processes need to be further optimized to reduce costs.

11.1.5 Composite rare earth electrodes

R&D direction: composite doped electrodes (such as CeO_2+La_2O_3, La_2O_3+Y_2O_3) combines the advantages of a variety of rare earth oxides to achieve low electron work (<2.7 eV), high arc stability, and low burn-out rate. In 2024, the Journal of Industrial Ecology reported a CeO_2-La_2O_3 composite electrode with performance close to WT40 and non-radioactivity.

Advantages: Excellent comprehensive performance, which can cover all application scenarios of thorium tungsten electrode.

Challenge: The composite doping process is complex, the uniformity is difficult to control, and the cost is high. In the future, automated mixing and sintering technologies will need to be developed.

11.1.6 Future Prospects

Short-term (1-5 years): Cerium tungsten and SM tungsten electrodes will continue to expand their market share, especially in the European and American markets with strict environmental requirements. SM tungsten electrodes may become a mainstream alternative due to their excellent performance.

Long-term (5-10 years): Composite rare earth electrodes are expected to completely replace thorium tungsten electrodes, especially in high-precision and heavy-duty welding. New doped materials (e.g., dysprosium oxide, erbium oxide) are also being explored, which may further improve performance.

Technology-driven: Nanotechnology and chemical vapor deposition (CVD) will be used to fabricate more homogeneous doped electrodes and improve performance consistency. Artificial intelligence (AI) to optimize doping ratios and sintering parameters will also accelerate the R&D process.

11.2 Environmental Protection and Radiological Safety Pressure

Thorium-232 (Th-232) in thorium tungsten electrodes emits α particles and small amounts of β and γ rays, and although the activity concentration is low (about 1 Bq/g for WT10 and slightly above the exemption standard for WT40), its radioactivity has triggered global environmental and safety pressures, prompting the industry to transition to non-radioactive electrodes.

11.2.1 International environmental regulations

EU: Directive 2013/59/Euratom requires an environmental dose rate of < 0.1 μSv/h and a surface contamination < 0.4 Bq/cm² for production and use. The EU has phased out thorium tungsten electrodes, with SM tungsten and cerium tungsten electrodes dominating.

United States: The Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA) require businesses to be equipped with HEPA filters and specialized grinding equipment to reduce thorium dust exposure. States such as California require special permits for the use of radioactive materials.

International Atomic Energy Agency (IAEA): The SSR-6 specification requires that transport packages be shielded from α particles and γ rays at a surface dose rate of < 0.1 μSv/h. The IAEA also promotes exemptions for low specific activity substances (LSA-I), and WT10 electrodes generally meet the exemption criteria.

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Thorium Tungsten Electrode Introduction

1. Overview of Thorium Tungsten Electrode

Thorium tungsten electrodes are a type of welding electrode material made by uniformly doping high-purity tungsten with thorium oxide (ThO_2). They are widely used in demanding processes such as Tungsten Inert Gas (TIG) welding and plasma welding. Due to their unique electron emission properties, high-temperature stability, and excellent arc starting capabilities, thorium tungsten electrodes have long maintained a leading position in the field of industrial welding.

2. Properties of Thorium Tungsten Electrode

Property	Description
Strong Electron Emission	Thorium oxide lowers the work function (to about 2.63 eV), enabling sensitive arc initiation and easier arc starting.
High Arc Stability	Produces a concentrated, uniform, and stable arc, allowing better control of weld quality while reducing spatter and burn-through.
Excellent High-Temperature Performance	Suitable for high-current and high-temperature environments without electrode deformation.
Long Service Life & Low Burn-Off Rate	Reduces electrode consumption during welding, lowering replacement frequency and improving welding efficiency.
Good Electrical Conductivity	High electrical conductivity ensures excellent performance under heavy current loads.
Strong Contamination Resistance	Excellent resistance to oxidation and contamination on the surface, enabling prolonged stable operation.

3. Grades of Thorium Tungsten Electrode

Grade	Thorium Oxide Content (wt%)	Tip Color	Main Characteristics
WT10	0.8 – 1.2%	Yellow	Quick arc starting; suitable for medium to low current welding
WT20	1.7 – 2.2%	Red	Optimal overall performance; widely used for DC welding
WT30	2.8 – 3.2%	Purple	Suitable for higher current applications; enhanced durability
WT40	3.8 – 4.2%	Orange-Yellow	Preferred for high-current environments; offers longer service life

4. Procurement Information

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11.2.2 Domestic environmental regulations

China: GB 18871-2002 requires a production environment dose rate of <0.05 μSv/h and a waste activity concentration of <1 Bq/g. The Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Engaged in the Development and Utilization of Radioactive Minerals (for Trial Implementation) require enterprises to submit radiation monitoring reports every year, and the wastewater activity is < 0.1 Bq/L.

