What Is Molybdenum Sheet

中钨智造科技有限公司

CTIA GROUP LTD

CTIA GROUP LTD

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

INTRODUCTION TO CTIA GROUP

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

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

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

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

Content

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

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Molybdenum Sheet Introduction

1. Overview of Molybdenum Sheet

Molybdenum sheet is a thin metal sheet made from high-purity molybdenum through rolling processes. It features excellent high-temperature resistance, thermal conductivity, and mechanical strength. It is widely used in electronics, metallurgy, vacuum equipment, aerospace, and lighting industries as heating elements, thermal shields, or structural components. With a smooth surface and precise dimensions, molybdenum sheets can be customized in various specifications to meet the requirements of advanced manufacturing and scientific research equipment.

2. Features of Molybdenum Sheet

High Purity Material: Purity ≥ 99.95%, with extremely low impurity levels
High-Temperature Resistance: Melting point up to 2610°C, stable performance in extreme conditions
Excellent Workability: High flatness, smooth surface, easy to punch, shear, and weld
Customizable Specifications: Various sizes and thicknesses available to suit different processes

3. Specifications of Molybdenum Sheet

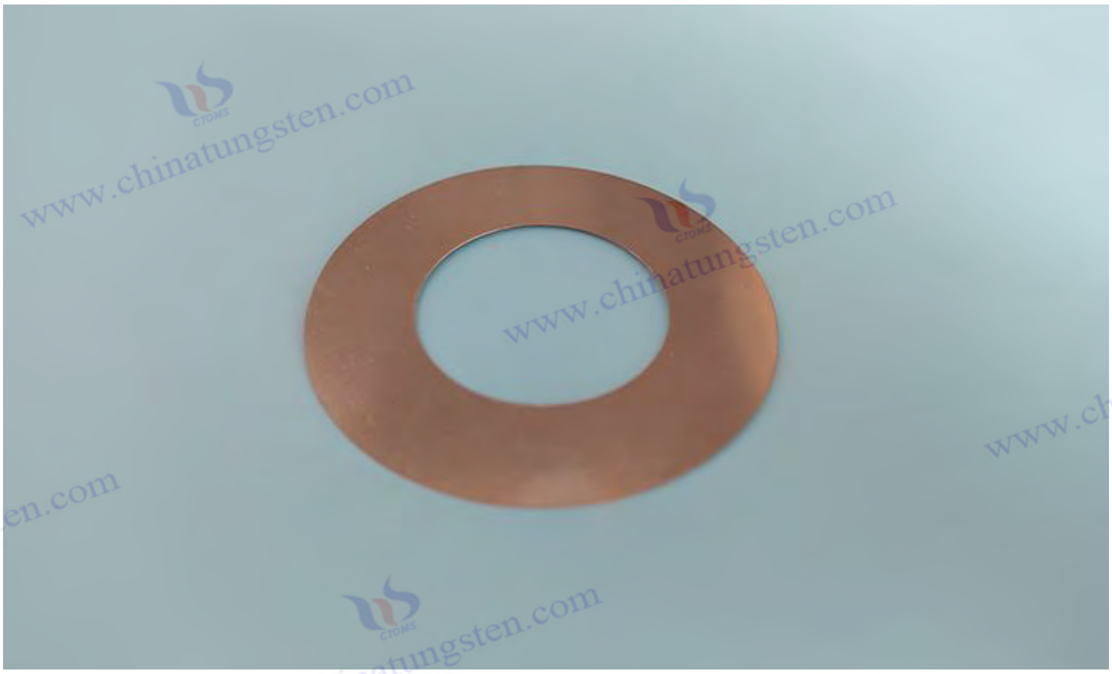
Parameter	Specification
Purity	≥ 99.95%
Thickness	0.01 mm - 3.00 mm
Width	50 mm - 600 mm
Length	Custom lengths or supplied in coil
Surface Finish	Polished, Alkali-cleaned, Sandblasted
Thickness Tolerance	±0.005 mm - ±0.2 mm
Surface Roughness	Ra 0.8 μm – Ra 3.2 μm

4. Production Process

Molybdenum Ingot (Raw Material) → Inspection → Hot Rolling → Leveling & Annealing → Alkali Cleaning → Inspection → Warm Rolling → Vacuum Annealing → Inspection → Cold Rolling → Leveling → Shearing → Vacuum Annealing → Inspection → Packaging

5. Purchasing Information

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



CTIA GROUP LTD molybdenum sheet

Chapter 1 Overview of Molybdenum Tablets

1.1 Molybdenum Sheet Definition

Molybdenum sheet is a thin sheet material made of high-purity molybdenum metal (the purity usually reaches more than 99.95%) through processes such as powder metallurgy, rolling or forging, and its appearance shows a silver-gray metallic luster. Molybdenum (chemical symbol Mo, atomic number 42) is a rare transition metal that occupies an important position in industry and science and technology due to its unique physical and chemical properties.

As a form of molybdenum metal processing, molybdenum sheet is usually presented in extremely thin thicknesses (ranging from 0.01 mm to 3 mm), and is widely used in aerospace, electronics industry, nuclear energy, medical equipment, and high-temperature stoves. Its high melting point (approx. 2620°C) and high strength make it excellent in extreme environments, especially in scenarios that require high temperature resistance and corrosion resistance. The manufacturing process of Molybdenum sheets typically involves extracting molybdenum from molybdenite (MoS_2) and then passing through multiple processes such as sintering, hot rolling, cold rolling, and annealing to make thin flakes with specific properties. This material not only plays an important role in traditional industries, but also shows irreplaceable value in emerging technology fields such as semiconductor manufacturing and new energy equipment.

1.2 Specifications of molybdenum sheets

The following is a table detailing the common specifications of molybdenum sheets, covering thickness, width, length, surface treatment type and related performance indicators to meet the needs of different industrial scenarios:

parameter	Specification range	remark
thickness	0.01 mm - 3 mm	Ultra-thin foils (0.01-0.1 mm) are used for high-precision electronic components, while thicker sheets (>1 mm) are used for structural parts
width	50 mm - 600 mm	It can be customized according to customer needs, and some wide molybdenum sheets require special rolling equipment
length	Custom lengths or roll forms	The coil form is used for continuous production, and the cutting length depends on the application
Surface treatment	Polished, pickled, sandblasted	The polished side is suitable for semiconductors, the pickled side is used in a vacuum environment, and the sandblasted side enhances adhesion
Thickness tolerances	± 0.005 mm - ±02 mm	Complies with ASTM B386, depending on thickness
Purity of the material	≥99.95%	High-purity Molybdenum sheets can be doped with lanthanum, titanium and other elements (such as TZM alloys) to improve performance
Annealed state	Stress relief annealing, complete annealing	The annealing temperature is 1100-1300°C, which improves ductility and reduces brittleness
Surface roughness	Ra 0.8 μm–Ra 3.2 μm	The roughness of the polished surface is the lowest, and the roughness of the sandblasted surface is higher

In the market, brand products such as CTIA GROUP LTD Molybdenum Sheet strictly follow the ASTM B386 standard, the thickness tolerance can be controlled within ±0.005 mm, and the surface roughness Ra value is as low as 0.4 microns, which meets the strict requirements of high-end applications. The specifications of the molybdenum sheet can also be optimized according to the alloy composition (e.g. TZM molybdenum alloy) or doped elements (e.g. lanthanum or titanium) to meet the special needs of sectors such as aerospace, nuclear industry or semiconductor manufacturing. For example, TZM molybdenum alloy sheet is superior to pure molybdenum sheet in terms of high-temperature strength and creep resistance, and is suitable for higher temperature environments (above 1500°C).

1.3 Characteristics of molybdenum sheets

Molybdenum sheet stands out among many high-performance materials due to its unique material properties. First of all, molybdenum sheet has an extremely high melting point (2620 °C), second only to tungsten, rhenium and other metals, so that it can still maintain excellent mechanical strength in high temperature environments, such as tensile strength of more than 700MPa at 1200 °C. Secondly, molybdenum sheets have a low coefficient of thermal expansion (about 4.8×10^{-6}/°C).), which matches

电话/TEL：0086 592 512 9696
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sales@chinatungsten.com

the coefficient of thermal expansion of many ceramic materials and semiconductor substrates, which makes them important applications in thermal barrier coatings and electronic packaging. In addition, molybdenum sheets have excellent thermal conductivity (thermal conductivity of about 138 W/m·K) and can effectively dissipate heat, making them suitable for thermal shielding of high-temperature stoves or heat dissipation substrates for electronic devices. However, Molybdenum sheets are brittle at room temperature, and their body-centered cubic crystal structure makes them limited in ductility at low temperatures, but when heated to the recrystallization temperature (1000-1200°C), the ductility is significantly improved, which is convenient for further processing. Molybdenum sheets also exhibit excellent corrosion resistance, especially in acidic environments and non-oxidizing atmospheres, but are prone to the formation of volatile oxides (e.g., MoO_3) in oxidizing atmospheres, so they are often used under vacuum or inert gas protection. In addition, molybdenum sheets have a high electrical conductivity (resistivity of about $5.2\times10^{-8}\Omega\cdot m$), so that it can be used as an electrode material or target in the electronics industry. Overall, molybdenum sheets have high strength, high temperature resistance, low thermal expansion, and excellent thermal and electrical conductivity, making them indispensable materials for aerospace, nuclear industry, and semiconductor manufacturing.

1.3.1 Appearance characteristics of molybdenum sheets

1.3.1.1 Appearance and cause of black-brown molybdenum sheet

Untreated Molybdenum sheets often have a blackish-brown appearance during production, a characteristic that is mainly due to the oxide layer that forms on their surface. During the processing of molybdenum sheets, such as rolling or annealing, when the molybdenum metal is exposed to air, its surface reacts with oxygen to form molybdenum oxide (MoO_3 or MoO_2). ）。 These oxides are usually black-brown or dark gray in color and cover the surface of the molybdenum sheet, forming a thin, dense oxide film. The occurrence of oxidation reactions is closely related to the temperature and oxygen concentration in the processing environment. For example, in the process of annealing at high temperatures (800-1000°C), molybdenum surfaces are highly susceptible to oxidation if not protected by vacuum or inert gases such as argon or nitrogen. In addition, the black-brown appearance of Molybdenum sheets can also be affected by lubricant residues used in the rolling process or trace surface impurities. These lubricants can carbonize at high temperatures, forming trace amounts of carbon-based compounds that further darken the surface color. Although the black-brown oxide layer protects the molybdenum sheet from further corrosion to some extent, in high-precision applications such as semiconductor targets or electronic components, this oxide layer often needs to be removed by post-processing to ensure surface cleanliness and consistent performance.

1.3.1.2 Silver-gray luster and treatment principle of Molybdenum sheets after alkali washing

Through caustic washing, the surface of the molybdenum sheet can take on the signature silver-gray metallic luster, which is not only an intrinsic characteristic of molybdenum metal, but also a reflection of its high purity and surface cleanliness. The caustic washing process typically uses a strong alkaline solution such as sodium hydroxide (NaOH) or potassium hydroxide (KOH) to soak the Molybdenum sheets at a specific temperature (50-80°C) to remove oxides, greases and organic residues from the surface. The chemical principle of caustic washing is based on the reaction of molybdenum oxide with an alkaline solution, for example, MoO_3 reacts with NaOH to produce soluble sodium molybdate (Na_2MoO_4).), thereby peeling off the surface oxide layer and revealing the true color of molybdenum metal. In addition, caustic washes are often followed by a deionized water rinsing and drying process to prevent secondary oxidation and ensure that the surface is free of residual chemicals. The surface roughness of the caustic washed molybdenum sheet can be as low as Ra 0.4 microns, showing a mirror-like silver-gray luster, which not only improves the aesthetics, but also significantly improves the performance of the molybdenum sheet in a vacuum environment, such as reducing the gas release rate, and is suitable for use in vacuum furnaces or sputtering targets. Precise control of the caustic washing process is particularly important for high-end Molybdenum sheets products, such as CTIA GROUP LTD Molybdenum sheets by optimizing the caustic washing process to ensure surface finish and consistency, and meet the requirements of ASTM B386 standard for high-precision Molybdenum sheets.

1.3.1.3 Flatness of molybdenum sheet

The flatness of Molybdenum sheets is an important indicator of their appearance characteristics and application performance, especially in high-precision applications such as thin film deposition, electronic packaging, and precision mechanical components. Flatness is usually quantified by surface waviness or flatness deviation, and the flatness deviation of high-quality molybdenum sheet can be controlled within ±0.01 mm/m. The flatness of a molybdenum sheet is affected by a variety of factors, including the rolling process, annealing treatment, and material thickness. Ultra-thin molybdenum sheets (thickness < 0.1 mm) are prone to internal stresses during the cold rolling process, resulting in slight surface undulations or ripples, so precise stress relief annealing (1100-1300°C) is required to improve the grain structure and relieve stress. Thicker molybdenum sheets (>1 mm) are relatively easy to control due to the high rigidity of the material, but excessive deformation or uneven cooling during the rolling process needs to be avoided. State-of-the-art rolling equipment and multi-pass annealing processes can significantly improve the flatness of the molybdenum sheet, for example by controlling the temperature gradient and cooling rate through a vacuum annealing furnace, which minimizes the surface waviness of the molybdenum sheet. In addition, flatness is also related to surface treatment, and molybdenum sheets after polishing or pickling usually have higher flatness due to more uniform surface stress distribution. In practice, Molybdenum sheets with high flatness can ensure a good fit between the target and the substrate during thin film deposition or reduce thermal stress concentrations in electronic packaging, thereby extending component lifetime.

CTIA GROUP LTD molybdenum sheet

Chapter 2 Performance of molybdenum sheets

2.1 Physical properties of molybdenum sheets

CTIA GROUP LTD molybdenum sheets favored for its excellent physical properties, it is used in aerospace, electronics and high-temperature applications, covering key properties such as density, melting point, boiling point, electrical conductivity, thermal conductivity and coefficient of thermal expansion. These properties are due to molybdenum's body-centered cubic crystal structure and plateau binding energy, which makes it exhibit excellent stability and functionality in extreme environments. The following will discuss in detail the coefficient of thermal expansion of molybdenum sheet, as well as its high strength, ductility and high-temperature creep resistance in mechanical properties, and conduct in-depth analysis based on professional data and process background to reveal its application value in high-precision and high-temperature scenarios.

2.1.1 Density of molybdenum sheets

The density of molybdenum sheet is an important indicator of its physical properties, usually around 10.22 g/cm^3 (at 20°C), slightly lower than tungsten (19.25 g/cm^3) but higher than many common metals such as iron (7.87 g/cm^3) or aluminum (2.70 g/cm^3). This density value reflects the compact atomic arrangement of molybdenum metal, which makes it relatively light in weight while maintaining high strength, making it suitable for applications that require both strength and weight, such as thermal shielding for aerospace components or high-temperature furnaces. The density of a molybdenum sheet is affected by its purity and trace amounts of doped elements. For example, the density of a high-purity molybdenum sheet (purity ≥ 99.95%) is close to the theoretical value, while a TZM molybdenum alloy

电话/TEL：0086 592 512 9696
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sales@chinatungsten.com

sheet doped with lanthanum or titanium may have a slight change in density (usually between 10.16 and 10.20 g/cm³) due to the addition of a small amount of other elements. During the production process, the density of the molybdenum sheet is precisely controlled by powder metallurgy and the subsequent rolling process. The particle size and sintering conditions of the initial molybdenum powder (e.g. temperature 1800-2000°C, vacuum or hydrogen protection) affect the density of the blank, while multiple passes of cold rolling and annealing further eliminate internal porosity and ensure uniform density of the molybdenum sheet. Density consistency is especially critical for thin film deposition or target applications, as any small density deviation can lead to uneven sputtering rates or unstable material properties. In the actual measurement, the density of the molybdenum sheet is usually verified by the Archimedes drainage method or X-ray density meter, and the error is controlled within ±0.01 g/cm³ to meet the needs of high-precision applications.

2.1.2 Melting point of molybdenum sheet

The melting point of molybdenum sheet is one of its most prominent physical properties, about 2620 °C (2893 K), second only to tungsten (3422 °C) and rhenium (3180 °C) among common metals. This extremely high melting point allows Molybdenum sheets to perform well in high-temperature environments and are widely used in heat-resistant components in vacuum furnaces, nuclear reactors, and aerospace engines. Molybdenum's high melting point is due to its strong metallic bonds and body-centered cubic crystal structure, which gives it high mechanical strength at high temperatures. For example, at 1200°C, the tensile strength of molybdenum sheets can still be maintained above 700 MPa, which is far higher than that of many other metal materials. The stability of the melting point is also closely related to the purity of the molybdenum sheet, which is closer to the theoretical value of high-purity molybdenum sheet (≥99.95%) due to its very low impurity content, while trace impurities (such as carbon, oxygen or nitrogen) may slightly reduce the melting point or cause local property changes. During the production process, the melting point characteristics of Molybdenum sheets are preserved through strict control of raw material purification and processing environment. For example, molybdenite (MoS_2) needs to be sintered at high temperatures in a vacuum or reducing atmosphere after purification to avoid oxide inclusions affecting material properties. In addition, Molybdenum sheets need to be careful about their oxidation tendency in high-temperature applications, and in oxidizing atmospheres above 600°C, molybdenum will rapidly form volatile oxides (e.g., MoO_3), so it is often used under vacuum or under the protection of inert gases such as argon or nitrogen to take advantage of its high melting point. This property of Molybdenum sheets makes them ideal for thermal shielding, sputtering targets and superalloy substrates in high-temperature furnaces.

2.1.3 Boiling point of molybdenum sheet

The boiling point of molybdenum sheet is another key characteristic of its physical properties, which is about 4639 °C (4912 K), which is one of the highest in the field of metal materials, second only to a few high melting point metals such as tungsten (5555 °C) and rhenium (5596 °C). This extremely high boiling point allows the molybdenum sheet to remain structurally stable under extremely high temperature conditions, making it particularly suitable for use in applications that require ultra-high temperature operation, such as plasma spraying, vacuum evaporation, or high-temperature melting equipment. The high boiling point of molybdenum is closely related to its strong metallic bonds and low vapor pressure (vapor pressure of only about 10^{-7} Pa at 3000°C), which means that even at temperatures close to the melting point, molybdenum sheets have extremely low volatilization losses and are able to maintain their physical form for a long time. The stability of the boiling point is affected by the purity of the molybdenum sheet, which is closer to the theoretical value due to the low content of impurities in high-purity Molybdenum sheets (≥99.95%), while trace impurities (such as oxygen or carbon) may cause local volatilization or surface defects. During the production process, the boiling point characteristics of Molybdenum sheets are optimized by the selection of high-purity raw materials and the processing process in a vacuum environment. For example, during vacuum sintering or annealing (the temperature is usually controlled at 1800-2000°C), the formation of oxides or nitrides can be effectively reduced and the stability of the material at high temperatures can be ensured. The high boiling point of Molybdenum sheets gives them unique advantages in the aerospace industry (e.g., rocket nozzle linings) or in the semiconductor industry (e.g., high-temperature evaporation boats), but high temperature exposure needs to be avoided in oxidizing atmospheres to prevent material loss due to oxide volatilization.

2.1.4 Conductivity of molybdenum sheets

The conductivity of molybdenum sheet is an important basis for its wide application in the electronics industry, and its resistivity is about 5.2×10^{-8} Ω·m (at 20°C), the corresponding conductivity is 1.92×10^{7} S/m, showing good conductivity. Compared to copper (resistivity 1.68×10^{-8} Ω·m) or silver (1.59×10^{-8} Ω·m), molybdenum sheet is slightly less conductive, but its conductivity stability at high temperatures is much higher than that of many common conductor materials. For example, at 1000°C, the resistivity of molybdenum sheets increases only to about 2.5 times, while the resistivity of copper can increase by more than 5 times. This high-temperature conductive stability makes molybdenum sheets ideal for electrode materials, sputtering targets, and high-temperature circuit components. The conductivity of molybdenum sheet is closely related to its crystal structure and purity, and the body-centered cubic structure of molybdenum metal has high electron mobility, while high purity (≥99.95%) can reduce grain boundary scattering and impurity resistance. During the production process, the conductive properties of the molybdenum sheet are further optimized by controlling the rolling process and annealing conditions. For example, stress relief annealing (1100-1300°C) improves grain structure and reduces grain boundary resistance, resulting in higher conductivity. In addition, surface treatments, such as polishing or pickling, reduce the effect of the oxide layer on the conductivity of the surface, ensuring stable electrical properties of the molybdenum sheet in a vacuum or inert environment. The electrical conductivity of molybdenum sheets is particularly important in semiconductor manufacturing, for example as a sputtering target for depositing conductive thin films, or as an anode material in X-ray tubes.

2.1.5 Thermal conductivity of molybdenum sheets

The thermal conductivity of Molybdenum sheets is a key advantage in high-temperature heat dissipation and thermal management applications, with a thermal conductivity of about 138 W/m·K at 20°C, which is close to aluminum (237 W/m·K) but much higher than stainless steel (about 16 W/m·K). This excellent thermal conductivity enables molybdenum sheets to transfer heat quickly, which is widely used in thermal shielding in high-temperature furnaces, heat dissipation substrates for electronic devices, and thermal management of aerospace components. The thermal conductivity of molybdenum sheet is closely related to its electronic structure and crystal regularity, and the body-centered cubic structure of molybdenum metal has a high free electron density, which is conducive to the rapid conduction of heat. The thermal conductivity decreases slightly with increasing temperature, e.g. to about 100 W/m·K at 1000°C, but is still sufficient for most high-temperature applications. The thermal conductivity of Molybdenum sheets is also affected by its purity and microstructure, with high-purity Molybdenum sheets (≥99.95%) having better thermal conductivity due to less scattering of grain boundaries and impurities, while doped alloys (e.g., TZM) may slightly reduce the thermal conductivity (about 120-130 W/m·K) due to the addition of elements. During production, the thermal conductivity of molybdenum sheets is improved by optimizing the sintering and rolling process, such as reducing internal porosity through vacuum sintering, or controlling grain size through cold rolling and annealing to minimize thermal resistance. In practical applications, the thermal conductivity of molybdenum sheets makes it a heat sink material in semiconductor packaging or as a thermal shielding layer in high-temperature furnaces, which can effectively reduce temperature gradients and extend equipment life.

2.1.6 Coefficient of thermal expansion of molybdenum sheet

The coefficient of thermal expansion of Molybdenum sheets is a critical physical property in high-temperature applications, averaging about 4.8×10^{-6}/°C (in the range of 20-1000°C), well below copper (16.5×10^{-6}/°C) and aluminum (23.1×10^{-6}/°C). However, it is similar to the coefficient of thermal expansion of many ceramic materials (e.g., alumina, approx. 7×10^{-6}/°C) and semiconductor substrates (e.g., silicon, approx. 2.6×10^{-6}/°C). This low coefficient of thermal expansion allows molybdenum sheets to effectively reduce thermal stress in high-temperature environments, making them ideal for applications that require thermal matching, such as electronic packaging, thin film deposition, and thermal barrier coatings. The low coefficient of thermal expansion is due to the body-centered cubic crystal structure of molybdenum metal, which has strong interatomic bonding force, which limits the expansion of the crystal lattice at high temperatures.

The thermal expansion performance of Molybdenum sheets is also affected by its purity and processing technology, with high-purity Molybdenum sheets (≥ 99.95%) having a more stable coefficient of thermal expansion, while doped alloys (such as TZM, containing titanium and zirconium) may slightly increase the coefficient of thermal expansion (about $5.0\text{-}5.3\times10^{-6}$/°C). ）。 During the production process, the uniformity of the coefficient of thermal expansion is controlled by precise rolling and annealing processes, e.g. by vacuum annealing (1100-1300°C) to optimize the grain structure, reduce microscopic stress concentrations, and ensure consistent thermal expansion behavior. The low coefficient of thermal expansion of molybdenum sheets is particularly critical in semiconductor manufacturing, for example as a substrate material for chip packaging, which can effectively reduce thermal mismatch stresses caused by temperature changes, thereby improving device reliability. In addition, in high-temperature furnaces or aerospace components, the low thermal expansion properties of molybdenum sheets help maintain structural stability and extend service life.

2.2 Mechanical properties of molybdenum sheets

The mechanical properties of molybdenum sheets, including high strength, ductility and creep resistance at high temperatures, are the core advantages of molybdenum sheets in harsh applications. The body-centered cubic crystal structure of molybdenum metal gives it excellent mechanical strength, but also brings a certain degree of low-temperature brittleness. Through advanced processing techniques, such as cold rolling, hot rolling, and annealing, the mechanical properties of molybdenum sheets can be optimized, making them perform well at both ambient and high temperatures. The following will analyze the high strength, ductility and creep resistance of molybdenum sheet in detail, and reveal its applicability in aerospace, nuclear industry and high-temperature furnaces with professional data.

2.2.1 High strength of molybdenum sheet

The high strength of molybdenum sheet is an important characteristic of it in high load and high temperature environments, and its tensile strength can reach 800-1000 MPa at room temperature, which is much higher than that of many common metals such as aluminum (about 200 MPa) or stainless steel (about 500 MPa). At high temperatures, such as 1200°C, the tensile strength of molybdenum sheets can still be maintained above 700 MPa, showing excellent strength stability. This high strength stems from molybdenum's strong metallic bonds and high modulus of elasticity (about 320 GPa), which allows it to withstand significant mechanical stresses. The strength of Molybdenum sheets is affected by its purity and processing technology, high-purity Molybdenum sheets (≥99.95%) have higher strength due to less impurities in grain boundaries, while doped alloys (such as TZM) further improve the high-temperature strength (up to more than 1200 MPa) by adding titanium, zirconium and other elements. During the production process, the strength of the molybdenum sheet is optimized by multi-pass rolling and stress relief annealing. The cold rolling process significantly improves strength by introducing dislocations and grain refinement, while annealing (1100-1300°C) balances strength and toughness and avoids over-embrittlement. The high strength of molybdenum sheets makes them important applications in the aerospace sector (e.g. the support structure of turbine blades) or in the nuclear industry (e.g. reactor vessel linings), where it can withstand extreme mechanical loads and high-temperature stresses.

2.2.2 Ductility of molybdenum sheets

The ductility of molybdenum sheet is an important aspect of its mechanical properties, although its body-centered cubic crystal structure shows a certain degree of brittleness at room temperature, it can achieve good ductility under appropriate conditions. At room temperature, molybdenum sheets typically have an elongation at break of between 5-10%, which is lower than that of highly ductile metals such as copper (about 50%), but can be significantly improved by high-temperature processing or annealing. For example, at a recrystallization temperature of 1000-1200°C, the elongation at break of molybdenum sheet can be increased to more than 20%, which is suitable for molding complex shapes. The improvement of ductility is closely related to the optimization of grain structure, and the cold-rolled molybdenum sheet is brittle due to the high fault density, but the grain recrystallization can be promoted by vacuum annealing (1100-1300°C), and the internal stress and dislocation density can be reduced, thereby enhancing the ductility. High-purity molybdenum sheet (≥99.95%) has better ductility due to less impurities, while doped alloys (such as TZM) have slightly reduced ductility at high temperatures, but are still better than pure molybdenum at low temperatures. During the production process, the ductility of molybdenum sheets is optimized by precisely controlled rolling passes and annealing processes, such as rolling with multiple passes with small deformations combined with low-temperature annealing, which improves ductility while maintaining strength. The ductility of molybdenum sheets makes them widely used in thin film deposition, stamping and precision machining, such as as flexible substrates or targets in the semiconductor industry.

2.2.3 Creep resistance of molybdenum sheets at high temperatures

The creep resistance of Molybdenum sheets at high temperatures is a key advantage under long-term loads at high temperatures, especially in applications such as aerospace and high-temperature stoves. Creep refers to the slow deformation of materials at high temperatures and constant stress, and molybdenum sheets have extremely low creep rates at high temperatures (1000-1500°C), such as 10^{-6} at 1200°C and 100 MPa stresses/s, which is much better than stainless steel (about 10^{-4}/s). This excellent creep resistance is due to the high melting point and strong metallic bonds of molybdenum metal, as well as the stability of its body-centered cubic crystal structure at high temperatures. Doped alloys (e.g., TZM) further enhance creep resistance by adding titanium, zirconium and carbon to form a precipitated phase, and their creep strength can be increased by 30-50% compared with pure molybdenum. During production, creep resistance is improved by optimizing grain size and doping processes, such as by controlling the sintering temperature (1800-2000°C) and cooling rate, resulting in a fine and uniform grain structure that reduces grain boundary slip and creep deformation. In addition, the creep resistance of molybdenum sheets is also related to their surface state and the environment in which they are used, and in a vacuum or inert atmosphere, molybdenum sheets can avoid oxide formation and thus maintain long-term high-temperature stability. The creep resistance of molybdenum sheets at high temperatures makes them irreplaceable in high-temperature furnace internals, nuclear reactor support structures, and aerospace high-temperature components, allowing them to maintain their shape and strength under extreme conditions.

2.2.4 Hardness of molybdenum sheets

The hardness of CTIA GROUP LTD molybdenum sheet is an important embodiment of its mechanical properties, which makes it have significant advantages in wear-resistant and high-load applications. The hardness of Molybdenum sheets is usually expressed in Vickers (HV) or Brinell (HB), and the Vickers hardness range of high-purity Molybdenum sheets (purity ≥ 99.95%) at room temperature is 220-250 HV, which is equivalent to a Brinell hardness of about 230-260 HB, much higher than aluminum (about 30 HV) and close to some low-alloy steels. This high hardness is due to the body-centered cubic crystal structure of molybdenum metal and its strong atom binding force, which can effectively resist surface scratches and deformation. The hardness of cold-rolled molybdenum sheet can be increased to more than 280 HV due to the increase of dislocation density, while the hardness of annealed (1100-1300°C) will be slightly reduced to 200-220 HV to balance the toughness. Doped alloys such as TZM (containing titanium, zirconium and carbon) can reach hardness of 300-350 HV through precipitation strengthening mechanism, which is especially suitable for high-temperature and high-load environments. In the production process, the hardness is precisely adjusted by controlling the amount of rolling deformation and the annealing process, e.g. multi-pass cold rolling combined with low-temperature annealing to optimize grain size, maintain high hardness and avoid brittleness. The high hardness of molybdenum sheets makes them excellent in sputtering targets, cutting tool coated substrates and high-temperature molds, withstanding mechanical wear and surface stresses.

2.2.5 Toughness of molybdenum sheets

The toughness of molybdenum sheet refers to its ability to absorb energy and resist fracture when subjected to force, although its body-centered cubic crystal structure exhibits a certain degree of brittleness at room temperature, with appropriate process optimization, molybdenum sheet can show moderate toughness. At room temperature, the fracture toughness (K_IC) of molybdenum sheet is usually between 10-15 MPa·m^1/2, which is lower than that of high-toughness metals such as copper (about 50 MPa·m^1/2), but at high temperature (1000-1200°C), the toughness is significantly improved, and the fracture toughness can reach more than 20 MPa·m^1/2. This is due to the enhancement of grain boundary slip and dislocation motion at high temperatures, which reduces the brittle fracture tendency. The toughness of Molybdenum sheets is affected by purity and microstructure, high-purity Molybdenum sheets (≥ 99.95%) have cleaner grain boundaries and better toughness due to less impurities, while doped alloys such as TZM can maintain the balance of toughness and strength at high temperatures through precipitation phase strengthening. In production, toughness is effectively improved and crack propagation is reduced by controlling grain size and optimizing the annealing process, such as vacuum annealing (1100-1300°C) to form uniform and fine grains. The toughness of molybdenum sheets gives them an advantage in aerospace components such as high-temperature nozzles and electronic substrates, where they can withstand thermal shock and mechanical vibration without being prone to breakage.

2.2.6 Fatigue resistance of molybdenum sheets

The fatigue resistance of molybdenum sheet reflects its ability to resist fatigue crack initiation and propagation under cyclic stress, which is a key characteristic in dynamic load applications. At room temperature, the fatigue limit of molybdenum sheet (i.e., the stress that does not break at 10^7 cycles) is about 400-500 MPa, which is about 50% of its tensile strength. At high temperatures (1000°C), the fatigue limit drops slightly to 300-400 MPa, but is still better than many metal materials. The fatigue resistance of molybdenum sheet is closely related to its crystal structure and surface quality, and the body-centered cubic structure of molybdenum metal has higher fatigue crack propagation resistance, while high-purity molybdenum sheet (≥99.95%) has better fatigue performance due to less impurities at grain boundaries. Doped alloys such as TZM can further increase fatigue life by precipitation strengthening. In the production process, fatigue resistance is improved by optimizing rolling and surface treatment processes, such as polishing surfaces (Ra ≤0.4 microns) to reduce the initiation point of surface microcracks, and stress relieving annealing (1100-1300°C) to reduce residual stress and extend fatigue life. The fatigue resistance of Molybdenum sheets makes it excellent in aerospace (e.g., turbine blade support) and high-temperature vibration environments (e.g., nuclear reactor components), and is able to withstand long-term cyclic loads without failure.

2.3 Chemical properties of molybdenum sheets

The chemical properties of molybdenum sheets, including corrosion resistance and oxidation resistance, determine their suitability in harsh chemical environments. Due to its stable chemical properties and low reactivity, molybdenum metal exhibits excellent corrosion resistance in non-oxidizing acids, alkalis and a variety of chemical media, but special attention should be paid to its surface protection in oxidizing atmospheres. The corrosion and oxidation resistance of molybdenum sheets will be discussed in detail below, combined with expert data to reveal how they behave in chemical environments.

2.3.1 Corrosion resistance of molybdenum sheets

The corrosion resistance of molybdenum sheets is an important advantage in the chemical industry and in extreme environments, especially in non-oxidizing acids and alkaline environments. Molybdenum sheets have excellent corrosion resistance to non-oxidizing acids such as hydrochloric acid, sulphuric acid and hydrofluoric acid, e.g. at a concentration of 10% hydrochloric acid (20°C), the corrosion rate is less than 0.01 mm/year, which is much better than stainless steel (about 0.1 mm/year). In alkaline environments such as sodium hydroxide solutions, molybdenum sheets also perform well, with corrosion rates below 0.005 mm/year. This is due to the chemically inert nature and high electrode potential of molybdenum metal, which makes it less prone to electrochemical reactions with non-oxidizing media. However, among oxidizing acids (e.g., concentrated nitric acid), molybdenum sheets have poor corrosion resistance due to the formation of soluble molybdates. The corrosion resistance of Molybdenum sheets is closely related to their surface condition and purity, high-purity Molybdenum sheets (≥99.95%) have a low tendency to corrode at grain boundaries due to fewer impurities, while polishing or pickling the surface (Ra ≤0.4 microns) can further reduce the corrosion point. In production, corrosion resistance is enhanced by optimized purification processes and surface treatments, such as the removal of oxygen and nitrogen impurities by vacuum sintering or the removal of surface oxides by caustic washing. The corrosion resistance of molybdenum sheets makes it widely used in chemical reactor linings, electrode materials, and marine engineering.

2.3.2 Oxidation resistance of molybdenum sheets

The oxidation resistance of molybdenum sheet is the limiting factor of its chemical properties in a high-temperature environment, because molybdenum metal is prone to form volatile oxides in an oxidizing atmosphere. At temperatures below 600°C, a thin and dense oxide layer (e.g., MoO_2) can form on the surface of the molybdenum sheet to provide some protection, but above 600°C, molybdenum rapidly oxidizes to form volatile molybdenum trioxide (MoO_3). The evaporation rate can reach 0.1 $g/cm^2 \cdot h$ at 800°C, resulting in rapid material loss. This property limits the use of molybdenum sheets in oxidizing atmospheres for high-temperature applications, often under the protection of vacuum or inert gases such as argon or nitrogen to avoid oxidation losses. In a vacuum environment, the oxidation resistance of molybdenum sheets is significantly improved, and the surface remains stable even at 1500°C. The oxidation resistance is affected by the purity and surface treatment of the molybdenum sheet, and the high-purity molybdenum sheet (≥99.95%) has a lower oxidation rate due to less impurities, while the doped alloy (such as TZM) can slightly improve the oxidation resistance by adding titanium and zirconium. In production, oxidation resistance is optimized by surface coatings (e.g. silicide or alumina coatings) or by vacuum annealing processes, e.g. at 1200°C to reduce surface oxygen adsorption. The oxidation resistance of Molybdenum sheets limits its direct use in high-temperature air environments, but its high-temperature stability makes it ideal in vacuum furnaces, semiconductor manufacturing, and the nuclear industry.

2.4 CTIA GROUP LTD Molybdenum Sheet MSDS

CTIA GROUP LTD molybdenum sheets as a high-purity metal material, its Material Safety Data Sheet (MSDS) or Safety Data Sheet (SDS) is an important document to ensure its safe use, storage and transportation, and meets the requirements of the International Harmonized System of Classification and Labelling of Hazardous Chemicals (GHS). Although molybdenum sheets themselves are considered non-hazardous under normal conditions, their MSDS provides detailed information on physicochemical properties, health and environmental risks, safe operating guidelines, and emergency measures to ensure occupational safety and compliance. The following elaborates the MSDS content of CTIA GROUP LTD Molybdenum Sheet from the aspects of physical and chemical properties, health and environmental impact, operation and storage, protective measures and emergency treatment.

The physical and chemical properties of CTIA GROUP LTD Molybdenum sheets are the core part of MSDS, providing users with basic physical and chemical information of materials. Its chemical composition is high-purity molybdenum (purity≥99.95%), chemical symbol Mo, atomic number 42, density of about 10.22 g/cm³ (20 °C), melting point of about 2620 °C, boiling point of about 4639 °C. Molybdenum sheets have a silver-gray metallic sheen and are usually found in the form of flakes or foils, with thicknesses ranging from 0.01 mm to 3 mm. Surface treatments, such as polishing or pickling, affect their appearance and roughness (Ra 0.4-1.6 microns). Molybdenum sheets are chemically stable at room temperature, insoluble in water, and have low reactivity with non-oxidizing acids (such as hydrochloric acid, sulfuric acid) and alkaline solutions, but are prone to volatile molybdenum trioxide (MoO_3) in a high-temperature oxidizing atmosphere (>600 °C). The MSDS clearly states that the flash point and auto-ignition point of Molybdenum sheets are not applicable because they are solid metals and do not pose a risk of explosion or flammability under normal conditions. These features provide the basis for safe operation, ensuring that users are aware of their physical behavior and potential chemical reactions.

Health and environmental impacts are important components of the MSDS, which aims to assess the potential risks of molybdenum sheets to humans and the environment. Molybdenum tablets have no significant health hazard to humans under normal conditions of use, their toxicity is extremely low, and acute oral toxicity (LD50) data are generally not available, as pure molybdenum is not considered a toxic substance. However, molybdenum dust or fumes can be produced during processing, such as cutting, grinding, or welding, inhalation of high concentrations of dust may cause mild respiratory irritation, and long-term exposure may cause lung discomfort. MSDS recommends avoiding inhalation of dust and ensuring that the workplace is well ventilated. Skin and eye contact with molybdenum sheets is usually harmless, but sharp edges can cause mechanical scratches and should be handled safely. From an environmental point of view, Molybdenum sheets themselves have no direct risk of pollution to water, soil and air, but the molybdenum dust or waste produced by processing may have an impact on the local environment if not properly treated. MSDS emphasizes that molybdenum sheet waste should be sorted and recycled according to local regulations and avoid direct discharge into the environment to meet environmental protection requirements.

Safe handling and storage is a key part of the MSDS to ensure the safe use of Molybdenum sheets in the workplace. CTIA GROUP LTD molybdenum sheets should be stored in a dry and well-ventilated environment, avoiding high temperature (>600°C) and oxidizing atmosphere to prevent surface oxidation. The storage area should be kept away from strong oxidants (e.g., concentrated nitric acid) or high-temperature ignition sources, as molybdenum may react with oxygen at high temperatures to form MoO_3。MSDS recommends the use of appropriate personal protective equipment (PPE) such as protective gloves, safety glasses, and dust masks, especially when cutting, grinding, or welding, to prevent dust inhalation or mechanical injury. When operating the equipment, a local exhaust ventilation system should be equipped to ensure that dust concentrations are below occupational exposure limits (e.g., OSHA PEL or ACGIH TLV, the recommended exposure limit for molybdenum dust is approximately 10 mg/m³). In terms of transportation, Molybdenum sheets do not fall under the category of dangerous goods under the International Maritime Dangerous Goods (IMDG) or the International Air Transport Association (IATA), but they need to be properly packaged to avoid physical damage or contamination. MSDS also recommends that storage facilities be inspected regularly to ensure that no moisture or high temperatures can affect material properties.

Emergency measures are another core element of MSDS, providing guidance for rapid response to unexpected situations. In the event of dust inhalation from molybdenum sheet processing, MSDS recommends moving affected individuals to fresh air and seeking medical attention if symptoms persist. When the skin comes into contact with the molybdenum sheet and causes scratches, the wound should be immediately rinsed with water and appropriate wound treatment should be carried out; If molybdenum dust gets into your eyes, rinse with plenty of water for at least 15 minutes and seek medical advice. In the event of a fire, the molybdenum sheet itself is not flammable, but if high-temperature oxidation is involved, dry powder or carbon dioxide extinguishing agent should be used, and water-based extinguishing agent should be avoided to prevent the reaction from intensifying. For spills or waste disposal, MSDS requires the use of vacuuming equipment or wet cleaning methods to collect molybdenum dust to avoid fugitive dust, and to send the waste to an authorized recycling facility for disposal, and prohibits discarding. Emergency contact information usually includes the manufacturer's emergency phone number and address in case of an accident.

The MSDS of CTIA GROUP LTD molybdenum chips also needs to comply with international and regional regulatory requirements, such as OSHA hazard communication standard (29 CFR 1910.1200), EU REACH regulation (EC No 1907/2006) and China GB/T 16483-2008 standard. The document is formatted in 16 sections of the GHS standard, including substance identification, hazard classification, ingredient information, first aid measures, fire protection measures, spill emergency response, operation and storage, exposure control, physicochemical properties, stability and reactivity, toxicological information, ecological information, disposal information, transportation information, regulatory information, and other information. The MSDS needs to be updated every three years or revised as new hazard information becomes available to ensure accuracy and compliance. Users can obtain the latest MSDS documents through the official website of CTIA GROUP LTD or contact its customer service department to ensure that the operation complies with occupational safety and environmental protection regulations.

CTIA GROUP LTD
Molybdenum Sheet Introduction

1. Overview of Molybdenum Sheet

Molybdenum sheet is a thin metal sheet made from high-purity molybdenum through rolling processes. It features excellent high-temperature resistance, thermal conductivity, and mechanical strength. It is widely used in electronics, metallurgy, vacuum equipment, aerospace, and lighting industries as heating elements, thermal shields, or structural components. With a smooth surface and precise dimensions, molybdenum sheets can be customized in various specifications to meet the requirements of advanced manufacturing and scientific research equipment.

2. Features of Molybdenum Sheet

High Purity Material: Purity ≥ 99.95%, with extremely low impurity levels
High-Temperature Resistance: Melting point up to 2610°C, stable performance in extreme conditions
Excellent Workability: High flatness, smooth surface, easy to punch, shear, and weld
Customizable Specifications: Various sizes and thicknesses available to suit different processes

3. Specifications of Molybdenum Sheet

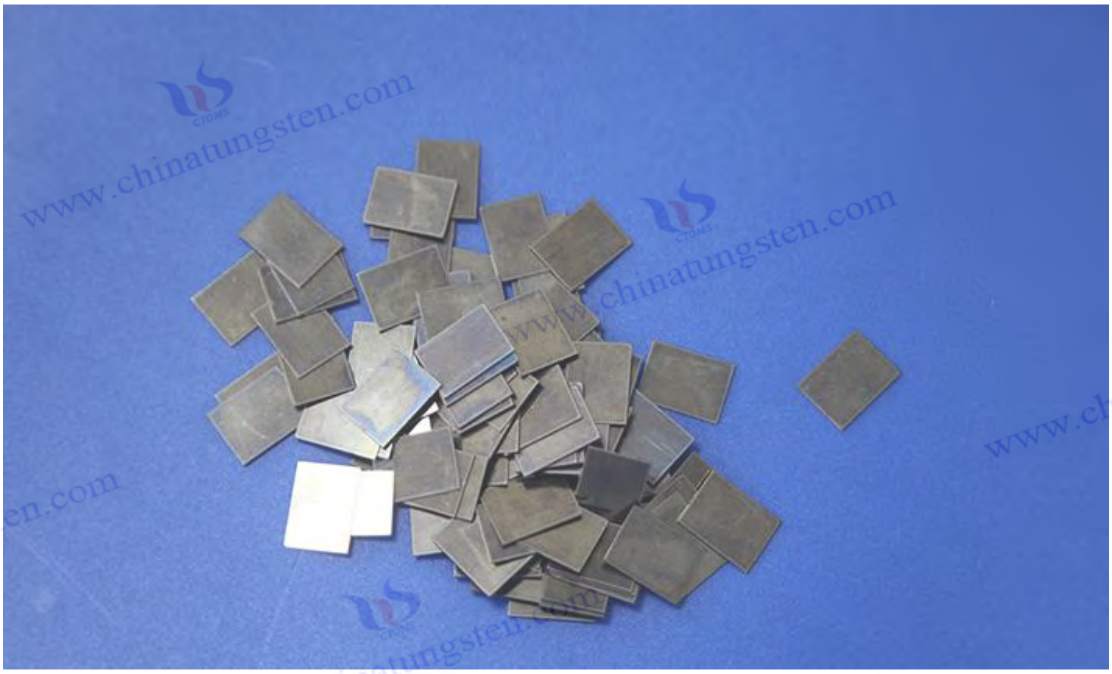
Parameter	Specification
Purity	≥ 99.95%
Thickness	0.01 mm - 3.00 mm
Width	50 mm - 600 mm
Length	Custom lengths or supplied in coil
Surface Finish	Polished, Alkali-cleaned, Sandblasted
Thickness Tolerance	±0.005 mm - ±0.2 mm
Surface Roughness	Ra 0.8 µm – Ra 3.2 µm

4. Production Process

Molybdenum Ingot (Raw Material) → Inspection → Hot Rolling → Leveling & Annealing → Alkali Cleaning → Inspection → Warm Rolling → Vacuum Annealing → Inspection → Cold Rolling → Leveling → Shearing → Vacuum Annealing → Inspection → Packaging

5. Purchasing Information

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



CTIA GROUP LTD molybdenum sheet

Chapter 3 Classification of molybdenum sheets

Molybdenum sheets are classified in a variety of ways, usually based on their purity, alloy composition, processing technology, or application scenarios to meet the needs of different industrial sectors. Purity is one of the important bases for the classification of molybdenum sheets, because purity directly affects its physical, chemical and mechanical properties, and then determines its applicability in high temperature, electronics, aerospace and other fields. With its high quality and diversified classification standards, CTIA GROUP LTD molybdenum sheet has been widely used in the market. The following will focus on the classification of Molybdenum sheets by purity, and analyze in detail the characteristics, preparation processes and application scenarios of high-purity Molybdenum sheets (≥ 99.95% purity) and ordinary purity Molybdenum sheets (99% - 99.9% purity).

3.1 Classification of Molybdenum sheets by purity

Classification by purity is one of the most common grading methods for Molybdenum sheets, which are usually divided into high-purity Molybdenum sheets (purity ≥ 99.95%) and ordinary purity Molybdenum sheets (purity 99% - 99.9%) based on the purity level of molybdenum metal. The difference in purity is mainly due to the control of impurities in the raw material purification process and production process, which affects the performance parameters of molybdenum sheets, such as electrical conductivity, thermal conductivity, corrosion resistance and high temperature stability. Molybdenum sheets of different purities differ significantly in terms of production process, cost, and application areas, with high-purity Molybdenum sheets typically used in high-precision and demanding environments, while ordinary-purity Molybdenum sheets are more suitable for cost-sensitive general-purpose scenarios.