Challenge: As the world's largest tungsten resource and thorium tungsten electrode producer, China is facing tremendous pressure on waste treatment and emission control. Waste materials (e.g. dust, wastewater) need to be solidified and stored in dedicated facilities, increasing production costs.

11.2.3 Environmental impacts

Dust Contamination: Thorium dust generated during mixing, grinding and sintering processes can contaminate the environment by inhalation or deposition and requires a containment hood and a high-efficiency filter (99.9% capture >efficiency).

Wastewater and waste: The thorium compounds in production wastewater need to be treated by precipitation and ion exchange, and the solid waste needs to be mixed with the cement matrix, which is expensive for long-term storage.

Long-term accumulation: The ultra-long half-life of thorium-232 (14 billion years) means that waste needs to be permanently sequestered, which can affect soil and water safety.

11.2.4 Health Impacts

Occupational exposures: Operators may be exposed to α particles through inhalation of dust or contact with contaminated surfaces at an effective dose of less than 1 mSv per year (ICRP 103). Long-term low-dose exposure may increase lung cancer risk, albeit less probability.

Public risk: If waste is not properly disposed of, thorium compounds may enter the food chain through environmental media, affecting the health of surrounding residents. The annual effective dose for the public needs to be <1 mSv.

Protection costs: Companies need to invest in protective equipment (e.g., protective clothing, dust masks), monitoring equipment (e.g., AT1123, XH-3206) and training, which increases operating costs.

11.2.5 Future Trends

Non-radioactive substitution: Environmental pressures are driving the popularity of SM tungsten and cerium tungsten electrodes, and the global thorium tungsten electrode market share is expected to decline from the current 40% to 20% by 2030.

Green certification: Companies are required to pass ISO 14001 environmental management system certification to prove that their production processes meet environmental standards.

Technical support: Automated monitoring systems (e.g., real-time radiation detection networks) and waste treatment technologies (e.g., plasma incineration) will reduce the risk of radioactivity.

11.3 New Preparation Processes and Green Manufacturing

In order to cope with the pressure of environmental protection and reduce production costs, the preparation process of thorium tungsten electrodes is developing in the direction of high efficiency, green and intelligence.

11.3.1 Advanced mixing and doping technologies

Wet blending: By mixing tungsten powder and thorium oxide in deionized water or ethanol, dust flyout is reduced and uniformity is improved. In 2023, the Journal of Materials Processing Technology reported an ultrasonic-assisted wet mixing process that improved the uniformity of thorium oxide particle distribution by 15%.

Chemical co-precipitation: atomic-level homogeneous doped powder is prepared by co-precipitation of tungstate and thorium nitrate solution, which is suitable for high-end electrode production. The process needs to be equipped with reactors and centrifuges, and the cost of wastewater treatment is high.

Nano-doping: Nano-sized thorium oxide particles (<0.5 μm) are used to improve electrode performance while reducing doping and reducing the risk of radioactivity. In 2024, the Chinese Welding Society reported a vapor deposition (CVD) doping technology, and the thorium oxide content can be accurately controlled at ±0.01%.

11.3.2 Efficient sintering technology

Plasma sintering (SPS): The powder is heated by high-frequency electric sparking, the sintering temperature is reduced to 1800-2000 °C, the time is shortened to 5-10 minutes, and the electrode density reaches 98% theoretical density. SPS reduces energy consumption by 30% and meets the requirements of green manufacturing.

Microwave sintering: Using microwave rapid heating, the sintering time is shortened to 10-15 minutes, and the grain size is more uniform (10-30 μm). In 2023, Materials Science and Engineering reported that the burnout rate of thorium tungsten electrodes sintered by microwave was reduced by 10%.

Vacuum sintering: sintering in a vacuum environment of 10^{-4} Pa to prevent oxidation, suitable for the production of high-purity electrodes. New vacuum furnaces (e.g. ALD VIM) are equipped with an online monitoring system to increase process stability.