3.1.1 High purity Molybdenum sheets (≥ 99.95% purity)

High-purity Molybdenum sheets refer to thin sheet materials with a molybdenum metal content of 99.95% or more, which are usually extracted from molybdenite (MoS_2) through a multi-stage purification process, and use advanced vacuum smelting or electron beam refining technology to remove impurities such as oxygen, carbon, and nitrogen. The impurity content is very low (total impurities < 500 ppm), and the content of elements such as iron, nickel, and silicon is usually controlled within 10-50 ppm. This high purity imparts excellent electrical, thermal, and mechanical properties to molybdenum sheets, such as resistivity as low as 5.2×10^{-8} Ω·m, the thermal conductivity is about 138 W/m·K, and the tensile strength can reach 800-1000 MPa at room temperature. The surface quality of the high-purity molybdenum sheet is also better, and the surface roughness can be as low as Ra 0.4 microns after polishing or pickling, making it suitable for high-precision applications. During the production process, high-purity Molybdenum sheets need to be sintered (1800-2000°C) and rolled in a vacuum or high-purity inert gas (e.g. argon) to prevent oxidation and the introduction of impurities. The annealing process (1100-1300°C) further optimizes the grain structure and improves ductility and toughness. Typical applications for high-purity Molybdenum sheets include sputtering targets for the semiconductor industry for depositing high-precision thin films; high-temperature components in the aerospace sector, such as rocket nozzle linings; and radiation shielding materials in the nuclear industry, which reduce neutron trapping cross-sections due to their low impurity content. In addition, high-purity Molybdenum sheets also perform well in X-ray tube anodes and high-temperature vacuum furnace thermal shielding, with a high melting point (2620°C) and low coefficient of thermal expansion (4.8×10^{-6}/°C) ensuring stability under extreme conditions. However, the high preparation cost of high-purity Molybdenum sheets and the complex purification and processing processes make them mainly used in high-end applications.

3.1.2 Ordinary purity Molybdenum sheets (99% - 99.9% purity)

Ordinary purity Molybdenum sheets refer to flake materials with a molybdenum content between 99% and 99.9%, and their impurity content (1000-10,000 ppm) is higher than that of high-purity Molybdenum sheets, and common impurities include iron, nickel, carbon, oxygen, etc., and the content may be in the range of 100-500 ppm. The performance of ordinary purity Molybdenum sheets is slightly lower than that of high purity Molybdenum sheets, for example, the resistivity is slightly higher (about $5.5\text{-}6.0\times10^{-8}$ Ω·). m), the thermal conductivity is slightly lower (about 130-135 W/m·K), and the tensile strength is 700-900 MPa at room temperature. Still, its performance is sufficient for many industrial needs, and its production costs are low, making it suitable for large-scale production and cost-sensitive applications. The preparation process of ordinary purity Molybdenum sheets is relatively simplified, and conventional powder metallurgy technology is usually used to obtain molybdenum oxide (MoO_3) by roasting molybdenite), which is then reduced by hydrogen to make molybdenum powder, which is then sintered and rolled. The sintering process can be carried out under hydrogen protection (1600-1800°C) to reduce the risk of oxidation, but the impurity control requirements are not as stringent as those of high-purity molybdenum sheets. The surface treatment is mostly pickled or sandblasted, and the surface roughness is generally between Ra 0.8-1.6 microns, which meets the needs of general applications. Ordinary purity Molybdenum sheets are widely used in thermal shielding of high-temperature furnaces, corrosion-resistant lining of chemical equipment, and low-precision electrode materials in the electronics industry. For example, in a resistive heating furnace, ordinary purity Molybdenum sheets are used as heating elements or support structures to withstand high temperatures of 1000-1500°C. In some mechanical components, its moderate strength and ductility also make it an economical choice. Although ordinary purity Molybdenum sheets are slightly inferior to high-purity Molybdenum sheets in terms of corrosion resistance and high temperature stability, they have significant cost-effective advantages in non-oxidizing environments or scenarios with medium precision requirements.

3.2 Classification of molybdenum sheets according to the manufacturing process

The manufacturing process of molybdenum sheet has an important impact on its properties, microstructure, and application scenarios, so classification by manufacturing process is another important way to classify molybdenum sheet. The manufacturing process mainly includes powder metallurgy and rolling process, in which the rolling process is further divided into two ways: hot rolling and cold rolling. Molybdenum sheets produced by different processes have significant differences in grain structure, surface quality, mechanical properties and cost, etc., to meet the diverse needs of high-temperature industry to precision electronics. By optimizing the manufacturing process, CTIA GROUP LTD Molybdenum Sheet ensures that the product performance meets the requirements of specific application scenarios. The following will discuss in detail the process characteristics, performance and application fields of molybdenum sheets, hot-rolled molybdenum sheets and cold-rolled molybdenum sheets manufactured by powder metallurgy.

3.2.1 Molybdenum sheets manufactured by powder metallurgy

Powder metallurgy is the basic process for the production of Molybdenum sheets, which is suitable for the preparation of molybdenum sheet materials with high purity and complex shapes. The process includes the extraction of molybdenum oxide (MoO_3) from molybdenite (MoS_2).), which is reduced by hydrogen to produce high-purity molybdenum powder (purity ≥ 99.95%), which is subsequently pressed, sintered and subsequently processed. Molybdenum powder is usually pressed into a billet at high pressure (100-200 MPa) and sintered under a vacuum or hydrogen protective atmosphere (temperature 1800-2000°C) to form a dense molybdenum billet. During the sintering process, the molybdenum powder particles are combined by diffusion, and the grain size is usually controlled at 10-50 microns, and the density can reach more than 98%. Molybdenum sheets manufactured by powder metallurgy have a uniform microstructure and high purity, and the impurity content (e.g., oxygen, carbon) can be controlled within 50 ppm, making them suitable for high-precision applications. The density of the resulting molybdenum sheet is close to the theoretical value (10.22 g/cm³), the tensile strength is about 700-900 MPa at room temperature, and the surface roughness (Ra 0.8-1.6 microns) can be optimized by subsequent polishing. The advantage of the powder metallurgy process is the ability to produce ultra-thin molybdenum sheets (0.01-0.1 mm thick) as well as custom-shaped blanks, suitable for sputtering targets in the semiconductor industry and thermal shielding in high-temperature furnaces. However, the high cost of this process and the long cycle time limit its use in large-scale, low-cost applications. Molybdenum sheets manufactured by powder metallurgy are widely used in the electronics, nuclear and aerospace industries, for example as anode materials for X-ray tubes or as components of high-temperature vacuum furnaces.

3.2.2 Hot-rolled molybdenum sheets manufactured by rolling process

The hot rolling process is to prepare molybdenum sheets with a thickness of 0.5-3 mm by rolling molybdenum billets at high temperatures (usually 1000-1400°C). The hot rolling process is usually carried out under vacuum or under the protection of an inert gas such as argon to prevent the oxidation of molybdenum at high temperatures. Molybdenum billets are first prepared by powder metallurgy, and then rolled in multiple passes in a high-temperature rolling mill with a controlled deformation of 20-30% each time to gradually thin and improve the grain structure. Hot-rolled molybdenum sheets have a larger grain size (50-100 microns) and are recrystallized due to high-temperature processing, giving them good ductility (elongation at break of about 10-15%) and low internal stress. The tensile strength of hot-rolled molybdenum sheet is about 600-800 MPa at room temperature, which is slightly lower than that of cold-rolled molybdenum sheet, but its high-temperature strength (about 500 MPa at 1000°C) is excellent, and it is suitable for high-temperature environments. In terms of surface quality, the surface roughness of hot-rolled molybdenum sheet is generally Ra 1.0-2.0 microns, which can be optimized by pickling or sandblasting. The advantage of the hot rolling process is that it has high production efficiency, is suitable for manufacturing thicker molybdenum sheets, and the cost is lower than that of powder metallurgy, but the thickness control accuracy (±0.05 mm) is slightly inferior to that of the cold rolling process. Hot-rolled molybdenum sheets are widely used in heating elements for high-temperature furnaces, aerospace structural parts (e.g. turbine blade supports) and corrosion-resistant linings for chemical equipment, where they meet the requirements for moderate precision and durability due to their combination of strength and high-temperature stability.

3.2.3 Cold-rolled molybdenum sheets manufactured by rolling process

The cold rolling process is the further rolling of molybdenum billets or hot-rolled molybdenum sheets at or near room temperature to produce ultra-thin molybdenum sheets with a thickness of typically 0.01-1 mm. The cold rolling process is achieved by a high-precision rolling mill, and the amount of deformation is controlled at 10-20% each time to avoid excessive stress and cracking. The grain size of cold-rolled molybdenum sheet is small (5-20 microns), and due to the significant work hardening effect, the dislocation density increases, so that its tensile strength can reach 900-1200 MPa at room temperature, which is much higher than that of hot-rolled molybdenum sheet. However, cold-rolled molybdenum sheets have low ductility (elongation at break of about 5-8%), and it is often necessary to improve the toughness by stress relief annealing (800-1100°C), and the strength is slightly reduced to 800-1000 MPa after annealing, but the elongation at break can be increased to 10-12%. The surface quality of cold-rolled molybdenum sheet is excellent, the surface roughness can be as low as Ra 0.4 microns after polishing, and the thickness tolerance is controlled within ±0.005 mm, which meets the needs of high-precision applications. The advantage of the cold rolling process is that it can produce ultra-thin, high-strength molybdenum sheets, which are suitable for high-precision sputtering targets, semiconductor packaging substrates and flexible electronic components in the electronics industry. However, the cold rolling process is highly demanding, and the lubrication and temperature during the processing process need to be tightly controlled to prevent surface defects or cracks. Cold-rolled molybdenum sheets are widely used in thin film deposition, microelectronics, and medical devices (such as X-ray tube assemblies) due to their high strength, excellent surface quality, and dimensional accuracy, making them the material of choice for high-end manufacturing.

3.3 Classification of molybdenum sheets according to application fields

The diversified properties of molybdenum sheets make them widely used in many industrial fields, and can be divided into electronic fields, metallurgical industries, chemical fields, aerospace fields and other fields according to different application scenarios. Different applications require varying levels of purity, thickness, surface quality, and performance for Molybdenum sheets, prompting manufacturers to optimize their production processes to meet specific needs. With its high quality and customization characteristics, CTIA GROUP LTD molybdenum sheet has performed well in various fields. The following will discuss in detail the application characteristics, performance requirements and typical uses of molybdenum sheets in electronics, metallurgical industry, chemical industry, aerospace and other fields.

3.3.1 Molybdenum sheets used in the electronic field

In the field of electronics, molybdenum sheets are known for their excellent electrical conductivity (resistivity approx. 5.2×10^{-8} Ω·m), thermal conductivity (approx. 138 W/m·K), and low coefficient of thermal expansion (approx. 4.8×10^{-6}/°C), especially in semiconductor manufacturing and microelectronic devices. High-purity Molybdenum sheets (≥99.95%) are preferred in the electronics field due to their low impurity content to reduce grain boundary resistance and gas emissions, ensuring device reliability.

Molybdenum sheets are commonly used in sputtering targets to produce conductive layers for thin-film transistors (TFTs), solar cells and integrated circuits, typically with a thickness of 0.01-0.1 mm and a surface roughness as low as Ra 0.4 microns to ensure film uniformity. In addition, molybdenum sheets are used as heat dissipation substrates in electronic packaging, and are compatible with silicon (thermal expansion coefficient of about 2.6×10^{-6}/°CIt has a good thermal match with ceramic materials, which can effectively reduce thermal stress and prolong the life of the chip. In X-ray tubes, molybdenum sheets are used as an anode or support material to withstand high-energy electron bombardment due to their high melting point (2620°C) and good electrical conductivity. In production, molybdenum sheets in the electronics field need to be cold-rolled and vacuum annealed (1100-1300°C) to ensure high precision and surface quality. These properties of molybdenum sheets make them indispensable in the semiconductor, display, and optoelectronics industries.

3.3.2 Molybdenum sheets used in the metallurgical industry

In the metallurgical industry, molybdenum sheets are mainly used in components of high-temperature

电话/TEL：0086 592 512 9696

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furnaces and smelting equipment, with their high melting point (2620°C) and excellent high-temperature strength (tensile strength of about 700 MPa at 1200°C). Ordinary purity Molybdenum sheets (99%-99.9%) are commonly used in the manufacture of heat shields, heating elements and crucible linings due to their low cost, and the thickness range is usually 0.5-3 mm. Due to its good ductility (elongation at break of about 10-15%) and low internal stress, hot-rolled molybdenum sheet is suitable for the processing of complex shape components in high-temperature furnaces. Under vacuum or inert atmosphere (such as argon or nitrogen), Molybdenum sheets can withstand high temperatures above 1500°C without deformation, and are widely used in high-temperature sintering furnaces, single crystal growth furnaces and glass melting equipment. The creep resistance of molybdenum sheets at high temperatures (creep rates as low as 10^{-6}/s at 1200°C) ensures stability under long-term high temperature loads. In production, metallurgical molybdenum sheets mostly use powder metallurgy and hot rolling processes, and the surface can be pickled to improve corrosion resistance. The use of molybdenum sheets in the metallurgical industry has significantly improved equipment durability and process efficiency, for example as a key component in the smelting of tungsten, molybdenum and other refractory metals.

3.3.3 Molybdenum sheets used in the chemical industry

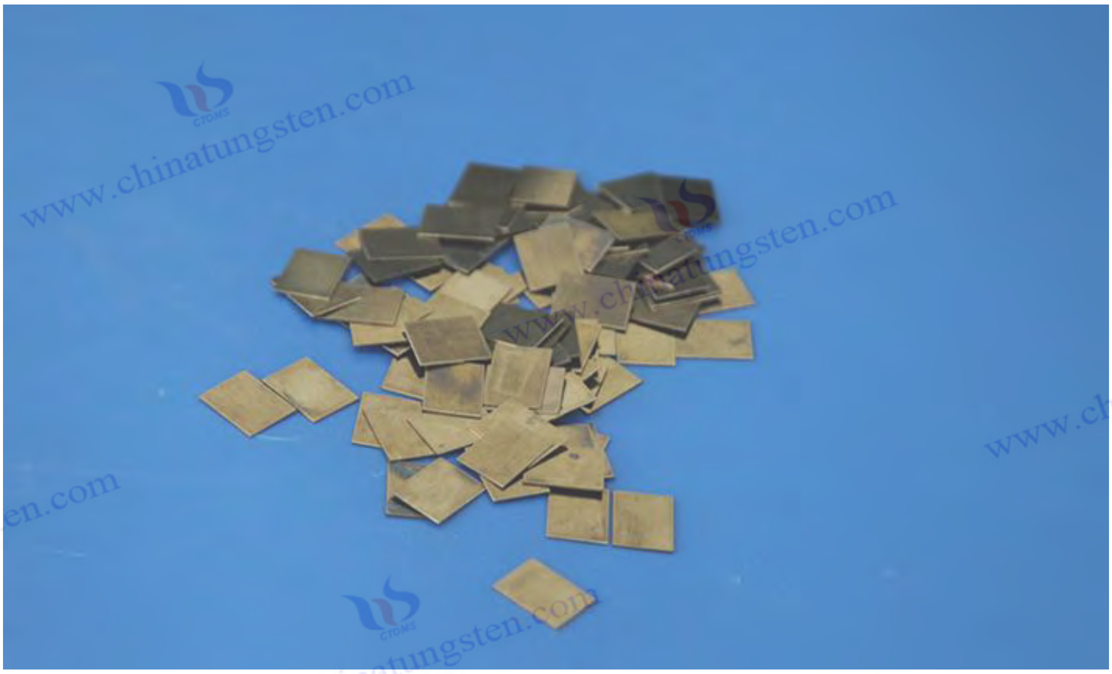
In the chemical industry, molybdenum sheets are widely used in reactor linings, electrode materials and corrosion-resistant components due to their excellent corrosion resistance, especially in non-oxidizing acids (such as hydrochloric acid, sulfuric acid) and alkaline environments, with a corrosion rate of less than 0.01 mm/year in 10% hydrochloric acid (20°C). Ordinary purity Molybdenum sheets (99%-99.9%) are often used in chemical equipment due to their high cost-effectiveness, the thickness is generally 0.2-2 mm, and the surface is mostly pickled (Ra 0.8-1.6 microns) to ensure cleanliness. Molybdenum sheets are used as electrode materials in the electrochemical industry, for example in the electrolysis of chlorine or hydrogen, and are resistant to corrosive electrolytes due to their high conductivity and chemical stability. However, molybdenum sheets are susceptible to the formation of volatile MoO_3 in oxidizing acids (e.g., concentrated nitric acid) or in high-temperature oxidizing atmospheres, which need to be applied by surface coatings (e.g., silicides) or in an inert atmosphere for enhanced protection. In production, chemical Molybdenum sheets are optimized through powder metallurgy and rolling process, and oxygen and nitrogen impurities (<100 ppm) are strictly controlled to improve corrosion resistance. The use of molybdenum sheets in the chemical industry, such as corrosion-resistant reactor linings and pipe support materials, significantly increases the life of equipment in harsh chemical environments.

3.3.4 Molybdenum sheets used in the aerospace field

In the aerospace sector, molybdenum sheets are used for high-temperature structural and heat-resistant components due to their high strength (tensile strength 800-1000 MPa at room temperature), high melting point (2620°C) and low coefficient of thermal expansion (4.8×10^{-6}/°C). High-purity Molybdenum sheets (≥ 99.95%) or TZM alloy Molybdenum sheets (containing titanium and zirconium) are due to their excellent high-temperature properties (tensile strength up to 800 MPa at 1500°C) and creep resistance (creep rate 10^{-6}). /s), which are commonly used for rocket nozzle linings, turbine blade supports, and thermal shielding of re-entry vehicles. The low density of molybdenum sheet (10.22 g/cm³) has a weight advantage over tungsten (19.25 g/cm³), which is suitable for aerospace lightweighting requirements. Cold-rolled molybdenum sheets are widely used in precision components such as satellite thermal control systems due to their high precision (thickness tolerance ± 0.005 mm) and surface quality (Ra ≤ 0.4 microns). In the production of aerospace molybdenum sheets, vacuum sintering and multi-pass rolling processes are used to ensure that the grains are small (5-20 microns) to improve strength and toughness. The use of molybdenum sheets in the aerospace sector significantly improves the reliability of components under extreme high temperatures and mechanical stresses, such as in rocket engines and high-temperature propulsion systems.

3.3.5 Molybdenum sheets used in other fields

In other fields, molybdenum sheets are used in medical, energy, and scientific research applications due to their versatility. In the medical field, high-purity molybdenum sheets (≥99.95%) are used in anode targets for X-ray and CT equipment, which can withstand high-energy electron bombardment due to their high melting point and conductivity, typically 0.1-1 mm thick, and the surface needs to be polished to Ra 0.4 microns to ensure radiation uniformity. In the energy sector, molybdenum sheets are used in the back electrodes of solar thin-film cells and in the radiation shielding of nuclear reactors due to their low thermal neutron capture cross section and high temperature stability (stable at 1500°C). In the field of scientific research, molybdenum sheets are widely used in materials science and physics experiments as a sample substrate or electrode material for high-temperature experiments, and its thickness can be as low as 0.01 mm to meet the needs of high-precision experiments. Other applications include jewelry processing (as high-temperature molds) and the lighting industry (as filament support materials). In production, these Molybdenum sheets are produced using cold rolling and vacuum annealing processes to optimize the grain structure and surface quality to suit specific needs. Despite the variety of applications, these molybdenum sheets are often used in a vacuum or inert atmosphere to avoid high-temperature oxidation and ensure consistent performance.



CTIA GROUP LTD molybdenum sheet

Chapter 4 Molybdenum Sheet Production and Preparation Process

4.1 Preparation of raw materials before the production of molybdenum sheets

The production and preparation process of Molybdenum sheets begins with the acquisition and processing of high-quality raw materials, which are the key links to ensure the performance of Molybdenum sheets, which directly affect their purity, microstructure and final application results. The raw material of Molybdenum sheets is mainly derived from molybdenum ore, of which molybdenite (MoS_2) is the main source of molybdenum. The raw material preparation process includes ore mining, beneficiation and initial purification to provide high-purity molybdenum powder for subsequent powder metallurgy and rolling processes. CTIA GROUP LTD Molybdenum sheets ensure high purity and consistency of raw materials through a strict raw material preparation process, and meet the demanding requirements of aerospace, electronics and high-temperature industries. The following will discuss in detail the types and characteristics of molybdenum ore, mining and beneficiation methods, focusing on the characteristics and distribution of molybdenite, as well as the process and key points of open-pit mining.

4.1.1 Types and characteristics of molybdenum ore

Molybdenum ore is the basic raw material for the production of Molybdenum sheets, mainly in the form of sulfides, and molybdenite (MoS_2) is the most common molybdenum mineral, accounting for the main part of the global molybdenum resources. Other molybdenum ore types include molybdate (e.g., calcium molybdate $CaMoO_4$) and molybdenite oxide (e.g., MoO_3). However, it is less used because of the small reserves or the difficulty of exploitation. Molybdenite has become the main raw material for the production of molybdenum sheets due to its high molybdenum content (about 60% molybdenum) and easy separation. The properties of molybdenum ore directly affect the purification process and the performance of the final molybdenum sheet, for example, impurities in the ore (such as copper, iron, silicon) will affect the purity of molybdenum powder, which needs to be removed by beneficiation and chemical treatment. In addition, the physical properties of molybdenum ore, such as hardness and crystal structure, also affect the crushing and beneficiation efficiency. Molybdenum ore is often associated with porphyry copper ore or other sulphide minerals, which require a complex sorting process to extract high-grade molybdenum concentrate.

4.1.1.1 Characteristics and distribution of molybdenite

Molybdenite (MoS_2) is a layered sulphide mineral with a silvery-gray to ferrous luster with a hardness of 1-1.5 on the Mohs scale and a density of about 4.7-5.0 g/cm³. Its chemical composition is mainly molybdenum (59.94%) and sulfur (40.06%), and the crystal structure is hexagonal crystal system, and the interlayer binding force is weak, which gives it good lubricity and easy peeling. Molybdenite is often flake or flake in nature and is easy to separate by flotation. It is thermally stable and begins to oxidize to form MoO_3 when heated to 600°C in air, but can withstand higher temperatures (about 1200°C) in an inert atmosphere. The chemical stability of molybdenite makes it resistant to acid and alkali attack, but it is easy to react with oxidants (such as nitric acid), so it is necessary to pay attention to environmental control in the process of beneficiation and purification. The distribution of molybdenite resources in the world is concentrated, and the main production areas include China (accounting for about 40% of the global reserves, mainly in Henan, Shaanxi, Jilin and other places), the United States (Colorado, Montana), Chile, Canada and Australia. The Luanchuan area of Luoyang, China is the world's largest molybdenum mining area, with ore grades generally ranging from 0.1% to 0.3% (molybdenum content), and high-grade ores can reach more than 0.5%. Molybdenite is often associated with sulfide ores such as copper, lead, zinc, etc., and the content of associated elements (such as iron and copper) needs to be strictly controlled by beneficiation to ensure the purity of molybdenum powder (≥99.95%) for subsequent purification.

4.1.2 Mining and beneficiation methods of molybdenum ore

The mining and beneficiation of molybdenum ore is the core step of raw material preparation, aiming to extract high-grade molybdenum concentrate from low-grade ore and provide high-quality raw materials for subsequent metallurgical purification. Mining methods are divided into open-pit mining and underground mining according to the geological conditions of the deposit, and open-pit mining is dominant because of its low cost and high efficiency, and is suitable for large shallow deposits. The beneficiation method mainly uses flotation technology, combined with gravity separation, magnetic separation and other auxiliary means, to separate molybdenite in molybdenum ore from associated minerals, and obtain a concentrate with ≥ 50% molybdenum content. In the beneficiation process, the grinding particle size (usually to -200 mesh, about 74 microns), flotation reagents (such as xanthate, foaming agent) and pH value (8-10) need to be strictly controlled to improve the recovery rate of molybdenite (usually 85-95%). The molybdenum concentrate after beneficiation needs to be further roasted to produce molybdenum oxide (MoO_3), which lays the foundation for the subsequent hydrogen reduction to prepare molybdenum powder. Beneficiation efficiency and concentrate purity directly affect the performance of molybdenum sheets, for example, high levels of impurities (iron, copper) may reduce the conductivity and corrosion resistance of molybdenum sheets.

4.1.2.1 Molybdenum ore open-pit mining process and key points

Open-pit mining is the main mode of molybdenum mining, which is suitable for deposits with shallow ore body burial and large reserves, such as Luanchuan in China and Klemax mine in the United States. The process includes exploration, stripping, blasting, loading, transportation and stockpiling. During the exploration phase, geological drilling and geophysical methods are used to determine the location of the ore body, grade (typically 0.1%-0.3% molybdenum) and reserves, and to develop a mining plan. The stripping phase removes the topsoil and waste rock that covers the ore body, and the stripping ratio (waste rock to ore volume ratio) is typically 3:1 to 10:1 and needs to be optimized to reduce costs. Blasting uses precisely controlled explosives (such as ammonium nitrate) to crush the ore body, the blasting hole size is generally 100-250 mm, and the ore particle size is controlled at 0.1-1 m after blasting for subsequent crushing. Large excavators (10-30 cubic meters of bucket capacity) and dump trucks (50-200 tons of load) are used to transport the ore to the concentrator. In the stacking stage, it is necessary to classify and stack according to grade to avoid mixing of high and low grade ores.

Key takeaways from open pit mining include: optimizing blasting design to reduce ore dilution (target < 10%) and improve grade consistency; the second is to use high-efficiency equipment, such as electric shovels and heavy-duty trucks, to improve production efficiency (up to 100,000 tons of ore per day); The third is environmental protection, controlling blasting dust (dust suppression through spraying) and wastewater discharge (recycling rate >80%), in line with environmental protection regulations. The open-pit molybdenum ore enters the beneficiation process after preliminary crushing, providing high-quality raw materials for the production of Molybdenum sheets.

4.1.2.2 Underground mining methods of molybdenum ore

The production of Molybdenum sheets relies on high-quality molybdenum ore raw materials, while underground mining is the acquisition of molybdenum ore (MoS_2) under deep or complex geological conditionsIt is suitable for deposits where the ore body is buried deep or the surface conditions are not suitable for open-pit mining, such as some molybdenum mines in Jilin, China or Canada. The process of underground mining includes mine construction, roadwaying, blast mining, ore hoisting and surface transportation. The construction of the mine begins with the opening of the ore body through vertical or inclined shafts, equipped with ventilation, drainage and lifting systems to ensure the safety of operations. Roadgoing tunneling adopts roadheader or blasting method, and horizontal or inclined roadways are laid along the ore body, and the size of the roadway is usually 3-5 meters wide and 3-4 meters high. In the mining stage, the room-and-pillar method or the filling method is mainly adopted, and the room-and-pillar method supports the roof by retaining the ore pillar, and the recovery rate is about 70-80%; The filling method fills the goaf with tailings or cement, and the recovery rate can reach more than 90%, but the cost is high. Blasting uses precision charges, such as emulsion explosives, to break the ore to a particle size of 0.1-0.5 meters, which is then lifted to the surface by loaders and minecarts.

The key points of underground mining include: first, safety management, which requires strict control of ventilation (air volume ≥ 3 m^3/s·person) and support (anchors, steel mesh) to prevent collapse; The second is to optimize the mining sequence, give priority to the mining of high-grade ore bodies (0.2-0.5% molybdenum content), and reduce the dilution rate (target <15%); The third is energy conservation and environmental protection, using low-energy consumption equipment (such as electric loaders) and tailings backfill to reduce environmental impact. The molybdenum ore mined underground enters the beneficiation process after preliminary crushing, providing stable raw materials for the production of Molybdenum sheets.

4.1.2.3 Principles and processes of flotation method for molybdenum ore

Flotation is the core method of molybdenite beneficiation, which is widely used to extract high-grade molybdenum concentrate from low-grade molybdenite, and its principle is based on the difference between the hydrophobicity of molybdenite and the hydrophilicity of associated minerals. Molybdenite (MoS_2) is naturally hydrophobic on the surface and is easily adsorbed by collectors (such as xanthate or mercaptan) and attached to bubbles, while associated minerals (such as quartz, feldspar) are highly hydrophilic and remain in the slurry. The flotation process consists of five stages: crushing, grinding, slurrying, flotation and dewatering. Crushing crushes the raw ore (grain size 0.1-1 m) to 10-50 mm, and grinding further grinds the ore to -200 mesh (about 74 microns), so that the molybdenite monomer dissociation degree reaches more than 80%. In the slurry conditioning stage, a collector (e.g., butyl xanthate, 0.1-0.3 kg/t), a foaming agent (e.g., terpineol, 0.05-0.1 kg/t) and an inhibitor (e.g., sodium silicate, 0.5-1 kg/t) were added to adjust the pH of the slurry to 8-10 to optimize the flotation effect. Flotation takes place in a flotation cell, where bubbles (air or nitrogen) are stirred to bring molybdenite to the foam layer to produce a molybdenum concentrate (50-60% molybdenum content) with a recovery rate of typically 85-95%. The tailings are further recovered by multi-stage flotation to recover the residual molybdenum. The dewatering reduces the concentrate moisture to less than 10% by a thickener and a filter press. The advantages of flotation are that it is highly efficient and adaptable, and can treat low-grade ores (0.1-0.3% molybdenum content), but it needs to strictly control the amount of chemicals and wastewater treatment (recycling rate > 80%) to reduce environmental pollution. The molybdenum concentrate obtained by flotation provides high-quality raw materials for subsequent roasting and purification.

4.1.2.4 Principles and processes of gravity separation method for molybdenum ore

The gravity separation method is an auxiliary method for molybdenite beneficiation, which uses the density difference between molybdenite (density 4.7-5.0 g/cm^3) and associated minerals (such as quartz, density 2.65 g/cm^3) for separation, which is suitable for the recovery of coarse-grained molybdenite or associated heavy minerals. The principle of gravity separation is based on gravity sedimentation or centrifugal force, and molybdenite settles rapidly in gravity separation equipment due to its high density, while light gangue minerals are washed away. The gravity separation process includes crushing, grinding, classifying, gravity separation, and dewatering. The raw ore is first crushed to 50-100 mm and ground to 0.5-2 mm to release molybdenite particles. The grading is carried out by means of a spiral classifier or hydrocyclone to divide the slurry into coarse and fine grains, and the coarse grains (>0.5 mm) enter the gravity separation equipment. Jigs or shakers are commonly used for gravity separation, and the jigging machine stratified the ore particles according to density through the pulsating water flow, and the molybdenite sinks to the bottom layer to produce coarse concentrate (molybdenum content 20-40%); The shaker utilizes lateral water flow and vibration to achieve a recovery rate of 70-85%. Fine-grained slurry (<0.5 mm) is usually transferred to the flotation process. Dewatering reduces gravity separation concentrate moisture to less than 10%. The advantages of gravity separation are that the equipment is simple, the cost is low, and it is suitable for processing high-grade coarse-grained ore (molybdenum content >0.3%), but it is less efficient for fine-grained ore, and is often used in combination with flotation. The gravity separation concentrate needs to be further flotation and purification to provide high-quality raw materials for the production of Molybdenum sheets.

4.1.2.5 Principles and processes of magnetic separation of molybdenum ore

Magnetic separation is an auxiliary means of molybdenum ore beneficiation, which is used to remove magnetic impurities (such as magnetite, Fe_3O_4) or associated magnetic minerals in molybdenite and improve the purity of molybdenum concentrate. The principle of magnetic separation is based on the magnetic differences of minerals, molybdenite is a non-magnetic material (magnetic susceptibility < 10^{-6} cm^3/g), while magnetite has strong magnetism (magnetic susceptibility 10^2-10^3 cm^3/g), which is easily adsorbed in the magnetic field. The magnetic separation process includes crushing, grinding, magnetic separation, and dewatering. The raw ore is crushed to 50-100 mm and ground to -200 mesh (about 74 microns) to dissociate the magnetic impurities from the molybdenite. Magnetic separation adopts a wet magnetic separator, the magnetic field strength is usually 0.1-0.6 T, the magnetic impurities are adsorbed on the magnetic drum, and the non-magnetic molybdenite flows out with the slurry to produce a pre-concentrate (molybdenum content 10-30%). After magnetic separation, the slurry usually enters the flotation process for further purification. Dewatering reduces concentrate moisture to less than 10% by concentrators and filter presses. The advantage of magnetic separation is that it can effectively remove ferromagnetic impurities (such as iron content from 1% to less than 0.1%) and improve the quality of molybdenum concentrate, but it is ineffective against non-magnetic impurities (such as quartz) and needs to be used in combination with other beneficiation methods. The magnetic separation equipment needs to be regularly maintained to ensure that the magnetic field is stable, and the wastewater recycling rate needs to reach more than 80% to meet environmental protection requirements. The molybdenum concentrate pretreated by magnetic separation provides a low-impurity feedstock for subsequent purification and molybdenum sheet production.

4.1.3 Refining and conversion of molybdenum concentrate

The refining and conversion of molybdenum concentrate is a key step in converting the molybdenum concentrate (mainly molybdenite, MoS_2) obtained by beneficiation into high-purity molybdenum compounds or metal molybdenum powder, which provides high-quality raw materials for the subsequent production of molybdenum sheets. The refining process mainly removes impurities such as sulfur and iron through oxidative roasting combined with hydrometallurgy (such as ammonia leaching or acid leaching) to obtain high-purity molybdenum oxide (MoO_3) or ammonium molybdate ($(NH_4)_2MoO_4$), and finally molybdenum powder is prepared by reduction. The choice of refining process directly affects the purity of molybdenum powder (99.95% ≥ is required to meet the demand for high-purity Molybdenum sheets), particle size distribution and production cost. Through advanced refining technology, CTIA GROUP LTD Molybdenum sheets ensure the high purity and consistency of raw materials and meet the needs of high-end applications such as electronics and aerospace. The following discusses in detail the oxidative roasting-ammonia leaching method, oxidative roasting-acid leaching refining process and the preparation process of molybdenum powder of molybdenum concentrate.

4.1.3.1 Oxidative roasting-ammonia leaching refining process of molybdenum concentrate

Oxidative roasting-ammonia leaching is the mainstream process for refining molybdenum concentrate, which is suitable for the production of high-purity molybdenum compounds and is widely used in the preparation of high-purity molybdenum sheet raw materials. The principle is that molybdenite (MoS_2) is oxidized to molybdenum oxide (MoO_3) by high-temperature roasting, and then dissolved with ammonia to produce soluble ammonium molybdate, which is then purified by crystallization. The process consists of five stages: roasting, ammonia leaching, filtration, crystallization and drying. The roasting stage is carried out in a rotary kiln or a multi-chamber furnace at a temperature controlled at 550-650°C, and air is introduced to oxidize MoS_2 to MoO_3At the same time, sulfur is converted to SO_2 (which requires off-gas treatment to meet environmental standards, and the recovery rate of SO_2 is >95%). After roasting, molybdenum concentrate (molybdenum content 50-60%) is converted into crude molybdenum oxide (molybdenum content > 95%), and impurities such as iron and copper are partially volatilized or oxidized. In the ammonia leaching stage, crude molybdenum oxide is reacted with ammonia water (concentration 10-15%) at 50-70 °C and pH 8-9 to generate ammonium molybdate solution, and insoluble impurities such as iron and silicon are filtered and separated. The filtered ammonium molybdate solution is crystallized by evaporation to obtain high-purity ammonium molybdate crystals (purity ≥ 99.5%), which are finally dried at 120-150 °C. The advantage of the ammonia leaching method is that the purification efficiency is high, and the content of impurities (such as iron and copper) can be reduced to less than 50 ppm, which is suitable for the production of high-purity molybdenum sheet raw materials. However, the use of ammonia water requires strict control of waste liquid treatment (ammonia recovery rate > 90%) to reduce environmental pollution. The ammonium molybdate produced by this process provides high-purity raw materials for the subsequent preparation of molybdenum powder.

4.1.3.2 Oxidative roasting-acid leaching refining process of molybdenum concentrate

Oxidative roasting-acid leaching is another commonly used molybdenum concentrate refining process, which is suitable for processing molybdenum concentrate containing complex impurities, especially when there are many associated metals such as copper and lead. The principle is to oxidize molybdenite to molybdenum oxide (MoO_3) by roasting, and then dissolve impurities with an acidic solution to retain

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high-purity molybdenum oxide. The process includes roasting, pickling, filtration, washing and drying. The roasting stage is similar to the ammonia leaching method, which is carried out in an air atmosphere of 550-650°C, where molybdenite is oxidized to MoO_3 and sulfur is converted to SO_2 (a high-efficiency exhaust gas absorption device is required, and the removal rate of SO_2 is >95%). In the acid leaching stage, crude molybdenum oxide is reacted with dilute hydrochloric acid (concentration 5-10%) or sulfuric acid at 60-80 °C to dissolve impurities such as iron, copper, and calcium, while MoO_3 is retained because it is insoluble in dilute acid. After filtering and separating the impurity solution, the molybdenum oxide solids are washed several times with deionized water to ensure that the impurity content (e.g., iron, copper) is reduced to less than 100 ppm. The washed molybdenum oxide is dried at 150-200 °C to obtain high-purity molybdenum oxide (purity ≥ 99.5%).

The advantages of the acid leaching method are that it can effectively remove a variety of metal impurities, and the process adaptability is strong, which is suitable for the treatment of low-grade or complex ores, but the acid waste liquid treatment cost is high (it needs to be neutralized to pH 6-8 before discharge). Compared with the ammonia leaching method, the acid leaching method is simpler to operate, but the purity is slightly lower, and it is suitable for the raw material production of ordinary purity Molybdenum sheets (99%-99.9%). The obtained molybdenum oxide provides a reliable basis for the subsequent preparation of molybdenum powder.

4.1.3.3 Preparation of molybdenum powder from molybdenum concentrate extracts

The molybdenum concentrate extract (molybdenum oxide or ammonium molybdate) is converted into high-purity molybdenum powder through a hydrogen reduction process, which provides the final raw material for the production of Molybdenum sheets. The principle is to use hydrogen to reduce MoO_3 or $(NH_4)_2MoO_4$ to metal molybdenum at high temperatures, while removing oxygen and residual impurities. The process includes reduction, screening and quality control. The reduction phase takes place in a tube furnace or rotary furnace and is carried out in two steps: the first step reduces MoO_3 or ammonium molybdate to MoO_2 at 400-600 °C in a hydrogen gas stream (purity ≥ 99.99% and flow rate 1-2 m^3/h). , at the same time release water vapor and ammonia (need to be tail gas treatment); The second step is further reduced to metal molybdenum powder at 900-1100 °C, the particle size is usually 1-10 microns, and the purity can reach more than 99.95%.

During the reduction process, the purity of hydrogen and the atmosphere in the furnace should be strictly controlled to avoid oxidation (oxygen content < 50 ppm) due to oxygen residues. During the screening stage, a vibrating screen (100-200 mesh) is used to remove large particles or agglomerates to ensure that the particle size of the molybdenum powder is uniform (about 2-5 microns for D50). Quality control is performed by ICP-MS detection of impurities (e.g., iron, copper<20 ppm) and X-ray diffraction to confirm the crystal structure (body-centered cube). The properties of molybdenum powder directly affect the quality of molybdenum sheets, for example, the fine and uniform particle size is conducive to sintering density (>98%), and the high purity ensures conductivity and corrosion resistance. The prepared molybdenum powder is further processed into molybdenum sheets through powder metallurgy and rolling to meet the needs of aerospace, electronics and other fields.

4.2 Molding process of molybdenum sheet

The molding process of molybdenum sheet is a key step to transform it from high-purity molybdenum powder or molybdenum blank into a sheet material with specific thickness, size and properties, which directly determines the mechanical properties, surface quality and application adaptability of molybdenum sheet. The forming process mainly includes powder metallurgy and rolling process, in which the rolling process is further divided into two ways: hot rolling and cold rolling. These processes optimize the grain structure, strength, and ductility of Molybdenum sheets by precisely controlling temperature, deformation, and environmental conditions to meet the needs of industries such as electronics, aerospace, and high-temperature industries. CTIA GROUP LTD molybdenum sheet is made through advanced molding technology to ensure the high precision and consistency of products. The following will discuss in detail the process characteristics, performance influences and application advantages of powder metallurgy for the preparation of molybdenum sheets, the preparation of molybdenum sheets by hot rolling process, and the preparation of molybdenum sheets by cold rolling process.

4.2.1 Preparation of molybdenum sheets by powder metallurgy

Powder metallurgy is the basic forming process for the production of molybdenum sheets, which is suitable for the preparation of high-purity and homogeneous structure of molybdenum sheets, especially for the production of ultra-thin molybdenum sheets (thickness 0.01-0.1 mm) or complex shape components. The process includes molybdenum powder pressing, sintering and subsequent processing. High-purity molybdenum powder (purity≥99.95%, particle size 1-10 microns) is pressed into blanks by cold isostatic pressing (pressure 100-200 MPa), and the shape of the blanks can be customized according to requirements (such as plates or rods). The pressed blank is sintered under vacuum or hydrogen protective atmosphere, the temperature is controlled at 1800-2000 °C, and the sintering time is 2-6 hours, so that the molybdenum powder particles are combined by diffusion to form a dense green body, and the density is more than 98%. During the sintering process, the grain size is controlled at 10-50 microns to balance strength and toughness. The tensile strength of the sintered billet is about 500-700 MPa, and the density is close to the theoretical value (10.22 g/cm³). For further preparation of the sheets, the sintered billet is rolled or forged, and the surface is pickled or polished with a roughness of Ra 0.8-1.6 microns. The advantage of powder metallurgy is that it can produce molybdenum sheets with high purity and uniform structure, with a low impurity content (iron, copper< 20 ppm), which is suitable for semiconductor targets and high-temperature furnace components. However, the process is complex and costly, making it suitable for high-precision applications, such as sputtering targets in the electronics industry or radiation shielding in the nuclear industry.

4.2.2 Preparation of molybdenum sheet by rolling process

The rolling process is the most commonly used forming method in the production of molybdenum sheets, in which the sintered molybdenum billet is progressively thinned to the desired thickness while improving its mechanical properties and surface quality. Rolling is divided into two methods: hot rolling and cold rolling, which are suitable for molybdenum sheets with different thickness and performance requirements. The rolling process is carried out in a vacuum or in an inert atmosphere (e.g. argon) to prevent oxidation at high temperatures and to ensure that no volatile MoO_3 is formed on the surface of the molybdenum sheet. During the rolling process, the amount of deformation, rolling temperature and annealing process directly affect the grain size, strength and ductility of molybdenum sheets. Hot rolling is suitable for the production of thicker molybdenum sheets (0.5-3 mm), while cold rolling is used for ultra-thin molybdenum sheets (0.01-0.1 mm). The tensile strength of rolled molybdenum sheet can reach 800-1200 MPa, and the surface roughness can be as low as Ra 0.4 microns by polishing, which meets the precision requirements of electronics, aerospace and other fields.

4.2.2.1 Preparation of molybdenum sheets by hot rolling process

The hot rolling process prepares molybdenum sheets with a thickness of 0.5-3 mm by rolling the molybdenum billet at a high temperature (1000-1400 °C) for multiple passes, which is suitable for high-temperature furnace components and aerospace structural parts. Molybdenum billets (usually prepared by powder metallurgy) are processed in a vacuum or inert gas-shielded hot rolling mill with a controlled deformation of 20-30% per roll to avoid cracking. During the hot rolling process, the molybdenum grains undergo dynamic recrystallization, and the grain size is larger (50-100 microns), which gives the molybdenum sheet good ductility (elongation at break 10-15%) and low internal stress. The tensile strength of hot-rolled molybdenum sheet is about 600-800 MPa at room temperature, and it can still reach 500 MPa at high temperature (1200°C), which is suitable for high-temperature environments. The surface roughness is generally Ra 1.0-2.0 microns and can be optimized by pickling or sandblasting. The advantages of the hot rolling process are that it has high production efficiency, is suitable for mass production, and has a lower cost than the powder metallurgy method, but the thickness tolerance (±0.05 mm) is slightly inferior to that of cold rolling. Hot-rolled molybdenum sheets are widely used in heating elements for high-temperature furnaces, corrosion-resistant linings for chemical equipment and high-temperature support structures for aerospace, where their high-temperature strength and creep resistance (creep rate 10^{-6}/s) ensure long-term stability.

4.2.2.2 Preparation of molybdenum sheets by cold rolling process

The cold rolling process is the further rolling of hot-rolled molybdenum sheets or sintered molybdenum blanks at or near room temperature to produce ultra-thin molybdenum sheets with a thickness of 0.01-1 mm, suitable for high-precision electronic and microelectronic applications. Cold rolling uses high-precision four-high or multi-roll mills, and the amount of deformation is controlled at 10-20% each time to prevent cracks caused by work hardening. Cold-rolled molybdenum sheets have a small grain size (5-20 microns), a high dislocation density, and a tensile strength of up to 900-1200 MPa, but low ductility (elongation at break 5-8%). In order to improve the toughness, stress relief annealing (800-1100°C) is carried out after cold rolling, so that the elongation at break is increased to 10-12%, and the strength is slightly reduced to 800-1000 MPa. The surface quality of cold-rolled molybdenum sheet is excellent, the roughness after polishing can reach Ra 0.4 microns, and the thickness tolerance is controlled at ±0.005

mm, which meets the needs of semiconductor targets and flexible substrates. The cold rolling process has the advantage of producing ultra-thin, high-strength Molybdenum sheets for high-precision applications, but with high equipment requirements and strict control of lubricants (usually oil-based lubrication) to avoid surface defects. Cold-rolled Molybdenum sheets are widely used in thin film deposition, semiconductor packaging, and medical devices such as X-ray tube anodes, where their high strength and excellent surface quality significantly improve device performance.

电话/TEL：0086 592 512 9696

sales@chinatungsten.com

CTIA GROUP LTD

Molybdenum Sheet Introduction

1. Overview of Molybdenum Sheet

Molybdenum sheet is a thin metal sheet made from high-purity molybdenum through rolling processes. It features excellent high-temperature resistance, thermal conductivity, and mechanical strength. It is widely used in electronics, metallurgy, vacuum equipment, aerospace, and lighting industries as heating elements, thermal shields, or structural components. With a smooth surface and precise dimensions, molybdenum sheets can be customized in various specifications to meet the requirements of advanced manufacturing and scientific research equipment.

2. Features of Molybdenum Sheet

High Purity Material: Purity ≥ 99.95%, with extremely low impurity levels

High-Temperature Resistance: Melting point up to 2610°C, stable performance in extreme conditions

Excellent Workability: High flatness, smooth surface, easy to punch, shear, and weld

Customizable Specifications: Various sizes and thicknesses available to suit different processes

3. Specifications of Molybdenum Sheet

Parameter	Specification
Purity	≥ 99.95%
Thickness	0.01 mm - 3.00 mm
Width	50 mm - 600 mm
Length	Custom lengths or supplied in coil
Surface Finish	Polished, Alkali-cleaned, Sandblasted
Thickness Tolerance	±0.005 mm - ±0.2 mm
Surface Roughness	Ra 0.8 μm – Ra 3.2 μm

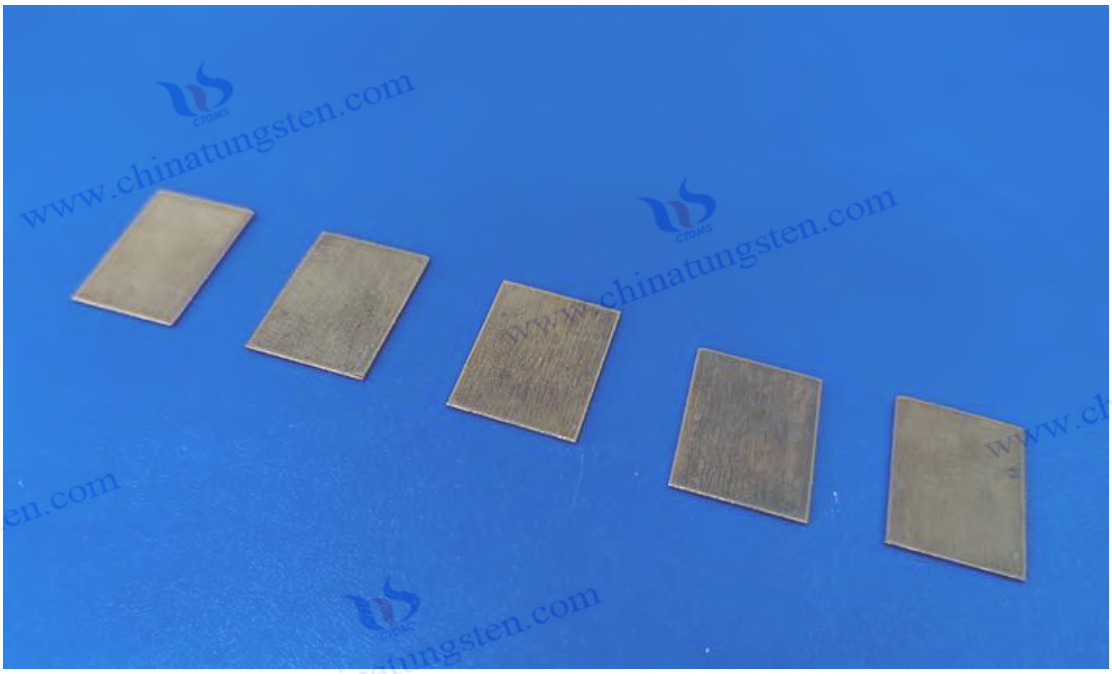
4. Production Process

Molybdenum Ingot (Raw Material) → Inspection → Hot Rolling → Leveling & Annealing → Alkali Cleaning → Inspection → Warm Rolling → Vacuum Annealing → Inspection → Cold Rolling → Leveling → Shearing → Vacuum Annealing → Inspection → Packaging

5. Purchasing Information

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

Website: molybdenum.com.cn



CTIA GROUP LTD molybdenum sheet

Chapter 5 Production and performance testing equipment for molybdenum sheets

5.1 Mining equipment for molybdenum ore

The mining of molybdenum ore is the first step in the production of Molybdenum sheets, and the selection of equipment directly affects the efficiency and cost of obtaining raw materials. According to the geological conditions of the deposit, the mining equipment is divided into open-pit mining equipment and underground mining equipment, which are suitable for shallow large deposits and deep complex deposits. CTIA GROUP LTD Molybdenum sheets relies on efficient mining equipment to ensure the high quality and stable supply of molybdenite (MoS_2) raw materials. The following is a detailed discussion of the types, functions and application points of open-pit and underground mining equipment.