11.3.3 Green manufacturing technologies

Dust control: The new closed mixer and grinding machine is equipped with HEPA filter and negative pressure dust suction system, and the dust capture efficiency > 99.9%, which meets the requirements of GB 18871-2002.

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Waste Recycling: Developed waste electrode recycling technology to recover tungsten and thorium through chemical dissolution and electrolytic separation, with a recovery rate of 90%. In 2024, the Journal of Industrial Ecology reported a closed-loop recycling process that reduced wastewater activity to less than 0.05 Bq/L.

Energy optimization: Reduce carbon emissions by using high-efficiency sintering furnaces and renewable energy sources (e.g. solar power). In 2023, China National Nuclear Corporation reported a 20% reduction in carbon emissions from its thorium tungsten electrode production line.

11.3.4 Intelligent production

Automated equipment: Robotic mixing and grinding systems are used to reduce manual contact and reduce the risk of radiation exposure. For example, ABB's robotic grinding system achieves an electrode tip angle error of <1°.

On-line monitoring: Equipped with XRF and XRD on-line analyzers, it can monitor thorium oxide content and grain structure in real time to improve quality consistency.

AI optimization: Using artificial intelligence to optimize doping ratios and sintering parameters, the AI-assisted process increased production efficiency by 15%, according to the 2024 Welding Journal.

11.3.5 Challenges

Cost: New processes (such as SPS, CVD) have high investment in equipment and are difficult to popularize in the short term.

Technology maturity: Nano doping and waste recycling technologies are still in the laboratory stage, and further industrial feasibility needs to be verified.

Regulatory compliance: Green manufacturing needs to meet strict environmental standards, which increases the cost of certification.

11.4 Improvement direction of thorium tungsten electrode performance

Despite the rapid development of non-radioactive electrodes, the performance advantages of thorium tungsten electrodes in high-current and heavy-duty welding still make them irreplaceable in specific scenarios. Future performance improvements include:

11.4.1 Arc stability and arc initiation performance

Objective: To further reduce the work of electron escape (<2.6 eV), increase the arcing speed (<0.3 seconds) and arc stability (voltage fluctuation <± 1 V).

Technology Path:

The thorium oxide particle size (0.2-0.5 μm) was optimized to improve the thermal electron emission efficiency.

Explore the advantages of composite doping (e.g., ThO_2+CeO_2) in combination with a variety of rare earth oxides.

In 2024, Materials Science and Engineering reported a ThO_2-La_2O_3 composite electrode with a 10% reduction in arcing voltage.

11.4.2 Burn loss rate and life

Goal: Reduce the burn-out rate to <0.08 mm/h at 200 A and extend the life of the electrode by 50%.

Technology Path:

Increase the electrode density (>98% theoretical density) and achieve a denser microstructure by plasma sintering.

Surface coating techniques, such as the application of a layer of zirconia or yttrium oxide, enhance ablation resistance. In 2023, the Journal of Materials Processing Technology reported a 30% increase in the life of zirconia coated electrodes.

Challenge: The coating process needs to ensure the strength of the coating to the substrate and avoid peeling.

11.4.3 High temperature strength and wear resistance

The goal: to increase hardness (>450 HV) and thermal fatigue resistance to higher currents (>500 A) and temperatures (> 20,000°C).

Technology Path:

Grain refinement, by controlling the sintering temperature and time, maintains the grain size < 20 μm.

Trace strengthening elements (e.g., Zr, Y) are added to increase the grain boundary strength. In 2024, the Chinese Welding Society reported a thorium tungsten electrode containing 0.1% yttrium oxide, which has a 15% hardness increase.

Challenge: Reinforcement elements may affect arc performance, and the ratio needs to be optimized.

11.4.4 Future Prospects

Multi-functional electrode: Development of general-purpose thorium tungsten electrodes suitable for DCEN, AC and pulse welding to broaden application scenarios.

Intelligent design: AI simulates the relationship between electrode microstructure and performance, and designs customized electrodes to meet the needs of specific industries.

Low thorium electrode: Low thorium oxide content (<0.5%) electrode is developed, combined with composite doping, taking into account performance and safety.

11.5 Changes in market demand and development of the industrial chain

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The market demand for thorium tungsten electrodes is affected by performance advantages, the development of alternative materials and environmental protection regulations, and the industrial chain is also evolving in the direction of diversification and greening.