5.1.1 Open-pit mining equipment for molybdenum ore

Open-pit mining equipment is used to process shallowly buried molybdenite deposits, such as Luanchuan in Luoyang in China or Klemax in the United States, and mainly includes drilling rigs, blasting equipment, excavators, dump trucks and loaders. Drilling rigs (e.g. rotary or down-the-hole drilling rigs) are used for pre-blasting drilling, typically with a hole diameter of 100-250 mm and a penetration rate of up to 20-50 m/h, equipped with a high-precision GPS positioning system to optimize the blasting layout. The blasting equipment uses ammonium nitrate or emulsion explosives, and the blasting is precisely controlled by electronic detonators to crush the ore to a particle size of 0.1-1 meter, reducing the dilution rate (target < 10%). Excavators (e.g. electric shovels or hydraulic excavators, 10-30 m^3 capacity) are responsible for stripping waste rock and extracting ore with a production capacity of 5,000-10,000 t/h. Dump trucks (50-200 tons, e.g. Caterpillar 797F) are used to transport ore to concentrators and are equipped with automatic navigation systems to improve transportation efficiency. Loaders (e.g. wheel loaders, with a bucket capacity of 5-15 cubic meters) are used for the stacking and transfer of ore and waste rock. Key takeaways include: high wear resistance to cope with molybdenite hardness (1-1.5 on the Mohs scale), blasting and excavation to reduce stripping ratios (3:1 to 10:1); Environmental measures such as spray dust suppression (dust concentration < 10 mg/m³) and wastewater recycling (> 80%) are strictly enforced. The efficient synergy of these facilities ensures that open pit mining provides high-grade molybdenum ore (0.1-0.5% molybdenum).

5.1.2 Underground mining equipment for molybdenum ore

Underground mining equipment is suitable for molybdenite deposits with deep or complex geological conditions, such as Jilin, China or parts of Canada, mainly including roadheaders, rock drills, loaders, mine trucks and hoisting systems. TBMs (e.g. full-section TBMs or anchor excavators) are used to excavate tunnels at a speed of approx. 5-10 m/day and are equipped with laser navigation to ensure roadway accuracy (deviation < 5 cm). Rock drills (e.g. hydraulic drill rigs) are used for blasting and drilling, with a hole diameter of 50-100 mm and a drilling efficiency of 10-20 m/h, suitable for room-and-pillar or fill-and-fill mining. Loaders (e.g. scrapers, bucket capacity 2-5 m³) are responsible for loading crushed ore (0.1-0.5 m particle size) and are equipped with snow chains to accommodate slippery roadways. Minecarts (10-30 tonnes) transport ore to the hoisting shaft via a track or trackless system, which (e.g. a winch or winch, 500-2000 kW) lifts the ore to the surface with an efficiency of 1000-5000 tonnes/day. Key takeaways include: the equipment needs to be compact enough to fit narrow aisles (3-5 m wide and 3-4 m high); Ventilation system (air volume ≥ 3 m³/s·person) to ensure operation safety; Automated controls, such as remotely operated rock drills, increase efficiency and reduce labor risks. Underground mining equipment requires regular maintenance to cope with high wear and tear, ensuring ore recovery (70-90%) and grade consistency, and providing a stable feedstock for molybdenum sheet production.

5.2 Mineral processing equipment for molybdenum ore

The beneficiation equipment is used to process low-grade molybdenum ore (0.1-0.3% molybdenum content) into high-grade molybdenum concentrate (50-60% molybdenum content), which is the core link in the preparation of raw materials for molybdenum sheet production. Mineral processing equipment includes crushing equipment, grinding equipment, classification equipment and flotation equipment, which separate molybdenite from associated minerals (such as quartz and magnetite) by physical and chemical methods. The following is a detailed analysis of the functions, performance, and key points of operation of these devices.

5.2.1 Crushing equipment for molybdenum ore

The crushing plant is used to crush the raw ore (0.1-1 m) to a suitable particle size (10-50 mm) for beneficiation, laying the foundation for subsequent grinding and flotation. The main equipment includes jaw crusher, cone crusher and impact crusher. Jaw crushers (e.g. PE series, power 75-200 kW) are used for primary crushing, with a processing capacity of 100-1000 t/h, crushing ore to 50-150 mm, suitable for high hardness molybdenite. Cone crushers (e.g. HP series, 200-500 kW) are used for secondary crushing with a particle size of 10-50 mm and a crushing ratio of up to 4:1 and are equipped with a hydraulic adjustment system to ensure uniform particle size. The impact crusher is used for fine crushing, suitable for ores with a large gangue content, and produces a particle size of 5-20 mm. Key takeaways include: equipment needs to be equipped with wear-resistant liners (e.g., high manganese steel) to cope with the abrasive nature of molybdenum; The vibrating screen (screen hole 10-50 mm) is used in combination with the crusher to ensure that the particle size meets the requirements; Dust control (spray or bag removal, dust concentration <10 mg/m³) meets environmental standards. The efficient operation of the crushing plant ensures that the ore is fully dissociated and provides high-quality input for beneficiation.

5.2.2 Grinding equipment for molybdenum ore

The grinding equipment further refines the crushed ore to -200 mesh (about 74 microns), so that the dissociation degree of molybdenite monomer reaches more than 80%, which meets the requirements of flotation. The main equipment is ball mill and rod mill. Ball mills (e.g. MQG series, 200-1000 kW) are ground by means of steel balls (20-100 mm diameter) and ore collisions, with a capacity of 50-500 t/h and a grinding fineness of 70-80%-200 mesh, equipped with an automatic control system to optimize the feed rate and speed (20-30 rpm). The rod mill is used for coarse grinding or clay-bearing ores, and the steel rods (2-3 m in length) are reduced for over-grinding and produce a grain size of 0.5-2 mm. Key points include: the grinding medium needs to be changed regularly to maintain efficiency (ball consumption of 0.5-1 kg/t); Wet grinding (water-to-ore ratio 1:1-2:1) reduces dust and improves dissociation; Closed-circuit grinding is combined with classifiers to ensure uniform particle size distribution (D50 approx. 50-100 microns). The high efficiency of the grinding equipment has a direct impact on the flotation recovery rate (85-95%).

5.2.3 Grading equipment for molybdenum ore

Classifiers are used to separate the ground slurry by particle size and optimize flotation efficiency, and commonly used equipment includes spiral classifiers and hydrocyclones. Spiral classifiers (e.g. FG series, power 5-15 kW) separate coarse (>0.15 mm) from fine (<0.15 mm) through spiral blades, with a capacity of 20-200 t/h and a grading efficiency of 70-85%.

Hydrocyclones (e.g. FX series, inlet pressure 0.1-0.3 MPa) use centrifugal force to classify fine-grained slurries (<0.1 mm) with high classification accuracy (error <5%) and a capacity of 10-100 m³/h. Key takeaways include: the classifier needs to have a closed-circuit cycle with the mill, and the return ratio (100-300%) needs to be optimized to reduce overgrinding; Equipment linings (e.g. polyurethane) for improved wear resistance; The wastewater recycling rate > 80% to reduce water consumption. The grading equipment ensures that the particle size of molybdenite is suitable for flotation and improves the concentrate grade.

5.2.4 Flotation equipment for molybdenum ore

The flotation equipment uses the hydrophobic separation of molybdenite to separate molybdenum concentrate, and the core equipment is the flotation machine. Mechanical stirred flotation cells (e.g. SF or XCF series, power 15-100 kW) generate bubbles (air or nitrogen, flow rate 1-2 m^3/min) through an impeller (speed 200-400 rpm), to which molybdenite adheres to the bubbles to form a foam layer to produce molybdenum concentrate (50-60% molybdenum content). The flotation cell has a volume of 4-20 m^3, equipped with an automatic dosing system (xanthate 0.1-0.3 kg/t, terpineol 0.05-0.1 kg/t), and pH control at 8-10. Key points include: the flotation cell requires multiple tanks in series (6-12 tanks) for rough separation, selection and sweeping, with a recovery rate of 85-95%; Bubble size (0.5-2 mm) and slurry concentration (20-30%) need to be precisely controlled; Tailings and wastewater need to be treated (recycling rate > 80%) to meet environmental standards. The efficient operation of the flotation equipment ensures high grade and low impurities of molybdenum concentrate, providing high-quality raw materials for molybdenum sheet production.

5.3 Molding equipment for molybdenum sheets

The forming equipment of molybdenum sheet is the core tool for processing it from high-purity molybdenum powder or molybdenum blank into thin sheet material, which directly affects the thickness accuracy, surface quality and mechanical properties of molybdenum sheet. The molding equipment mainly includes powder metallurgy equipment and rolling equipment, of which powder metallurgy equipment is used to prepare molybdenum billets with high purity and uniform structure, which is the basic link in the production of molybdenum sheets. Relying on advanced molding equipment, CTIA GROUP LTD Molybdenum Sheet ensures high precision and consistency of products, and meets the needs of electronics, aerospace and high-temperature industries. The following is a detailed discussion of the functions, performance and operation points of powder pressing equipment and sintering equipment in powder metallurgy equipment.

5.3.1 Powder metallurgy equipment for Molybdenum sheets

Powder metallurgy equipment is used to process high-purity molybdenum powder (purity ≥ 99.95%, particle size 1-10 microns) into dense molybdenum billets, which provides the basis for subsequent rolling or direct forming of molybdenum sheets. The powder metallurgy process consists of two main steps, powder pressing and sintering, involving equipment such as cold isostatic presses, hydraulic presses, and vacuum sintering furnaces. These machines provide the basis for the production of high-performance Molybdenum sheets by precisely controlling pressure, temperature and atmosphere to ensure high density (>98%) and low impurity content (iron, copper< 20 ppm).

5.3.1.1 Powder pressing equipment for molybdenum sheets

Powder pressing equipment is used to press molybdenum powder into a blank with a certain shape and strength, and common equipment includes cold isostatic presses (CIP) and hydraulic presses. Cold isostatic presses (e.g. CIP-400 series, pressure 100-400 MPa) apply uniform pressure to molybdenum powder through a liquid medium (e.g. water or oil) and press it into plate or rod blanks (size 100-500 mm) with a density of 60-70%. Its advantage is that the pressure is evenly distributed, avoiding the concentration of stress inside the billet, and it is suitable for the production of large size or complex shape of molybdenum billet. Hydraulic presses (e.g. four-column hydraulic presses, power 200-1000 kW) are used for one-way pressing, pressure 50-200 MPa, suitable for small blanks (thickness 10-50 mm), high production efficiency (1-3 pieces per minute). During the pressing process, the molybdenum powder needs to be pre-sieved (100-200 mesh) and a small amount of binder (e.g. polyvinyl alcohol, 0.1-0.5%) is added to improve the strength of the blank. Key takeaways include: molds need to be made of high-strength steel or carbide to withstand high pressures; Pressing parameters (e.g. pressure holding time 10-30 seconds) need to be optimized to ensure blank uniformity; The equipment is equipped with a dust suppression system (dust concentration < 5 mg/m^3) to protect the operating environment. The pressed molybdenum billet provides a high-quality input for sintering, ensuring consistent performance of the subsequent molybdenum sheet.

5.3.1.2 Sintering equipment for molybdenum sheets

The sintering equipment is used to consolidate the pressed molybdenum billet into a high-density billet at high temperature, which is the core step of powder metallurgy. Commonly used equipment includes vacuum sintering furnaces and hydrogen protection sintering furnaces. Vacuum sintering furnace (such as VSF series, power 100-500 kW) operates at a vacuum degree of 10^{-3}-10^{-5} Pa and a temperature of 1800-2000 °C, and the sintering time is 2-6 hours, so that the molybdenum powder particles are combined by diffusion, the grain size is controlled at 10-50 microns, and the density reaches 98-99%. The vacuum environment effectively prevents oxidation, and the oxygen content is reduced to <50 ppm, which is suitable for the production of high-purity Molybdenum sheets (≥99.95%) raw materials. Hydrogen protection sintering furnace (temperature 1600-1900°C, hydrogen purity ≥ 99.99%, flow rate 1-2 m^3/h) removes trace oxides through a reducing atmosphere, suitable for ordinary purity Molybdenum sheets (99-99.9%). The tensile strength of the sintered molybdenum billet is about 500-700 MPa, and the density is close to the theoretical value (10.22 g/cm^3). Key points include: precise control of the ramp-up rate (5-10°C/min) to avoid billet cracking; Furnace atmosphere monitoring to ensure no oxygen leakage; The cooling rate (10-20°C/min) optimizes the grain structure. The high performance of the sintering equipment ensures the high density and low impurities of the molybdenum billet, which provides a high-quality basis for subsequent rolling processing and meets the needs of electronic targets and high-temperature components.

5.3.2 Rolling equipment for molybdenum sheets

Rolling equipment is the core tool in the molybdenum sheet forming process, which is used to process sintered molybdenum billets into thin sheets of specific thickness, size and performance, and is widely used in electronics, aerospace and high-temperature industries. The rolling equipment is divided into hot rolling mill and cold rolling mill, which are used to produce thicker (0.5-3 mm) and ultra-thin (0.01-0.1 mm) Molybdenum sheets, respectively, and optimize the grain structure, strength and surface quality of

Molybdenum sheets by precisely controlling the amount of deformation, temperature and atmosphere. CTIA GROUP LTD Molybdenum Sheet relies on advanced rolling equipment to ensure the high precision and consistency of products and meet the needs of high-end applications. The following is a detailed discussion of the functions, performance, and key points of operation of hot and cold rolling mills for molybdenum sheets.

5.3.2.1 Hot rolling mills for molybdenum sheets

The hot rolling mill is used for multi-pass rolling of molybdenum billets at high temperatures (1000-1400°C) to produce molybdenum sheets with a thickness of 0.5-3 mm, suitable for high-temperature furnace components and aerospace structural parts. Commonly used equipment is a four-high hot rolling mill or a reversible hot rolling mill (e.g. SMS Group equipment, 500-2000 kW) equipped with a vacuum or inert gas (e.g. argon) protection system to prevent molybdenum oxidation at high temperatures to form volatile MoO_3。 The working roll diameter of the hot rolling mill is 300-600 mm, the rolling speed is 1-5 m/min, and the deformation is controlled at 20-30% each time to avoid cracks. Molybdenum billet (usually prepared by powder metallurgy method, thickness 10-50 mm) is heated to 1100-1300 °C in a preheating furnace and then enters the rolling mill, where it is gradually thinned in multiple passes (6-10 passes) with a grain size of 50-100 microns, giving the molybdenum sheet good ductility (elongation at break 10-15%) and high-temperature strength (about 500 MPa at 1200 °C). The surface roughness is generally Ra 1.0-2.0 microns and can be optimized by pickling. Key points include: precise control of roll gap and temperature (deviation < 10°C) to ensure thickness tolerances (±0.05 mm); Protects the purity of the atmosphere (≥99.99%) against oxidation; Equipped with an in-line thickness gauge and cooling system (cooling rate 10-20°C/min) to optimize grain structure. The advantages of the hot rolling mill are high production efficiency (10-50 tons per day), suitable for high-volume production, and widely used in the manufacture of chemical equipment linings and high-temperature furnace heating elements.

5.3.2.2 Cold rolling mill for molybdenum sheets

The cold rolling mill further rolls hot-rolled molybdenum sheets or sintered molybdenum blanks at or near room temperature to produce ultra-thin molybdenum sheets with a thickness of 0.01-1 mm, suitable for semiconductor targets and microelectronic substrates. Commonly used equipment is a high-precision four- or multi-roll cold rolling mill (e.g. Sendzimir mill, 200-1000 kW) equipped with high-strength work rolls (diameter 100-300 mm, hardness HRC 60-65) and automatic roll gap control system (accuracy ± 0.001 mm). The deformation of cold rolling is controlled at 10-20% each time, and the rolling speed is 0.5-3 m/min to avoid cracks caused by work hardening. Cold-rolled molybdenum sheets have a small grain size (5-20 microns) and a tensile strength of 900-1200 MPa, but low ductility (elongation at break 5-8%) and toughness (elongation at break 10-12%) through stress relief annealing (800-1100°C). The surface quality is excellent, the roughness after polishing can reach Ra 0.4 microns, and the thickness tolerance is controlled at ±0.005 mm.

Key takeaways include: the use of oil-based lubricants (viscosity 10-20 cSt) to reduce surface defects; Equipped with in-line defect detection (e.g. laser scanning) to ensure surface quality; Annealing furnaces need to be vacuum or hydrogen protected (purity≥ 99.99%) to prevent oxidation. The cold rolling mill has the advantage of producing ultra-thin, high-precision Molybdenum sheets for demanding applications in the electronics industry, such as thin film deposition and X-ray tube assemblies, but with high equipment costs and regular maintenance of roll surfaces and control systems.

5.4 Performance testing equipment for molybdenum sheets

Performance testing equipment for Molybdenum sheets is used to evaluate their physical and chemical properties to ensure that products meet the stringent requirements of electronics, aerospace, and high-temperature industries. The test equipment covers key parameters such as density, melting point, electrical and thermal conductivity, and provides reliable data through high-precision instrumentation to verify the purity, structure and functionality of molybdenum sheets. CTIA GROUP LTD molybdenum sheet has passed advanced testing equipment to ensure that the performance parameters meet the ASTM B386 standard, such as density of 10.22 g/cm³ and resistivity of about 5.2×10^{-8} Ω·m and thermal conductivity of about 138 W/m·K. The following is a detailed discussion of the types, functions and operation points of density measurement equipment, melting point test equipment, conductivity test equipment and thermal conductivity test equipment for molybdenum sheets.

5.4.1 Density measuring equipment for molybdenum sheets

Density measuring equipment is used to determine the density of molybdenum sheets (theoretical value 10.22 g/cm³) to evaluate their density and purity, suitable for quality control and material certification. Commonly used equipment includes the Archimedes drainage device and an X-ray densitometer. Archimedes drainage devices (e.g., Mettler Toledo density meter, accuracy ±0.001 g/cm³) calculate the density by measuring the mass of the molybdenum sheet in air and liquid (usually deionized water) with a test range of 0.1-20 g/cm³ and are suitable for molybdenum sheets with a thickness of 0.01-3 mm. During operation, the molybdenum sheet needs to be cleaned (ultrasonic cleaning, oil removal is removed), air bubbles should be avoided when immersed in liquid, and the measurement error should be controlled at ±0.01 g/cm³. X-ray densitometers (e.g., PANalytical X'Pert, with an accuracy of ±0.005 g/cm³) analyze the density of materials by X-ray absorption without destroying the sample, making them suitable for high-precision detection. Key takeaways include: calibrating equipment to ensure accuracy (using standard samples such as pure molybdenum blocks); The test environment needs to be kept at a constant temperature (20±1°C) to eliminate the effect of thermal expansion; Multiple measurements are averaged to improve reliability. Density measurement devices detect microscopic defects (e.g., porosity <2%) in molybdenum sheets to ensure they are suitable for semiconductor targets and high-temperature components.

5.4.2 Melting point test equipment for molybdenum sheets

Melting point testing equipment is used to verify the melting point of molybdenum sheets (about 2620°C) to confirm their high-temperature performance and purity, suitable for aerospace and high-temperature furnace applications. Commonly used equipment is high-temperature differential scanning calorimetry

(DSC) and laser flash melting equipment. High-temperature DSC (e.g., Netzsch STA 449, temperature range 25-2800 °C, accuracy ± 5 °C) determines the melting point by heating a molybdenum sheet sample (mass 5-10 mg) and recording endothermic peaks, equipped with tungsten crucible and argon protection (purity ≥ 99.99%) to prevent oxidation. Laser flash melting equipment (e.g. LFA 467, temperature range 1000-3000°C) heats the surface of the molybdenum sheet by laser pulse, combined with an infrared thermometer to record the melting temperature, and the test time is short (<1 minute), which is suitable for rapid detection. Key takeaways include: samples need to be of high purity (≥ 99.95%) to avoid impurities and lower melting point; The test atmosphere needs to be strictly controlled (oxygen content < 10 ppm); The equipment needs to be calibrated regularly (using tungsten standards, melting point 3422°C). The melting point test equipment ensures the stability of Molybdenum sheets in high-temperature environments (such as vacuum furnaces), and the error is controlled within ±10°C.

5.4.3 Conductivity test equipment for molybdenum sheets

Conductivity test equipment is used to measure the resistivity of molybdenum sheets (about 5.2×10^{-8} Ω·m), to evaluate its electrical properties, suitable for electrode and target applications in the electronics industry. Commonly used equipment is a four-probe tester and a conductivity meter. A four-probe tester (e.g., Keithley 2635B, accuracy ±0.01%) calculates the resistivity of the molybdenum sheet by applying a constant current (1-100 mA) and measuring the voltage through four equidistant probes (1-2 mm apart) with a test range of 10^{-9}-10^{-6} Ω·m, suitable for molybdenum sheets with a thickness of 0.01-3 mm. Conductivity meters (e.g., Sigmascope SMP350, frequency 10-100 kHz) measure conductivity (in S/m) by eddy current method without contact and are suitable for rapid detection of large areas of molybdenum sheets. Key points include: the surface of the molybdenum sheet needs to be polished (Ra ≤0.4 microns) to reduce contact resistance, and the test environment needs to be constant temperature and humidity (20±1°C, humidity <50%) to avoid interference; Multiple measurements (at least 5 times) are averaged to ensure accuracy. The four-probe tester detects the grain boundary resistance and impurity effects of molybdenum sheets, ensuring their conductivity stability in semiconductor thin film deposition.

5.4.4 Thermal conductivity test equipment for molybdenum sheets

The thermal conductivity test equipment is used to measure the thermal conductivity of molybdenum sheets (about 138 W/m·K) and evaluate their thermal management performance, and is suitable for heat dissipation substrates and high-temperature furnace components. Commonly used equipment is laser flash thermal conductivity meter and steady-state heat flow equipment. Laser flash thermal conductivity (e.g. Netzsch LFA 467, accuracy ±3%) heats one side of the molybdenum sheet (sample size 10×10×0.5-3 mm) by laser pulse, the infrared thermometer records the temperature rise on the other side, calculates the thermal conductivity, tests the temperature range 20-1500°C, and is equipped with argon protection (purity ≥ 99.99%) to prevent oxidation. Steady-state heat flow devices (e.g., Hot Disk TPS 2500S, with an accuracy of ±2%) measure the temperature gradient under a steady heat flow by embedding a thermal probe in the molybdenum disc and are suitable for large samples (20×20 mm). Key points include a flat sample surface (Ra ≤0.4 μm) to ensure thermal contact, testing in a vacuum or inert atmosphere to avoid oxidation effects, and equipment calibration using standard samples (e.g., stainless steel, thermal conductivity 16 W/m·K). Thermal conductivity test equipment verifies the thermal conductivity of molybdenum sheets, ensuring their performance in electronic packaging and high-temperature thermal shielding with an error of ±5 W/m·K.