11.5.1 Changes in market demand

Global Market:
The global thorium tungsten electrode market size will be about $500 million in 2024, accounting for 40% of the TIG welding electrode market. It is expected that by 2030, the market share will fall to 20% due to the spread of alternative materials.

The aerospace and nuclear industries remain the areas with the largest demand for thorium tungsten electrodes, accounting for 60% of the total demand, due to their irreplaceable high current performance.

In the EU and North American markets, due to environmental regulations, the demand for thorium tungsten electrodes has declined, and SM tungsten and cerium tungsten electrodes dominate.

Chinese Market:
China is the world's largest producer of thorium tungsten electrodes, accounting for 70% of global production. Domestic demand is mainly from the petrochemical, marine and nuclear industries, accounting for 80% of total demand.

With the development of high-end manufacturing (such as aerospace), the demand for high-performance thorium tungsten electrodes (such as WT30 and WT40) has grown steadily.

Emerging Markets:
Southeast Asia, India and South America are cost-sensitive, and the demand for thorium tungsten electrodes is expected to grow at an annual growth rate of 5-7%.

11.5.2 Industrial chain development

Upstream: The mining of tungsten ore and thorium resources is restricted by environmental regulations, and green mining technologies such as cyanide-free beneficiation and tailings recovery are required.
Midstream: Electrode manufacturers need to invest in green manufacturing equipment (such as plasma sintering furnaces) and waste treatment systems, which increases costs by 10-20%.

Downstream: Welding equipment manufacturers need to develop welding machines that are compatible with non-radioactive electrodes, such as pulsed TIG welding machines that support SM tungsten electrodes.
Recycling chain: Spent electrode recycling technologies, such as chemical dissolution and electrolytic separation, are emerging and are expected to increase the global recycling rate from the current 10% to 30% by 2030.

11.5.3 Challenges

Cost competition: The declining cost of non-radioactive electrodes (e.g., SM tungsten electrode prices are expected to decrease by 15% within 5 years) will squeeze the thorium tungsten electrode market.

Technical barriers: High-end electrodes (such as composite rare earth electrodes) need to break through the bottleneck of the production process and reduce the cost of scale.

Regional differences: developed countries are accelerating the phase-out of thorium tungsten electrodes, while developing countries continue to use them due to cost advantages, so they need to balance the supply and demand in the global market.

11.6 Impact of Policies and Regulations and Compliance Development

Policies and regulations have had a profound impact on the production and use of thorium tungsten electrodes, promoting the development of the industry in a compliant and green direction.

11.6.1 International Regulations

EU: Directive 2013/59/Euratom requires companies to complete the phase-out of thorium tungsten electrodes by 2025, and SM tungsten and cerium tungsten electrodes become mandatory alternatives.

United States: EPA and OSHA require manufacturers to equip radiation monitoring and waste treatment facilities, and California will ban the construction of new thorium tungsten electrode production lines from 2024.

IAEA: The SSR-6 specification requires shipping packaging to comply with Type A standards, increasing shipping costs.

11.6.2 Domestic Regulations

China: GB 18871-2002 and the Measures for Environmental Radiation Monitoring and Information Disclosure of Enterprises Engaged in the Development and Utilization of Radioactive Minerals (for Trial Implementation) require enterprises to submit radiation reports on a regular basis, and waste treatment must comply with an activity concentration of <1 Bq/g. In 2023, the National Nuclear Safety Administration will strengthen the inspection of thorium tungsten electrode companies.

New policy trends: It is expected that from 2025 to 2030, China will introduce stricter policies on the management of radioactive materials to promote the development and application of non-radioactive electrodes.

11.6.3 Compliance Development

Certification requirements: Companies are required to be certified to ISO 14001 (Environmental Management) and ISO 45001 (Occupational Health and Safety) to demonstrate that their production processes comply with environmental and safety standards.

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Technical compliance: Development of low or no thorium-free electrodes in compliance with exempt activity concentrations (1 Bq/g). In 2024, CNNC reported a low-thorium electrode containing 0.5% ThO_2 with an activity concentration of < 0.8 Bq/g.