5.5 Molybdenum sheet mechanical properties testing equipment

Mechanical property testing equipment is used to evaluate the strength, hardness, toughness and fatigue resistance of molybdenum sheets to ensure that they meet the demanding requirements of aerospace, electronics and high-temperature industries. These devices measure key parameters such as tensile strength, hardness, and fracture toughness of molybdenum sheets by applying mechanical loads or shocks, providing data support for quality control and material certification. CTIA GROUP LTD molybdenum sheet meets ASTM B386 standard through advanced mechanical property testing equipment to ensure that its tensile strength (800-1200 MPa), hardness (220-250 HV) and toughness (fracture toughness 10-15 MPa·m^1/2) meet ASTM B386 standard. The following is a detailed discussion of the functions, performance and operation points of universal material testing machines, hardness testers and impact testing machines in testing the mechanical properties of molybdenum sheets.

5.5.1 Universal material testing machine to test the mechanical properties of molybdenum sheets

The Universal Materials Testing Machine (UTM) is the core equipment for testing the mechanical properties of molybdenum sheets, which is used to measure tensile strength, yield strength, elongation at break and elastic modulus, and is suitable for molybdenum sheets with a thickness of 0.01-3 mm. Commonly used equipment such as the Instron 5982 or the MTS Criterion series (load range 1-100 kN with an accuracy of ± 0.5%) evaluates the performance of molybdenum sheets by tensile, compression, or flexure tests. In a tensile test, a molybdenum sheet sample (standard size such as ASTM E8, width 5-10 mm) is fixed between fixtures, stretched to fracture at a constant rate (1-10 mm/min), and a stress-strain curve is recorded to give tensile strength (800-1200 MPa), yield strength (about 600-900 MPa), and elongation at break (5-15%). The high-temperature tensile test (1000-1500°C) needs to be equipped with a high-temperature furnace (argon protection, purity≥99.99%) to simulate the actual working conditions and test the high-temperature strength (about 500-700 MPa at 1200°C). Key points include: polishing the sample surface (Ra ≤0.4 microns) to avoid stress concentrations, fixture alignment accuracy (<0.1 mm) to ensure test consistency; The test environment needs to be constant temperature (20±1°C) or strictly controlled high temperature atmosphere (oxygen content < 10 ppm). Universal materials testing machines accurately evaluate the mechanical properties of molybdenum sheets and ensure their reliability in aerospace structures and high-temperature furnace components.

5.5.2 The hardness tester tests the mechanical properties of molybdenum sheets

Hardness tester is used to measure the hardness of molybdenum sheets, reflecting their resistance to deformation and wear, and is an important tool for evaluating their mechanical properties. Commonly used equipment includes Vickers hardness testers (e.g., Wilson VH3300, 0.1-10 kgf, accuracy ±1 HV) and Brinell hardness testers (e.g., ZwickRoell ZHU250, 5-3000 kgf). The Vickers hardness test applies a load of 1-5 kgf on the surface of the molybdenum sheet (polished to Ra ≤0.4 microns), presses the sample through a diamond indenter (136° cone angle), measures the indentation diagonal length, and calculates the hardness value (220-250 HV for high-purity molybdenum sheet, 300-350 HV for TZM alloy). The Brinell hardness test uses a carbide ball indenter (diameter 2.5-10 mm) for thicker molybdenum sheets (>1 mm) with a hardness value of about 230-260 HB. The test should be performed in a constant temperature environment (20±1°C) and at least 5 points should be averaged to reduce the effect of grain inhomogeneity. Key points include: the sample surface needs to be clean and free of oxide layer (pickling or ultrasonic cleaning); The indenter and load should be selected according to the thickness (low load for thin sheet < 0.1 mm); The equipment needs to be calibrated regularly (using standard hardness blocks). The hardness tester test results can verify the work hardening effect and wear resistance of molybdenum sheets, and are suitable for electronic targets and cutting tool coating substrates.

5.5.3 Impact testing machine to test the mechanical properties of molybdenum sheets

Impact testing machines are used to evaluate the toughness and impact resistance of molybdenum sheets, verifying their performance under dynamic loads by measuring fracture toughness (K_IC) or impact absorption energy. Commonly used equipment is Charlest impact testers (e.g., ZwickRoell HIT series, energy range 5-300 J, accuracy ± 0.1 J) and drop weight impact testers (e.g., Instron Dynatup, energy 50-1000 J). The Charlest impact test applies an instantaneous impact to a standard specimen (e.g., ASTM E23, size 10×10×55 mm with V-notched) and records the energy absorbed at break (about 5-15 J for molybdenum sheets) and reflects its toughness (fracture toughness 10-15 MPa·m^1/2). The drop weight test is suitable for thin molybdenum sheets (0.01-1 mm thick), measuring shock resistance by free-fall impact (height 0.5-2 m), and is suitable for simulating the vibration environment of aerospace components. The high temperature impact test (1000°C) needs to be equipped with an argon protection furnace (purity≥99.99%) to prevent oxidation. Key points include: the sample notches need to be machined precisely (2 mm depth, 45° angle); The test temperature needs to be controlled (20±1°C or high temperature ±10°C); Multiple tests (at least 3 times) are averaged to ensure reliability.

CTIA GROUP LTD

Molybdenum Sheet Introduction

1. Overview of Molybdenum Sheet

Molybdenum sheet is a thin metal sheet made from high-purity molybdenum through rolling processes. It features excellent high-temperature resistance, thermal conductivity, and mechanical strength. It is widely used in electronics, metallurgy, vacuum equipment, aerospace, and lighting industries as heating elements, thermal shields, or structural components. With a smooth surface and precise dimensions, molybdenum sheets can be customized in various specifications to meet the requirements of advanced manufacturing and scientific research equipment.

2. Features of Molybdenum Sheet

High Purity Material: Purity ≥ 99.95%, with extremely low impurity levels

High-Temperature Resistance: Melting point up to 2610°C, stable performance in extreme conditions

Excellent Workability: High flatness, smooth surface, easy to punch, shear, and weld

Customizable Specifications: Various sizes and thicknesses available to suit different processes

3. Specifications of Molybdenum Sheet

Parameter	Specification
Purity	≥ 99.95%
Thickness	0.01 mm - 3.00 mm
Width	50 mm - 600 mm
Length	Custom lengths or supplied in coil
Surface Finish	Polished, Alkali-cleaned, Sandblasted
Thickness Tolerance	±0.005 mm - ±0.2 mm
Surface Roughness	Ra 0.8 μm – Ra 3.2 μm

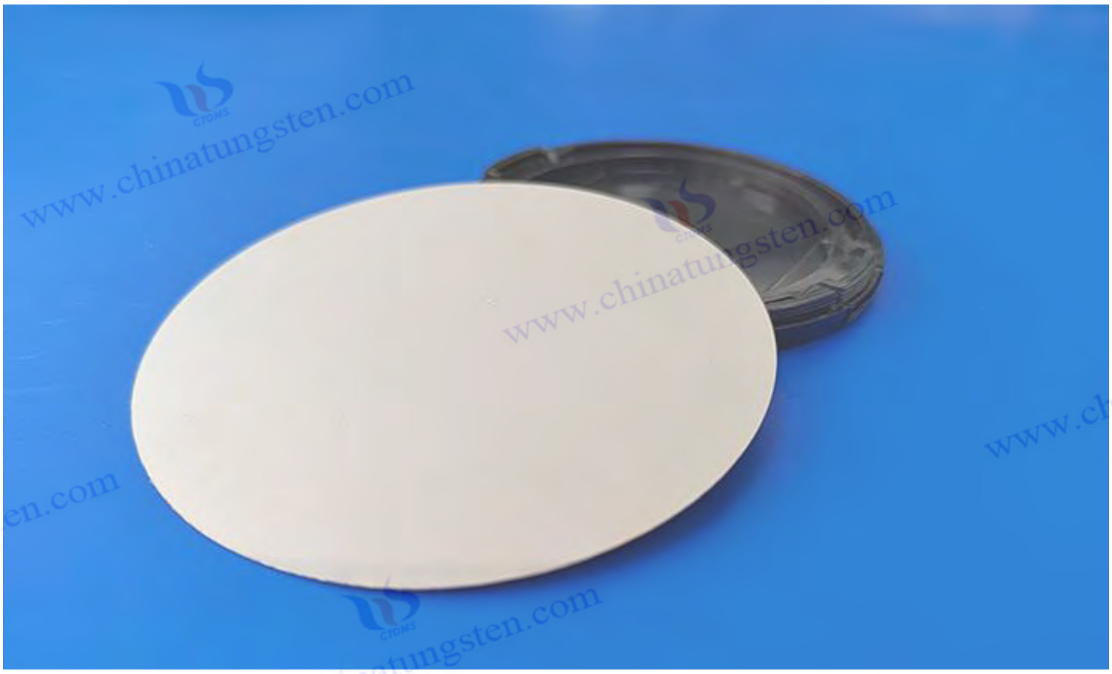
4. Production Process

Molybdenum Ingot (Raw Material) → Inspection → Hot Rolling → Leveling & Annealing → Alkali Cleaning → Inspection → Warm Rolling → Vacuum Annealing → Inspection → Cold Rolling → Leveling → Shearing → Vacuum Annealing → Inspection → Packaging

5. Purchasing Information

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

Website: molybdenum.com.cn



CTIA GROUP LTD molybdenum sheet

Chapter 6 Test methods for the performance of molybdenum sheets

Performance testing methods for Molybdenum sheets are used to accurately assess their physical and chemical properties to ensure they meet the stringent requirements of the electronics, aerospace, and high-temperature industries. Test methods cover key parameters such as density, melting point, and thermal stability, and provide reliable data to verify the purity, structure, and functionality of molybdenum sheets through standardized processes and equipment. CTIA GROUP LTD molybdenum chips are tested using international standards (e.g., ASTM B386) to ensure that performance parameters such as density (10.22 g/cm³), melting point (2620°C) and high temperature stability meet expectations.

6.1 Test method for density of molybdenum sheet

The test method for the density of molybdenum sheets is used to measure its density (theoretical value 10.22 g/cm³) to evaluate the density and purity of the material, suitable for quality control and certification. Commonly used methods are Archimedes drainage method and X-ray density analysis.

Based on the principle of buoyancy, the Archimedes drainage method measures the mass difference of molybdenum sheets in air and liquid, calculates the density, and the accuracy can reach ±0.01 g/cm³, which is suitable for molybdenum sheets with a thickness of 0.01-3 mm. The test process includes: 1) sample preparation, ultrasonic cleaning of molybdenum sheets (5 minutes, oil removal), drying (60°C, 10 minutes); 2) weighing, using a high-precision electronic balance (e.g. Mettler Toledo XS205, with an accuracy of ± 0.1 mg) to measure the mass in the air (m_1); 3) Immersion measurement, the molybdenum sheet is suspended in deionized water (density ρ_0=1 g/cm³, 20 °C) to ensure that there is no bubble attachment, and the mass in the water (m_2) is recorded; 4) Calculate the density, the formula is $\rho=m_1/(m_1-$

$m_2)\cdot\rho_0$, and repeat the measurement 3-5 times to take the average value.

X-ray densitometry uses an X-ray density meter (e.g., PANalytical X'Pert) to calculate the density from the X-ray absorption intensity with an accuracy of ± 0.005 g/cm³ without destroying the sample, making it suitable for high-precision detection. Key takeaways include: the test environment needs to be kept at a constant temperature (20±1°C) to eliminate the effects of thermal expansion; The sample surface needs to be flat (Ra ≤ 0.4 μm) to reduce errors, and calibration equipment uses standard samples (e.g., pure molybdenum blocks). Density testing detects porosity (target <2%) and impurity effects to ensure that the molybdenum sheet is suitable for semiconductor targets and high-temperature components.

6.2 Test method for melting point of molybdenum sheet

The test method for the melting point of Molybdenum sheets is used to verify its melting point (about 2620°C) to confirm high-temperature performance and purity, and is suitable for aerospace and high-temperature furnace applications. Commonly used methods are differential scanning calorimetry (DSC) and laser flash melting. The DSC method measures the endothermic peak of the molybdenum sheet during the heating process by a high-temperature differential scanning calorimeter (e.g., Netzsch STA 449, temperature range 25-2800°C, accuracy ±5°C). The test process consisted of: 1) sample preparation, cutting of molybdenum sheets (5-10 mg, thickness 0.1-1 mm), polishing (Ra ≤0.4 microns) and ultrasonic cleaning, 2) sample loading, placing the sample in a tungsten crucible and placing it in an argon protective atmosphere (purity≥99.99%, oxygen content <10 ppm); 3) Heating, heating to 2800°C at a rate of 5-10 °C/min, recording the endothermic peak temperature as the melting point; 4) Data analysis, repeat the test 3 times to take the average. The laser flash melting method uses a laser flash melting device (such as LFA 467, temperature range 1000-3000 °C) to quickly heat the surface of the molybdenum sheet (area 5×5 mm) by laser pulses, and the infrared thermometer records the melting temperature, and the test time is < 1 minute. Key takeaways include: samples need to be of high purity (≥ 99.95%) to avoid impurities and lower melting point; The test atmosphere needs to be strictly controlled to prevent oxidation; The device is calibrated using a standard sample (e.g. tungsten, melting point 3422°C). The melting point test error is controlled at ±10°C to ensure the stability of molybdenum sheets in vacuum furnaces or high-temperature components.

6.3 Test methods for thermal stability of molybdenum sheets

The test method for the thermal stability of molybdenum sheets is used to evaluate its structural and performance stability in high-temperature environments, especially in oxidizing or vacuum atmospheres, and is suitable for high-temperature furnaces and aerospace applications. The thermal stability test is mainly carried out by thermogravimetric analysis (TGA) and high-temperature annealing test method. The TGA method uses a thermogravimetric analyzer (e.g., TA Instruments Q500, temperature range 25-1500°C, accuracy ±0.1%) to measure the mass change of molybdenum sheet at high temperatures, assessing oxidation tendency and volatility loss. The test process includes: 1) sample preparation, cutting of molybdenum sheets (10-20 mg, thickness 0.1-1 mm), ultrasonic cleaning and drying, 2) test environment, argon (purity≥99.99%) or air atmosphere, heating rate 5-10°C/min to 600-1500°C; 3) record the data and measure the mass loss rate (the target < 0.1% in argon at 1000 °C, and MoO_3 may be generated above 600 °C in the oxidizing atmosphere); 4) Analyze the oxidation starting temperature and volatilization rate. The high-temperature annealing test method is performed in a vacuum annealing furnace (e.g. Carbolite Gero, temperature 1000-2000°C, vacuum degree 10^{-5}). Pa), the Molybdenum sheets were heated to 1200-1500 °C, incubated for 1-4 hours, and the surface topography (SEM observation) and grain changes (X-ray diffraction) were checked. Key points include: polishing the surface of the sample (Ra ≤ 0.4 μm) to reduce oxidation point, and a tightly controlled test atmosphere (oxygen content < 10 ppm); Multiple tests (3-5 times) to verify stability. Thermal stability testing confirms the oxidation resistance and structural integrity of molybdenum sheets at high temperatures, ensuring their reliability in vacuum furnace thermal shielding or rocket nozzle linings.

6.4 Test method for conductivity of molybdenum sheet

The test method for the conductivity of molybdenum sheet is used to measure its resistivity (about 5.2×10^{-8} Ω·m) to evaluate the electrical properties and ensure their suitability for electrodes and sputtering targets in the electronics industry. The commonly used methods are the four-probe method and the eddy current method. The four-probe method measures the resistivity of molybdenum sheets by a four-probe tester (e.g., Keithley 2635B, accuracy ±0.01%), suitable for samples with a thickness of 0.01-3 mm. The test process includes: 1) sample preparation, cutting of molybdenum sheets (size 10×10 mm), polishing to Ra ≤0.4 microns, ultrasonic cleaning to remove surface oil, 2) test setup, four-probe equidistant arrangement (1-2 mm spacing), application of constant current (1-100 mA), measurement of voltage drop; 3) Calculate the resistivity using the formula $\rho = (V/I)\cdot(A/L)$, where V is the voltage, I is the current, A is the cross-sectional area of the sample, L is the probe spacing, and the average value is taken by repeating the measurement 5 times; 4) Data calibration, taking into account the influence of sample thickness and temperature (20±1°C). The eddy current method uses a conductivity meter (e.g., Sigmascope SMP350, frequency 10-100 kHz) to measure conductivity in S/m by non-contact eddy currents, making it suitable for rapid detection of large areas of molybdenum sheets. Key takeaways include: no oxide layer on the sample surface; The test environment needs to be constant temperature and humidity (humidity < 50%) to reduce interference; The device is calibrated using standard conductors such as copper, resistivity 1.68×10^{-8} Ω·m）。 The four-probe method has high precision and is suitable for high-precision targets; The eddy current method is highly efficient and suitable for batch testing. Conductivity testing ensures the electrical stability of the molybdenum sheet in the deposition of semiconductor thin films.

6.5 Test method for thermal conductivity of molybdenum sheet

The test method for the thermal conductivity of molybdenum sheets is used to measure its thermal conductivity (about 138 W/m·K) and evaluate the thermal management performance, and is suitable for heat dissipation substrates and high-temperature furnace components. The commonly used methods are laser flash method and steady-state heat flow method. The laser flash method measures the thermal conductivity by a laser flash thermal conductivity meter (e.g., Netzsch LFA 467, with an accuracy of ±3%) and is suitable for molybdenum sheets with a thickness of 0.5-3 mm. The test process includes: 1) sample preparation, cutting of molybdenum sheet (10×10 mm), polishing to Ra ≤0.4 microns, ultrasonic cleaning, 2) test setup, sample placement in an argon protected environment (purity≥99.99%, oxygen content <10 ppm), laser pulse heating on one side, infrared thermometer recording the temperature rise on the other side; 3) Calculate the thermal conductivity using the formula $k=\alpha\cdot\rho\cdot C_p$, where α is the thermal diffusivity (measured by instrument), ρ is the density, and Cp is the specific heat capacity (about 0.25 J/g· K）; 4) Repeat the test 3-5 times to take the average. The steady-state heat flow method uses a heat flux meter (e.g., Hot Disk TPS 2500S, with an accuracy of ±2%) to measure the temperature gradient under a steady heat flow through a thermal probe and is suitable for large samples (20×20 mm). Key takeaways include: uniform thickness of the sample to ensure consistent heat flow; The test temperature is controlled at 20-1500°C; Calibrations were performed using standard samples (e.g., stainless steel, 16 W/m·K). The laser flash method is suitable for high-temperature testing, and the steady-state method is suitable for large samples at room temperature. The thermal conductivity test ensures the thermal conductivity efficiency of the molybdenum sheet in the electronic package, and the error is controlled at ±5 W/m·K.

6.6 Test method for thermal expansion coefficient of molybdenum sheet

The test method for the coefficient of thermal expansion of molybdenum sheets is used to measure its coefficient of linear expansion (about 4.8×10^{-6}/°C, 20-1000°C) to evaluate the thermal matching performance and is suitable for semiconductor packaging and high-temperature components. The most commonly used methods are the thermodilatometer method and the X-ray crystal analysis method. The dilatometer method uses a thermodilatometer (e.g., Netzsch DIL 402 with an accuracy of ± 0.1×10^{-6}/°CThe coefficient of thermal expansion is calculated by measuring the change in the length of the molybdenum sheet during heating. The test process consisted of: 1) sample preparation, cutting of molybdenum sheets (length 10-25 mm, thickness 0.1-1 mm), polishing to Ra ≤0.4 microns, 2) test setup, sample exposure to argon protected environment (purity≥99.99%), heating to 1000°C at 2-5 °C/min, recording of length changes (resolution 0.1 microns), 3) calculation of thermal expansion coefficient by formula $\alpha=\Delta L/(L_0).\cdot\Delta T)$, where ΔL is the length change, L_0 is the initial length, and ΔT is the temperature change; 4) Repeat the test 3 times to take the average. X-ray crystal analysis uses an X-ray diffractometer (e.g., Bruker D8, with an accuracy of $\pm0.05\times10^{-6}$/°C) to estimate the coefficient of thermal expansion by measuring the change in lattice constant at high temperatures, and is suitable for small samples. Key takeaways include: samples need to be free of surface defects; The test temperature needs to be precisely controlled (±1°C); Calibrations are performed using a standard sample (e.g., alumina, 7×10^{-6}/°C). The thermal expansion coefficient test ensures the thermal compatibility of the molybdenum sheet with silicon or ceramics, and the error is controlled at $\pm0.2\times10^{-6}$/°C.

6.7 Test method for strength of molybdenum sheet

The test method for the strength of molybdenum sheets is used to measure its tensile strength (800-1200 MPa) and yield strength (600-900 MPa) to evaluate mechanical properties and is suitable for aerospace and high-temperature structural parts. The most common method is the tensile testing method, using a universal materials testing machine (e.g., Instron 5982, load range 1-100 kN, accuracy ± 0.5%). The test process includes: 1) sample preparation, cutting of molybdenum sheets (ASTM E8 standard, width 5-10 mm, thickness 0.01-3 mm), polishing to Ra ≤0.4 microns;2) test setup, the sample is fixed in fixtures, stretched to fracture at a rate of 1-10 mm/min, and the stress-strain curve is recorded; 3) Data analysis to calculate tensile strength (maximum stress), yield strength (0.2% offset stress) and elongation at break (5-15%); 4) High temperature test (1000-1500°C) requires argon protection (purity≥ 99.99%). Key points include: fixture alignment accuracy (<0.1 mm) to avoid eccentric loads; The test environment is constant temperature (20±1°C) or high temperature control (±10°C); Repeat the test 3-5 times to average. The tensile test method evaluates the strength of molybdenum sheets at room temperature and high temperatures, ensuring their reliability in rocket nozzle linings and high-temperature furnace components.

6.8 Test method for hardness of molybdenum sheet

The test method for the hardness of molybdenum sheets is used to measure its Vickers hardness (220-250 HV, TZM alloy 300-350 HV) to evaluate the resistance to deformation and wear, and is suitable for electronic targets and cutting tool substrates. The most common method is the Vickers hardness test, which uses a Vickers hardness tester (e.g., Wilson VH3300, load 0.1-10 kgf, accuracy ± 1 HV). The test process consisted of: 1) sample preparation, cutting of molybdenum sheets (10×10 mm, thickness 0.1-3 mm), polishing to Ra ≤0.4 μm, ultrasonic cleaning, 2) test setup, using a diamond indenter (136° cone angle), applying a load of 1-5 kgf (0.1-0.5 kgf for lamella < 0.1 mm), holding for 10-15 seconds; 3) Measure the indentation, measure the diagonal length of the indentation using a microscope (magnification 400x), and calculate the hardness value ($HV=1.8544 \cdot F/d^2$, F is the load, d is the average length of the indentation diagonal); 4) Repeat the test 5-7 times to take the average. Key takeaways include: the sample surface needs to be free of an oxide layer (pickling); The load selection needs to match the thickness to avoid the substrate effect; Calibrations are made using standard hardness blocks (e.g., 200 HV). The Vickers hardness test is highly accurate and suitable for evaluating the work hardening and wear resistance of molybdenum sheets, ensuring their stability in sputtering targets.

6.9 Test methods for toughness of molybdenum sheets

The test method for the toughness of molybdenum sheets is used to evaluate its resistance to fracture and its ability to absorb impact energy, and to measure the fracture toughness (K_IC, about 10-15 MPa·m^1/2), which is suitable for aerospace and electronic substrate applications. The commonly used methods are the Charnaisian impact test method and the fracture toughness test method. The Chardens impact test method uses a Chardens impact tester (e.g., ZwickRoell HIT, energy range 5-300 J, accuracy ± 0.1 J). The test process includes: 1) sample preparation, cutting of molybdenum sheet (ASTM E23 standard, 10×10×55 mm, V-notch depth 2 mm, angle 45°), polishing to Ra ≤0.4 microns), 2) test setup, the sample is fixed in the testing machine to impact the notch with a pendulum, and the absorbed energy (about 5-15 J) is recorded; 3) Data analysis, calculate impact toughness, repeat the test 3-5 times to take the average; 4) High temperature test (1000°C) requires argon protection (purity≥ 99.99%, oxygen content<10 ppm). The fracture toughness test method uses a universal materials testing machine (e.g., Instron 5982, load 1-100 kN), using a single-sided notched tensile (SENB) sample (ASTM E399, thickness 0.5-3 mm), loaded at a rate of 0.5-2 mm/min, recording the crack propagation force, and calculating the K_IC. Key points include: notching accuracy (±0.01 mm) to avoid stress concentrations; The test environment is constant temperature (20±1°C) or high temperature control (±10°C); Calibrations are made using standard samples (e.g., steel, K_IC about 50 MPa·m^1/2). The toughness test ensures the fracture resistance of the molybdenum sheet under dynamic loads and is suitable for high-temperature nozzles and semiconductor substrates.

6.10 Test method for the ductility of molybdenum sheets

The test method for the ductility of molybdenum sheets is used to measure its elongation at break (5-15%) and plastic deformation ability, and to evaluate its molding properties, and is suitable for thin film deposition and flexible substrates. The most common method is the tensile testing method, which uses a universal materials testing machine (e.g., MTS Criterion, load 1-100 kN, accuracy ±0.5%). The test process includes: 1) sample preparation, cutting of molybdenum sheets (ASTM E8 standard, width 5-10 mm, thickness 0.01-3 mm), polishing to Ra ≤0.4 microns; 2) test setup, the sample is fixed in fixtures, stretched to fracture at a rate of 1-10 mm/min, and the strain curve is recorded; 3) Data analysis, calculate the elongation at break ($\Delta L/L_0 \times 100\%$) and area reduction rate, and repeat the test 3-5 times to take the average value; 4) High temperature ductility test (1000-1200°C) requires vacuum or argon protection (purity≥99.99%) to improve ductility (up to 20%). Key points include: fixture alignment accuracy (<0.1 mm) to ensure uniform force; The test environment is constant temperature (20±1°C) or high temperature control (±10°C); The sample surface is free of defects to avoid premature fracture. Ductility testing verifies the plastic processing capability of molybdenum sheets, ensuring their suitability for stamping and precision machining.

6.11 Test methods for fatigue properties of molybdenum sheets

The test method for the fatigue properties of molybdenum sheets is used to evaluate its durability under cyclic loads, to measure the fatigue limit (about 400-500 MPa, 10^7 cycles), and is suitable for aerospace and high-temperature vibration environments. The most common method is the high-cycle fatigue test method, using a fatigue testing machine (e.g., MTS 810, load 1-100 kN, frequency 10-100 Hz). The test process includes: 1) sample preparation, cutting of molybdenum sheets (ASTM E466, width 5-10 mm, thickness 0.1-3 mm), polishing to Ra ≤0.4 microns; 2) test setup, application of cyclic stress (stress ratio R=0.1-0.5), frequency 20-50 Hz, recording cycles until break or up to 10^7 times; 3) Data analysis, S-N curve drawing, fatigue limit determined, argon protection (purity≥99.99%) is required for high temperature test (1000°C); 4) Repeat the test 5 times to take the average. Key points include: the sample surface needs to be scratch-free (cleaned by ultrasonic); Stress control accuracy (±1 MPa) ensures consistency; Standard materials (e.g. stainless steel) are used for calibration, with a fatigue limit of approx. 200 MPa. Fatigue testing ensures the long-term stability of the molybdenum sheet in turbine blade support and nuclear reactor components.

6.12 Test method for corrosion resistance of molybdenum sheets

The test method for the corrosion resistance of molybdenum sheets is used to evaluate its stability in chemical media (e.g., non-oxidizing acids, bases) and to measure the corrosion rate (<0.01 mm/year in 10% hydrochloric acid) and is suitable for chemical equipment linings. The commonly used methods are immersion corrosion test method and electrochemical test method. The immersion corrosion test method uses a corrosion test chamber (e.g., Q-FOG CCT, 20-80°C). The test process includes: 1) sample preparation, cutting of molybdenum sheets (20×20 mm, thickness 0.1-3 mm), polishing to Ra ≤0.4 microns, ultrasonic cleaning, 2) test setup, immersion in corrosive media (such as 10% hydrochloric acid, sulfuric acid or NaOH, pH 1-14) at 20-60°C for 168-720 hours; 3) Data analysis, weighing the mass loss of the sample (accuracy ±0.1 mg), calculating the corrosion rate (mm/year), and repeating the test 3 times. The electrochemical test method uses an electrochemical workstation (e.g., Gamry Interface 1010, with an accuracy of ±0.01 mV) to measure the corrosion potential and current density by means of a Tafel curve, and the sample is placed in an electrolytic cell (e.g., 3.5% NaCl). Key takeaways include: media needs to be changed regularly to maintain concentration; There is no oxide layer on the surface of the sample; Calibrations are performed using standard electrodes (e.g., Ag/AgCl). Corrosion resistance testing ensures the stability of molybdenum sheets in chemical reactors and electrode materials.

6.13 Test methods for oxidation resistance of molybdenum sheets

The test method for the oxidation resistance of molybdenum sheet is used to evaluate its stability in a high-temperature oxidation environment, to measure the oxidation onset temperature (about 600°C) and the mass loss rate, and is suitable for vacuum furnaces and aerospace components. Commonly used methods are thermogravimetric analysis (TGA) and high-temperature oxidation testing. The TGA method uses a thermogravimetric analyzer (e.g., TA Instruments Q500, 25-1500°C, accuracy ±0.1%). The test process includes: 1) sample preparation, cutting of molybdenum sheets (10-20 mg, thickness 0.1-1 mm), polishing to Ra ≤0.4 microns;2) test setup, temperature rise to 600-1500°C at 5-10°C/min in air or argon (purity≥99.99%) atmosphere, recording quality changes; 3) Data analysis, determine the oxidation starting temperature (mass increase or MoO_3 volatilization point), repeat the test 3 times. The high-temperature oxidation test method is performed in a high-temperature furnace (e.g., Carbolite Gero, temperature 600-1500 °C), the molybdenum sheet is exposed to air, incubated for 1-4 hours, and the surface oxide layer thickness is observed by SEM (target < 1 micron at 600 °C). Key takeaways include: the test atmosphere needs to be precisely controlled (oxygen content < 10 ppm in argon); The surface of the sample is clean and defect-free; Calibration uses standard samples (e.g., tungsten). Oxidation resistance tests verify the stability of molybdenum sheets in high-temperature environments and ensure their suitability in vacuum or inert atmospheres.

CTIA GROUP LTD molybdenum sheet

Chapter 7 Application Fields of Molybdenum Sheets

7.1 Application of molybdenum sheet in the field of electronic information

Molybdenum sheet has excellent electrical conductivity (resistivity about 5.2×10^{-8} Ω·m), thermal conductivity (about 138 W/m·K), low coefficient of thermal expansion (about 4.8×10^{-6}/°C) and high melting point (2620°C) have a wide range of applications in the field of electronic information, especially in semiconductor manufacturing, electrode materials and lead frames. High-purity Molybdenum sheets (≥99.95%) have become the core materials for high-precision devices in the electronics industry due to their low impurity content and excellent surface quality (Ra ≤ 0.4 microns). Through precision machining and strict quality control, CTIA GROUP LTD molybdenum sheet meets the high standards of the semiconductor, microelectronics and optoelectronics industries.

7.1.1 Application of molybdenum sheets in semiconductors

Molybdenum chips are mainly used as sputtering targets and heat dissipation substrates in the semiconductor industry, and are widely used in the manufacture of thin-film transistors (TFTs), integrated circuits and solar cells. Molybdenum sheets (thickness 0.05-1 mm, purity ≥ 99.95%) for sputtering targets are deposited by magnetron sputtering to form a conductive layer or barrier layer, which is used in the electrodes of liquid crystal displays (LCDs), organic light-emitting diodes (OLEDs) and photovoltaic cells. Its low resistivity and high uniformity (grain size 5-20 μm) ensure that the film is electrically stable and can be deposited at a rate of 10-50 nm/min.

The low coefficient of thermal expansion of Molybdenum sheets is similar to that of silicon

(2.6×10⁻⁶/°C).) and ceramic substrates are thermally matched to reduce thermal stress and improve device life. As a heat dissipation substrate (0.1-2 mm thick), molybdenum sheets are used in power semiconductors (e.g. IGBT modules) for thermal management, with high thermal conductivity for efficient heat dissipation and operating temperatures up to 150-200°C. In production, molybdenum sheets are cold-rolled and vacuum annealed (1100-1300°C) to optimize surface quality (Ra ≤0.4 microns) and dimensional accuracy (tolerance ± 0.005 mm). Advantages include high purity reduced grain boundary resistance and low gas release rate (<10⁻⁸ mbar·). L/s) ensures the stability of the vacuum environment and is widely used in chip manufacturing and 5G communication equipment.

7.1.2 Application of molybdenum sheet in electrode materials

Molybdenum sheets are mainly used in high-temperature vacuum furnaces, X-ray tubes and electrochemical equipment in electrode materials, and perform well due to their high melting point and excellent electrical conductivity. High-purity Molybdenum sheets (thickness 0.1-2 mm, purity ≥ 99.95%) are used as heating electrodes or support electrodes in vacuum furnaces, withstanding high temperatures of 1500-2000°C, and tensile strength (approx. 500 MPa at 1200°C) ensures long-term stability. In X-ray tubes, molybdenum sheets are used as anode targets or support materials (0.5-3 mm thick), their high conductivity and resistance to electron bombardment support high-energy X-ray generation, and surface roughness (Ra ≤0.4 microns) ensures radiation uniformity. In the field of electrochemistry, Molybdenum sheets are used as electrodes for the electrolysis of chlorine or hydrogen gas due to their excellent corrosion resistance in non-oxidizing acids such as 10% hydrochloric acid with a corrosion rate of <0.01 mm/year). In production, molybdenum sheets are cold-rolled and polished to optimize surface quality, and hydrogen annealing (800-1100°C) reduces internal stresses. The advantages of molybdenum electrodes include low resistivity and high chemical stability, reduced electrode losses, and are suitable for use in industrial electrolyzers and medical imaging equipment.

7.1.3 Application of molybdenum sheet in lead frame

Molybdenum sheets are used as support and conductive parts for semiconductor packages in lead frames, and are widely used in integrated circuit (IC) and light-emitting diode (LED) packages. Molybdenum sheets (0.1-0.5 mm thickness, purity ≥ 99.95%) due to their matching coefficient of thermal expansion (4.8×10⁻⁶/°C) to silicon and ceramics), which can effectively reduce the thermal stress in the packaging process and improve the reliability of the device. Its high conductivity ensures a low-resistance connection of the lead frame with a current transmission loss of <1%. The mechanical strength (tensile strength 800-1000 MPa) and ductility (elongation at break 5-10%) of molybdenum sheets support the stamping of complex shapes, and the surface polishing (Ra ≤ 0.4 microns) improves welding performance. In production, molybdenum sheets are prepared by cold rolling and precision cutting processes with dimensional tolerances of ±0.005 mm, vacuum annealing (800-1100°C) to optimize the grain structure (5-20 microns). The advantages of molybdenum chip lead frames include high thermal conductivity (138 W/m·K), support for efficient heat dissipation, high temperature resistance, and adaptability to reflow soldering (250-300°C), which are widely used in power devices, microprocessors, and LED chip packaging.

7.2 Application of Molybdenum sheets in sapphire crystal growth furnace

Molybdenum sheets are widely used in sapphire crystal growth furnaces because of their high melting point (2620°C), excellent thermal stability (strength of about 500 MPa at 1500°C), low coefficient of thermal expansion (about 4.8×10^{-6}/°C) and good thermal conductivity (about 138 W/m·K), mainly used in the manufacture of reflective screens, covers and other key components. Sapphire crystal (Al_2O_3) growth furnaces (e.g. Chaister's or heat exchange) are required to operate at high temperatures (2050-2100°C) and in a vacuum or inert atmosphere, making Molybdenum sheets ideal for their high-temperature properties and creep resistance (creep rate of 10^{-6}/s). Through high purity (≥99.95%) and precision machining process, CTIA GROUP LTD molybdenum sheet meets the high requirements of high temperature resistance, corrosion resistance and thermal management of sapphire growth furnace. The following is a detailed discussion of the specific applications, performance requirements and technical advantages of molybdenum sheets in reflective screens and covers.

7.2.1 Reflective screen in the sapphire crystal growth furnace for the production of Molybdenum sheets

Molybdenum sheets are used as reflective screens in sapphire crystal growth furnaces, mainly for thermal field management, and optimize the temperature distribution in the furnace by reflecting radiant heat to ensure uniform crystal growth. Reflective screens are usually made of high-purity molybdenum sheets (purity≥99.95%, thickness 0.1-2 mm), prepared by cold rolling and vacuum annealing (1100-1300°C), and the grain size is controlled at 5-20 microns to balance strength and toughness. The surface of the reflective screen needs to be polished to Ra≤0.4 microns to improve the reflectivity of thermal radiation (about 0.8-0.9) and reduce heat loss. The low coefficient of thermal expansion of the molybdenum sheet is well matched to the sapphire crucible (about 5×10^{-6}/°C), which reduces the thermal stress at high temperatures (<50 MPa). The tensile strength of the molybdenum sheet (approx. 400-500 MPa) ensures structural stability and oxidation resistance in a vacuum or argon atmosphere (oxygen content < 10 ppm) without generating volatile MoO_3 in a vacuum or argon atmosphere。 In production, the reflective screen is formed by precision stamping or laser cutting, and the dimensional tolerance is ± 0.01 mm to ensure the uniformity of the thermal field. Its advantages include high thermal conductivity, effective heat conduction, excellent high temperature resistance, and extended service life (> 1000 hours), which is widely used in the production of sapphire crystals for LED substrates and optical windows.

7.2.2 Molybdenum sheets for the production of sapphire crystal growth furnace covers

Molybdenum sheets are used as cover plates in sapphire crystal growth furnaces to seal crucibles or protect the thermal field inside the furnace from heat leakage and contamination by impurities. Cover plates are usually made of high-purity molybdenum sheets (purity≥99.95%, thickness 0.5-3 mm), prepared by hot rolling or cold rolling process, with tensile strength of 800-1000 MPa, ductility (elongation at break 5-10%) to support complex shape processing. The surface of the lid should be pickled or polished (Ra ≤0.4 μm) to reduce gas adsorption and ensure a vacuum in the furnace (10^{-5} Pa).

At high temperatures of 2050-2100°C, the thermal stability (mass loss rate < 0.1% in argon) and creep resistance (creep rate 10^{-6}/s) of the molybdenum sheet ensure that the cover does not deform for a long time. In production, the cover plate is CNC machined or stamped and formed, with a dimensional accuracy of ± 0.02 mm, and the edges need to be deburred to avoid stress concentration.

The advantages of the molybdenum sheet cover plate include high thermal conductivity (138 W/m·K), thermal field stability, and low gas release rate (<10^{-8} mbar·). L/s) to maintain a clean environment in the furnace, suitable for Chai method or heat exchange method growth furnace. It improves crystal purity (impurities < 10 ppm) and growth efficiency in sapphire crystal production, and is widely used in sapphire manufacturing for smartphone screens and laser substrates.

7.3 Application of Molybdenum sheets in vacuum furnaces

Molybdenum sheets are widely used in vacuum furnaces because of their high melting point (2620°C), excellent high-temperature strength (about 500 MPa at 1500°C), low coefficient of thermal expansion (about 4.8×10^{-6}/°C) and good thermal conductivity (about 138 W/m·K), mainly used in the manufacture of reflective screens, heating heats and connectors. Vacuum furnaces (e.g., high-temperature sintering furnaces, heat treatment furnaces) need to be operated in a vacuum or inert atmosphere (10^{-5} Pa, oxygen content <10 ppm), usually at 1000-2000°C, and the creep resistance of Molybdenum sheets (creep rate 10^{-6}/s) and low gas release rate (<10^{-8} mbar·). L/s) makes it an ideal material.

Through high purity (≥99.95%) and precision machining process, CTIA GROUP LTD molybdenum sheet meets the high requirements of vacuum furnace for high temperature resistance, corrosion resistance and thermal management. The following is a detailed discussion of the specific applications, performance requirements and technical advantages of Molybdenum sheets in the reflective screen, heat heating and connectors in the vacuum furnace.

7.3.1 Reflective screens in vacuum furnaces for the production of Molybdenum sheets

Molybdenum sheets are used as reflective screens in vacuum furnaces, mainly for thermal field management, to optimize the temperature distribution in the furnace by reflecting radiant heat, and to ensure the uniformity of material sintering or heat treatment. The reflective screen is made of high-purity molybdenum sheet (purity≥99.95%, thickness 0.1-2 mm), prepared by cold rolling and vacuum annealing (1100-1300°C), and the grain size is controlled at 5-20 microns to balance strength and toughness. The surface is polished to Ra ≤0.4 microns, which improves the reflectivity of thermal radiation (about 0.8-0.9) and reduces heat loss. The low coefficient of thermal expansion of the molybdenum sheet is matched to the ceramic or metal parts in the furnace, reducing the thermal stress at high temperatures (<50 MPa). In a vacuum environment of 1500-2000°C, the tensile strength of the molybdenum sheet (about 400-500 MPa) ensures structural stability and oxidation resistance prevents the formation of volatile MoO_3. In production, the reflective screen is laser cut or stamped and formed, and the dimensional tolerance is ± 0.01 mm to ensure the uniformity of the thermal field. Its advantages include high thermal conductivity, effective heat conduction, excellent high temperature resistance, and long service life (> 1000 hours), which are widely used in ceramic sintering furnaces and semiconductor material heat treatment furnaces.

7.3.2 Heat in the vacuum furnace for the production of Molybdenum sheets

Molybdenum sheets are used as heating heats in vacuum furnaces to directly generate resistive heat as heating elements to support high-temperature sintering or heat treatment processes. The hair center is prepared by cold rolling process with high-purity molybdenum sheet (purity ≥ 99.95% and thickness 0.1-1 mm), with a tensile strength of 800-1000 MPa and a resistivity of about 5.2×10^{-8} Ω·m to ensure efficient electric-heat conversion. The surface should be polished (Ra ≤0.4 μm) or pickled to reduce gas adsorption and maintain vacuum (10^{-5} Pa). At 1500-1800°C, the thermal stability (mass loss rate < 0.1%) and creep resistance (creep rate 10^{-6}) of molybdenum sheets/s) to ensure that the heat is not deformed for a long time. In production, the hair heat is formed by precision stamping or wire cutting, with a width of 5-50 mm, a length customized according to the furnace type, and a dimensional tolerance of ± 0.02 mm. The advantages of the heat generation include high conductivity, support for rapid temperature rise (rate 10-20°C/min), high temperature resistance, adaptability to vacuum or argon atmosphere, and suitable for metal alloy sintering and single crystal material growth furnaces. Its efficient heat conversion increases the energy utilization rate in the furnace (>90%).

7.3.3 Connectors in vacuum furnaces for the production of Molybdenum sheets

Molybdenum sheets are used as connectors in vacuum furnaces to fix or connect reflective screens, heat heats or other components to ensure the stability of the thermal field structure. The connectors are made of high-purity molybdenum sheets (purity≥99.95%, thickness 0.5-3 mm), prepared by hot rolling or cold rolling, with tensile strength of 800-1000 MPa, ductility (elongation at break 5-10%) to support stamping or bending. Surface pickling or polishing (Ra ≤ 0.4 microns) reduces the gas release rate and maintains a clean environment in the furnace. At high temperatures of 1500-2000°C, the creep resistance and low coefficient of thermal expansion of molybdenum sheets ensure that the connectors do not deform or loosen. In production, the connectors are prepared by CNC machining or laser cutting to a tolerance of ± 0.01 mm, and the edges are deburred to avoid stress concentration. Its advantages include high strength support for complex structures, high thermal conductivity (138 W/m·K) and auxiliary thermal field uniformity, suitable for support frames and fixings for high-temperature vacuum furnaces. Connections improve structural reliability and service life in ceramic, metal, and composite heat treatment furnaces.

7.4 Application of molybdenum sheet in plasma coating

Molybdenum sheets are used in plasma coatings due to their high conductivity (resistivity approx. 5.2×10^{-8} Ω·· m), excellent thermal stability (melting point 2620 °C), low coefficient of thermal expansion (about 4.8×10^{-6}/°C) and high purity (≥99.95%), especially as a sputtering target in the magnetron sputtering process. Plasma coating is a technology that bombards the surface of a target with plasma in a vacuum environment to deposit thin films, and is widely used in semiconductor, display, and solar cell manufacturing. Through precision processing and strict quality control, CTIA GROUP LTD Molybdenum Sheet meets the stringent requirements of plasma coating for high purity, surface quality and dimensional accuracy. The following discusses in detail the specific applications, performance requirements and technical advantages of molybdenum sheet as a sputtering target.

7.4.1 Molybdenum sheet as a sputtering target for plasma coating

Molybdenum sheets are used as sputtering targets in plasma coatings, and molybdenum films are deposited by magnetron sputtering to form conductive layers, barrier layers or electrodes, which are widely used in thin-film transistors (TFTs), organic light-emitting diodes (OLEDs), solar cells and integrated circuit manufacturing. The sputtering target is made of high-purity Molybdenum sheets (purity ≥ 99.95%, thickness 0.05-1 mm), prepared by cold rolling and vacuum annealing (1100-1300°C), and the grain size is controlled at 5-20 microns to ensure the uniformity of the deposited film. Surface polishing to Ra ≤0.4 microns, reducing particle jetting during sputtering and improving film quality (defect density < 10/cm²). The low resistivity and high thermal conductivity (138 W/m·K) of Molybdenum sheets support high-efficiency plasma bombardment with deposition rates of 10-50 nm/min, and its low coefficient of thermal expansion matches that of silicon substrates (2.6×10^{-6}/°C) to reduce thermal stress (<50 MPa). In production, the molybdenum sheet targets are formed by laser cutting or CNC machining with dimensional tolerances of ± 0.005 mm, and impurities (iron, copper< 20 ppm) and gas release rates ($<10^{-8}$ mbar·) are strictly controlled L/s) to maintain a vacuum environment (10^{-6} Pa). Its advantages include high purity, stable electrical properties of thin films, excellent corrosion resistance (under argon atmosphere), extended target life (> 1000 hours), and is widely used in electrode deposition of LCDs, OLED displays and photovoltaic cells.

7.5 Application of molybdenum sheet in metallurgical industry

Molybdenum sheet is widely used in the metallurgical industry because of its high melting point (2620°C), excellent high-temperature strength (about 500 MPa at 1500°C) and corrosion resistance (corrosion rate <0.01 mm/year in non-oxidizing environments), mainly as steelmaking additives and high-temperature furnace components. Molybdenum can significantly improve the strength, toughness and corrosion resistance of steel, and is suitable for the production of high-performance alloy steels. Through powder metallurgy and rolling process, CTIA GROUP LTD Molybdenum Sheet provides high-quality additive materials to meet the needs of the metallurgical industry for a balance between performance and cost. The following discusses in detail the application, performance requirements and technical advantages of Molybdenum sheets as steelmaking additives.

7.5.1 Application of Molybdenum sheets as additives in steelmaking

Molybdenum sheets are used as additives in steelmaking to produce high-strength low-alloy steels (HSLA), stainless steels, and tool steels to improve the tensile strength (which can be increased by 20-30%), wear resistance, and corrosion resistance. Molybdenum sheets (0.5-3 mm thick, 99-99.9% pure) are prepared by hot or cold rolling and are typically 10-50 mm wide and 100-500 mm long in size, which are convenient for melting and adding in steelmaking furnaces such as electric arc furnaces or converters. The addition of Molybdenum sheets is generally 0.1-1% of the weight of the steel, and its mechanical properties (e.g., tensile strength of 1000-1500 MPa) are significantly improved by increasing the grain fineness and phase transformation strengthening of the steel (e.g., the formation of martensitic). In high-temperature steelmaking environments (1500-1600°C), the low impurity content of Molybdenum sheets (iron, copper<100 ppm) ensures that no harmful elements are introduced, and surface pickling (Ra 0.8-1.6 microns) reduces gas inclusions. In production, molybdenum sheets are sheared or crushed into small pieces with a dimensional tolerance of ± 0.05 mm to facilitate uniform melting. Its advantages include high melting point and chemical stability for a stable addition process, high thermal conductivity (138 W/m·K) for rapid melting, and is widely used in the production of high-strength steels in the automotive, marine and construction industries, such as pressure vessel steels and corrosion-resistant alloy steels.

7.6 Application of molybdenum sheet in high-temperature furnace structure

Molybdenum sheet is widely used in high-temperature furnace structural parts because of its high melting point (2620°C), excellent high-temperature strength (about 500 MPa at 1500°C), low thermal expansion coefficient (about 4.8×10^{-6}/°C) and good thermal conductivity (about 138 W/m·K), mainly used for heat shields and heating elements. High-purity Molybdenum sheets (≥99.95%) or TZM alloy Molybdenum sheets are known for their creep resistance (creep rate 10^{-6}/s) and low gas release rate (<10^{-8} mbar·). L/s) in high-temperature furnaces (e.g. sintering furnaces, heat treatment furnaces) in vacuum or inert atmospheres (argon, oxygen content < 10 ppm). Through precision machining and strict quality control, CTIA GROUP LTD Molybdenum sheets meet the high requirements of high-temperature furnaces for high temperature resistance, corrosion resistance and thermal management. The following is a detailed discussion of the specific applications, performance requirements and technical advantages of molybdenum sheets in heat shields and heating elements.