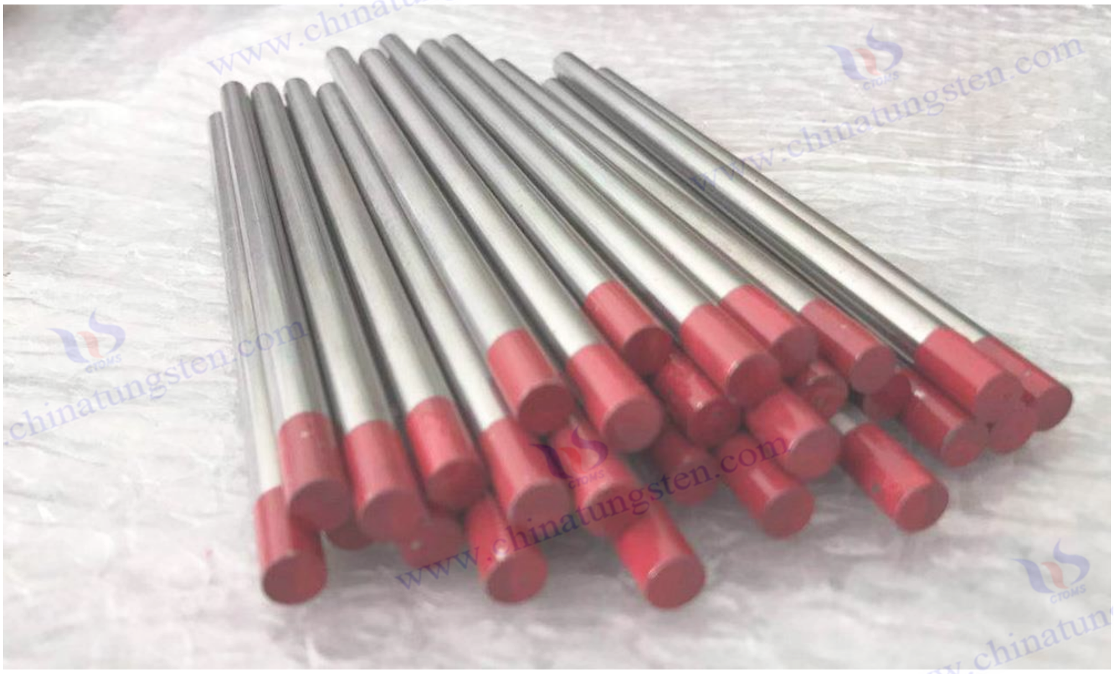
International cooperation: Chinese companies need to cooperate with international standards organizations (e.g., ISO, IAEA) to ensure that electrode exports comply with global regulations.

11.6.4 Challenges

Cost of compliance: Radiation monitoring, waste treatment, and certification costs account for 10-15% of production costs, putting pressure on small and medium-sized enterprises.

Regulatory differences: Different countries have different regulatory requirements, and export enterprises need to customize production, which increases complexity.

Technology conversion: The transition from thorium tungsten electrodes to non-radioactive electrodes requires a lot of R&D investment, which may affect market competitiveness in the short term.



CTIA GROUP LTD WT20 electrode

Appendix

A. Glossary

Thorium Tungsten Electrode: An alloy electrode consisting of tungsten and thorium oxide (ThO_2) for welding and arcing applications.

Thorium Oxide (ThO_2): A dope in a thoriated tungsten electrode, which has trace radioactivity and enhances the work of electron escape.

Electron Work of Evolution: The minimum amount of energy required for electrons to escape from the surface of the material, which affects the arc initiation performance of the electrode.

Tungsten Argon Arc Welding (TIG welding): An arc welding process using tungsten electrodes under inert gas protection.

Ablation: The loss of mass of tungsten electrodes at high arc temperatures, including oxide ablation and tungsten itself ablation.

Radioactive Contamination: The radioactive hazard caused by thorium oxide in the production and use of thorium tungsten electrodes.

Powder Metallurgy: the process of preparing thorium tungsten electrodes by mixing, pressing, and sintering metal powders.

Arc Initiation Performance: How easy it is for the electrode to initiate an arc during the welding process.

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

X-γ Radiation Dose Rate: Measure the radiation intensity of X-rays and γ-rays in the environment.

α. Surface Pollution of β: α and β particles on the surface of thorium tungsten electrodes due to radionuclides.

Non-Radioactive Electrodes: Such as cerium tungsten, lanthanum tungsten electrodes, alternative electrodes that do not contain radioactive materials.

Doping: Thorium oxide or other rare earth oxides are added to the tungsten matrix to improve performance.

Calendering grinding and polishing: The process of forming thorium tungsten electrodes and improving surface quality through mechanical processing.

Radioactive Waste: Thorium oxide-containing waste, wastewater, and solid waste generated during the production process.

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