7.6.1 Application of molybdenum sheet in heat shield

Molybdenum sheets are used as heat shields in high-temperature furnaces to optimize the distribution of the thermal field in the furnace by reflecting and shielding radiant heat, reducing energy losses and improving temperature uniformity. The heat shield is made of high-purity molybdenum sheet (purity≥99.95%, thickness 0.1-2 mm), prepared by cold rolling and vacuum annealing (1100-1300°C), and the grain size is controlled at 5-20 microns to balance strength and toughness. The surface is polished to Ra ≤0.4 microns, which improves the reflectivity of thermal radiation (about 0.8-0.9) and effectively reduces heat loss. The low coefficient of thermal expansion of the molybdenum sheet is matched to the ceramic or tungsten parts in the furnace, reducing the thermal stress at high temperatures (<50 MPa). The tensile strength (approx. 400-500 MPa) and oxidation resistance of molybdenum sheets ensure long-term stability and prevent the formation of volatile MoO_3 in a vacuum or argon environment at 1500-2000°C. In production, the heat shield is laser cut or stamped into shape with a dimensional tolerance of ± 0.01 mm, and stacked in multiple layers (3-5 layers) to enhance the thermal insulation effect. Its advantages include high thermal conductivity, support for stable thermal field, excellent high temperature resistance, and long service life (> 1000 hours), which are widely used in ceramic sintering furnaces, single crystal growth furnaces and high-temperature heat treatment furnaces.

7.6.2 Application of molybdenum sheet in heating element

Molybdenum sheets are used as heating elements in high-temperature furnaces, providing a stable high-temperature environment through resistance heating to support sintering, annealing, and heat treatment processes. The heating element is made of high-purity molybdenum sheet (purity ≥ 99.95%, thickness 0.1-1 mm), prepared by cold rolling, with a tensile strength of 800-1000 MPa and a resistivity of about 5.2×10^{-8} Ω·m to ensure efficient electric-heat conversion. Surface polishing or pickling (Ra ≤ 0.4 microns) reduces gas adsorption and maintains vacuum (10^{-5} Pa). At 1500-1800°C, the thermal stability (mass loss rate < 0.1%) and creep resistance (creep rate 10^{-6}) of Molybdenum sheets/s) to ensure that it does not deform. In production, the heating elements are formed by precision stamping or wire cutting, with a width of 5-50 mm, a length customized according to the furnace type, and a dimensional tolerance of ± 0.02 mm. Its advantages include high electrical conductivity, fast temperature rise (10-20°C/min), high temperature resistance, and resistance to vacuum or inert atmospheres, making it suitable for metal alloy sintering furnaces and semiconductor material heat treatment furnaces. The energy utilization rate of the molybdenum sheet heating element is high (>90%), which significantly improves the heating efficiency in the furnace.

7.7 Application of molybdenum sheet in anti-corrosion of chemical equipment

Molybdenum sheets are widely used in chemical equipment due to their excellent corrosion resistance (corrosion rate <0.01 mm/year in 10% hydrochloric acid), high strength (tensile strength 800-1000 MPa) and chemical stability, mainly used in reactor lining and pipeline components. Ordinary purity Molybdenum sheets (99-99.9%) are widely used in non-oxidizing acids (e.g., hydrochloric acid, sulfuric acid) and alkaline environments due to their cost-effectiveness, but oxidizing acids (e.g., concentrated nitric acid) should be avoided to prevent MoO_3 formation. CTIA GROUP LTD molybdenum sheet meets the requirements of chemical equipment for corrosion resistance and mechanical properties through hot rolling or cold rolling process. The following is a detailed discussion of the application, performance requirements and technical advantages of Molybdenum sheets in reactor linings and piping components.

7.7.1 Application of molybdenum sheet in reactor lining

Molybdenum sheet is used as a lining material in chemical reactors to protect the kettle body from corrosive media and prolong the life of the equipment. The inner lining is made of ordinary purity molybdenum sheets (purity 99-99.9%, thickness 0.5-3 mm), prepared by hot rolling or cold rolling, surface pickling (Ra 0.8-1.6 microns) to ensure cleanliness and corrosion resistance. In hydrochloric acid (10-20%, 20-60°C) or sulfuric acid environment, the corrosion rate of molybdenum sheet < 0.01 mm/year, and its tensile strength (700-900 MPa) supports the structural requirements of autoclaves (pressure 1-10 MPa). In production, molybdenum liners are stamped or welded to dimensional tolerances of ±.05 mm and need to be seamlessly connected to avoid media leakage. Its advantages include excellent resistance to non-oxidizing acids, high thermal conductivity (138 W/m·K) to assist in reactor thermal management, and are widely used in chloride production and organic acid synthesis reactors. The molybdenum sheet lining significantly improves equipment durability (life>5 years) and safety.

电话/TEL：0086 592 512 9696
CTIAQCD-MA-E/P 2018-2024V
sales@chinatungsten.com

7.7.2 Application of molybdenum sheet in pipeline components

Molybdenum sheets are used as linings or supports in chemical pipeline components to protect pipelines from corrosive liquids or gases, and are suitable for piping systems that transport acidic or alkaline media. The pipe parts are made of ordinary purity molybdenum sheets (purity 99-99.9%, thickness 0.2-2 mm), prepared by cold rolling, ductility (elongation at break 5-10%) to support bending forming, surface pickling (Ra 0.8-1.6 microns) to ensure corrosion resistance. In non-oxidizing media (e.g., 20% hydrochloric acid, corrosion rate <0.01 mm/year), molybdenum sheet is chemically more stable than stainless steel. In production, molybdenum sheets are stamped or rolled into tubular linings with dimensional tolerances of ± 0.02 mm, and welded joints are polished to avoid corrosion spots. Its advantages include high strength (700-900 MPa) to support the pipe structure, low coefficient of thermal expansion to reduce thermal distortion, and is suitable for use in piping systems in fertilizer production and petrochemical industries. Molybdenum sheet piping components improve system corrosion resistance and operational stability, and extend maintenance intervals (> 3 years).

7.8 Application of molybdenum sheet in satellite components

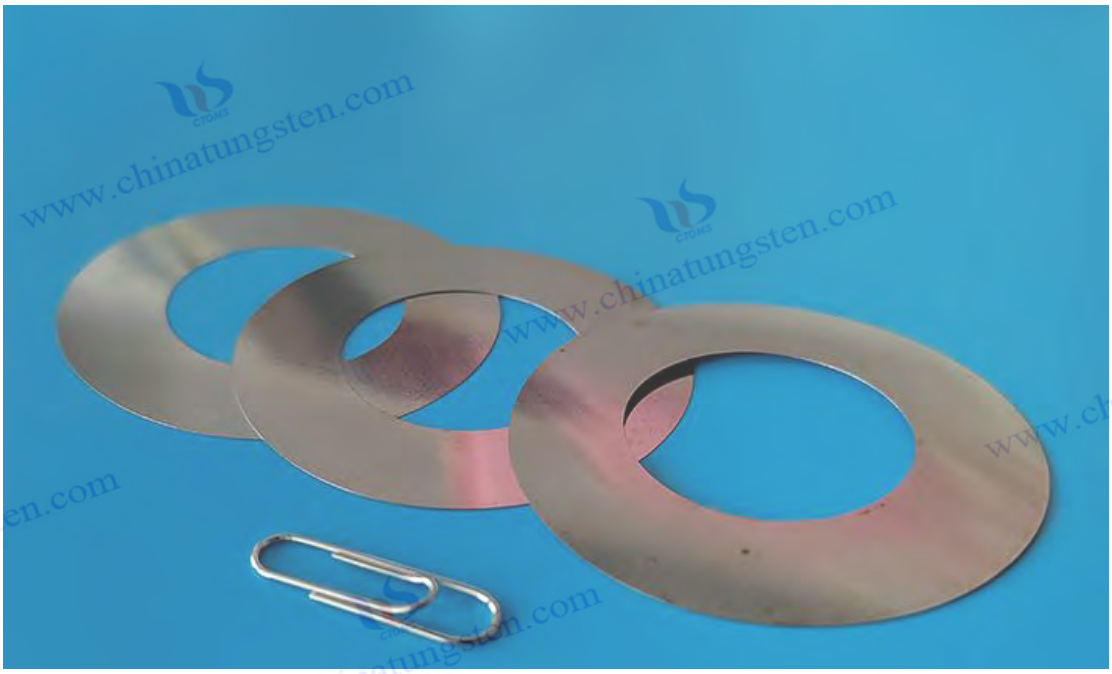
Molybdenum sheets are widely used in satellite components because of their high strength (tensile strength 800-1200 MPa), low coefficient of thermal expansion (about 4.8×10^{-6}/°C), excellent thermal conductivity (about 138 W/m·K) and high temperature resistance (melting point 2620°C), especially in antenna components and thermal control system radiators. Satellites operate in extreme space environments (-150°C to 150°C, vacuum 10^{-7} Pa), requiring materials with high reliability and low gas release rates (<10^{-8} mbar·). L/s) and radiation resistance. High-purity Molybdenum sheets (≥99.95%) or TZM alloy Molybdenum sheets are cold-rolled and vacuum annealed (1100-1300°C) to meet the needs of satellites for lightweighting, thermal management and mechanical properties. With its high precision and consistency, CTIA GROUP LTD molybdenum sheets are widely used as key components of communication satellites, remote sensing satellites and deep space probes. The following details the specific applications, performance requirements and technical advantages of molybdenum chips in antenna components and radiators for thermal control systems.

7.8.1 Application of molybdenum sheet in antenna components

Molybdenum sheets are mainly used as support structures or conductive layers in antenna components to support the structural stability and signal transmission efficiency of satellite communication antennas (such as parabolic antennas or phased array antennas). Molybdenum sheets (thickness 0.1-1 mm, purity ≥ 99.95%) are prepared by cold rolling and surface polished to Ra≤0.4 microns, ensuring high electrical conductivity (resistivity approx. 5.2×10^{-8} Ω·). m) and low signal loss (<0.1 dB). Its low coefficient of thermal expansion is matched to antenna substrates such as carbon fiber composites, approx. 2-5×10^{-6}/°C) to reduce deformation (strain < 0.01%) caused by thermal cycling. In a space vacuum environment, the low gas release rate and tensile strength (800-1000 MPa) of molybdenum sheets ensure long-term stability and resistance to radiation and micrometeorite impacts. In production, molybdenum sheets are formed by laser cutting or CNC stamping, with dimensional tolerances ± 0.005 mm, and the edges are deburred to avoid stress concentration. Its advantages include high conductivity to support efficient signal transmission, excellent fatigue resistance (fatigue limit of about 400 MPa, 10^7 cycles) to adapt to the vibration environment, and is widely used in the waveguide and support frame of satellite communication antennas to improve the accuracy and reliability of signal transmission.

7.8.2 Application of molybdenum sheet in radiator of thermal control system

Molybdenum sheets are used as heat sinks or thermal radiation surfaces in satellite thermal control system radiators to maintain the operating temperature (-50°C to 100°C) of satellite electronic equipment through efficient heat conduction and radiative heat dissipation. Molybdenum sheets (thickness 0.05-0.5 mm, purity ≥ 99.95%) are prepared by cold rolling and polishing process, with a surface roughness of Ra ≤ 0.4 microns and an increase in thermal emissivity (about 0.8-0.9). Its high thermal conductivity (138 W/m·K) efficiently transfers the heat generated by the electronics, and the low coefficient of thermal expansion reduces thermal stress and ensures thermal compatibility with aluminum or ceramic substrates. The tensile strength (900-1200 MPa) and creep resistance (creep rate 10^{-6}/s) of molybdenum sheet maintain structural stability under space temperature difference cycles, and the radiation resistance avoids material degradation. In production, molybdenum sheets are formed by precision stamping or bending to a dimensional tolerance of ±0.005 mm, and can be coated with a high-emissivity coating (e.g. alumina) to enhance heat dissipation efficiency. Its advantages include light weight (density of 10.22 g/cm³, better than tungsten 19.25 g/cm³), high thermal conductivity to support rapid heat dissipation, widely used in thermal control systems for communication satellites and scientific probes, and ensure the stable operation of equipment in extreme space environments.



CTIA GROUP LTD molybdenum sheet

Chapter 8 Safety and Environmental Protection Problems in Molybdenum Sheets Production

Molybdenum sheet production involves a number of complex processes, from molybdenum ore mining to beneficiation, refining, powder metallurgy and rolling, each of which can present safety and environmental challenges. Safety issues include blasting risks, dust explosions, and high-temperature operation hazards, while environmental issues involve exhaust gases, wastewater, solid waste, and energy consumption. CTIA GROUP LTD Molybdenum sheets can effectively reduce risks and environmental impact by adopting advanced safety management and environmental protection technologies, such as high-efficiency dust removal system (dust concentration < 10 mg/m³), wastewater recycling (>80%) and exhaust gas treatment device (SO_2 removal rate >95%).

8.1 Safety issues in the production of molybdenum sheets

Safety issues in molybdenum sheet production are primarily due to high-risk operations in mining, beneficiation, and processing, which can lead to injury, equipment damage, or production interruptions. The following analyzes the main safety issues and countermeasures from the three stages of mining, beneficiation and molding.

1. **Safety issues during the mining phase**
   - **Risk of blasting operations**: The use of ammonium nitrate or emulsion explosives in open-pit and underground mining carries the risk of uncontrolled explosions or flying rocks. Improper blasting can lead to collapse of the ore body, especially in underground mining (3-5 m wide and 3-4 m high).
   - **Dust hazards**: Molybdenite (MoS_2) crushing and transport produces large amounts of

dust (particle size < 10 microns), which can cause respiratory diseases or dust explosions (minimum explosion concentration of about 30-50 g/m³).

- **Countermeasures**: Adopt precision blasting technology (such as electronic detonator, control error <0.1 seconds) to reduce the risk of flying rocks and landslides; Equipped with a high-efficiency spray dust suppression system (dust concentration < 10 mg/m³) and a bag filter; Mandatory wearing of protective equipment (dust masks, goggles) and implementation of a ventilation system (underground mining air volume ≥ 3 m³/s·person).

2. **Safety issues in the beneficiation phase**
   - **Chemical risks**: Xanthate (butyl xanthate, 0.1-0.3 kg/t) and foaming agents (e.g., terpineol) used in the flotation process are toxic and volatile, and may cause poisoning or skin damage if inhaled or contacted.
   - **Mechanical damage**: Crushers (75-500 kW) and ball mills (20-30 rpm) are operating at risk of pinching or impact, especially during maintenance and cleaning.
   - **Countermeasures**: The flotation agent is stored in a closed container equipped with a ventilation and exhaust gas treatment system (activated carbon adsorption); Operators wear chemical protective clothing and respirators; The equipment is equipped with safety shields and emergency stop devices, and regular training is provided to ensure standardized operation.
3. **Safety issues in the molding process**
   - **High Temperature Operation Risk**: Powder metallurgy sintering (1800-2000°C) and hot rolling (1000-1400°C) involve high-temperature equipment, and there are scalding or fire hazards. Leaks in vacuum or hydrogen sintering furnaces (hydrogen purity ≥ 99.99%) can cause an explosion.
   - **Risk of dust explosion**: Molybdenum powder (particle size 1-10 microns) is prone to form high-concentration dust clouds during the pressing process, which may cause explosion in case of sparks.
   - **Countermeasures**: The sintering and rolling equipment is equipped with an automatic temperature control system (accuracy ± 10°C) and gas leak detection (hydrogen concentration <4%); The powder pressing plant uses an explosion-proof dust collector (dust concentration < 5 mg/m³) and inert gas protection; Operators are trained in hot work and equipped with insulated protective clothing.

8.2 Environmental problems in the production of molybdenum sheets

The environmental problems in the production process of Molybdenum sheets mainly involve waste gas, waste water, solid waste and energy consumption, which may cause pollution to air, water and soil. The following analyzes the main environmental problems and countermeasures from the three stages of mining, beneficiation and processing.

1. **Environmental issues at the mining stage**
   - **Waste rock and tailings pollution**: Open-pit mining stripping ratios (3:1 to 10:1)

produce large amounts of waste rock and tailings, which can lead to soil erosion and leakage of heavy metals (copper and iron).

- **Dust and exhaust emissions**: Blasting and transportation produce dust (PM10 concentration > 100 mg/m³) and mechanical exhaust gases (NO_x, CO), polluting the atmosphere.
- **Countermeasures**: Waste rock and tailings are stacked separately, and tailings backfill technology (backfill rate >50%) is used to reduce land occupation; Equipped with spray dust suppression and bag dust removal system (dust removal rate >95%); Use low-sulfur fuel and exhaust gas purification unit (NO_x removal rate >80%).

2. **Environmental issues in the beneficiation phase**
   - **Wastewater pollution**: The flotation process produces wastewater containing xanthate and heavy metals (lead, copper), pH 8-10, which may pollute the water body (COD>100 mg/L) if discharged directly.
   - **Tailings treatment**: beneficiation tailings (molybdenum content <0.05%) contain sulfide, which may oxidize to form acidic leachate (pH<4) and pollute soil and groundwater after long-term stacking.
   - **Countermeasures**: Wastewater is treated by flocculation and neutralization (pH adjustment to 6-8), and the recycling rate is > 80%; The tailings are stored dry or wet by dry stacking or wet stacking, and are covered with impermeable membranes to prevent leakage; The recovery of beneficiation agents (xanthate recovery rate >90%) reduces emissions.
3. **Environmental issues in the refining and processing phases**
   - **Exhaust emissions**: Oxidative roasting (550-650°C) produces SO_2 (concentration>1000 mg/m³) and volatile MoO_3, polluting the atmosphere. Hydrogen reduction (900-1100°C) may emit ammonia (decomposition from ammonium molybdate).
   - **Energy consumption**: Powder metallurgy and rolling processes have high energy consumption (e.g. 100-500 kW sintering furnace power) and high carbon emissions (about 5-10 tons CO_2 per ton of Molybdenum sheets).
   - **Countermeasures**: Equipped with a wet desulfurization device (SO_2 removal rate >95%) and an activated carbon adsorption system to treat ammonia; Optimization of the sintering and rolling process (e.g. lowering the sintering temperature to 1700°C) and increasing energy efficiency (20% reduction in energy consumption); Powered by renewable energy sources (e.g. photovoltaics) to reduce your carbon footprint.

Through the implementation of strict safety management (e.g., automated monitoring and protective equipment) and environmental technologies (e.g., waste gas and wastewater treatment and resource recycling), molybdenum sheet production can effectively reduce safety risks and environmental impacts, ensuring that the production process complies with international safety standards (e.g., ISO 45001) and environmental regulations (e.g., China's Environmental Protection Law).

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Molybdenum Sheet Introduction

1. Overview of Molybdenum Sheet

Molybdenum sheet is a thin metal sheet made from high-purity molybdenum through rolling processes. It features excellent high-temperature resistance, thermal conductivity, and mechanical strength. It is widely used in electronics, metallurgy, vacuum equipment, aerospace, and lighting industries as heating elements, thermal shields, or structural components. With a smooth surface and precise dimensions, molybdenum sheets can be customized in various specifications to meet the requirements of advanced manufacturing and scientific research equipment.

2. Features of Molybdenum Sheet

High Purity Material: Purity ≥ 99.95%, with extremely low impurity levels

High-Temperature Resistance: Melting point up to 2610°C, stable performance in extreme conditions

Excellent Workability: High flatness, smooth surface, easy to punch, shear, and weld

Customizable Specifications: Various sizes and thicknesses available to suit different processes

3. Specifications of Molybdenum Sheet

Parameter	Specification
Purity	≥ 99.95%
Thickness	0.01 mm - 3.00 mm
Width	50 mm - 600 mm
Length	Custom lengths or supplied in coil
Surface Finish	Polished, Alkali-cleaned, Sandblasted
Thickness Tolerance	±0.005 mm - ±0.2 mm
Surface Roughness	Ra 0.8 μm – Ra 3.2 μm

4. Production Process

Molybdenum Ingot (Raw Material) → Inspection → Hot Rolling → Leveling & Annealing → Alkali Cleaning → Inspection → Warm Rolling → Vacuum Annealing → Inspection → Cold Rolling → Leveling → Shearing → Vacuum Annealing → Inspection → Packaging

5. Purchasing Information

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

Website: molybdenum.com.cn

CTIA GROUP LTD molybdenum sheet

Chapter 9 Domestic and foreign standards for molybdenum sheets

As a high-performance material, molybdenum sheet is widely used in electronics, aerospace, high-temperature furnace and chemical industry, and its quality and performance requirements are subject to strict domestic and foreign standards. The standard specifies key parameters such as chemical composition, mechanical properties, dimensional tolerances, and surface quality of molybdenum sheets to ensure product consistency and reliability. CTIA GROUP LTD molybdenum sheet strictly follows the Chinese national standard (GB) and international standards (such as ASTM, ISO) to meet the global market demand. This chapter discusses in detail the Chinese national standards, international standards, and relevant standards of Europe, America, Japan, South Korea and other countries for molybdenum sheets, and analyzes their requirements and application scenarios.

9.1 Chinese National Standard for Molybdenum Sheets

The Chinese National Standard (GB) has clear provisions on the chemical composition, mechanical properties, size and processing requirements of molybdenum sheets, which are mainly issued by the Standardization Administration of the People's Republic of China and are applicable to the production and application of molybdenum sheets in China. The following are the main relevant criteria:

1. **GB/T 3462-2017**
   - **Scope of application**: Covers molybdenum sheet (thickness 0.01-3 mm), molybdenum plate and molybdenum bar, suitable for electronics, aerospace and high-temperature furnace components.
   - **Chemical composition**: high-purity Molybdenum sheets (Mo1) require a

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molybdenum content of ≥99.95% and an impurity content (such as Fe, Ni, Cu) of < 50 ppm; The molybdenum content of ordinary pure Molybdenum sheets (Mo2) ≥ 99.9%.

- **Mechanical properties**: tensile strength ≥ 700 MPa (cold rolled), elongation at break ≥5%, Vickers hardness 220-250 HV.
- **Dimensional tolerances**: thickness tolerances (0.01-0.1 mm± 0.005 mm, 0.1-3 mm ±0.02 mm), surface roughness Ra ≤0.8 microns.
- **Detection method**: The chemical composition adopts ICP-MS, the mechanical properties are according to GB/T 228.1 (tensile test), and the surface quality is checked by microscope.
- **Application**: Suitable for semiconductor targets, vacuum furnace heat and chemical equipment lining.

2. **GB/T 3876-1983**
   - **Scope of application**: Focus on thin molybdenum sheet (thickness 0.01-0.1 mm) for electronic and optical fields.
   - **Chemical composition**: molybdenum content ≥ 99.95%, oxygen content < 50 ppm.
   - **Performance requirements**: tensile strength ≥ 800 MPa, elongation at break ≥3%, no cracks and oxide layers on the surface.
   - **Dimensional tolerances**: width tolerances ± 0.05 mm, length tolerances ± 1 mm, thickness tolerances ± 0.003 mm.
   - **Application**: For sputtering targets and lead frames.

The Chinese national standard emphasizes high purity and high precision, which is suitable for the needs of domestic electronics and high-temperature industries, and ensures that the performance of molybdenum sheets is in line with international standards.

9.2 International standards for molybdenum sheets

International standards are developed by the International Organization for Standardization (ISO) and the American Society for Testing and Materials (ASTM), among others, and are widely used in the production and trade of molybdenum sheets worldwide. The following are the main international standards:

1. **ASTM B386-03 (2011)**
   - **Scope of application**: Covers molybdenum sheet (thickness 0.01-3 mm), molybdenum plate and molybdenum bar, suitable for aerospace, electronics and high-temperature furnaces.
   - **Chemical composition**: molybdenum content≥ 99.95% (Type 360/361), TZM alloy (Type 364) contains titanium 0.4-0.55%, zirconium 0.06-0.12%. Impurities (e.g., Fe, Ni) < 100 ppm.
   - **Mechanical properties**: tensile strength≥ 620 MPa (annealed), ≥ 760 MPa (cold-worked), elongation at break≥ 2-10% (depending on thickness).
   - **Dimensional tolerances**: ±5% at thickness 0.01-0.1 mm, ± 0.025 mm at 0.1-3 mm,

surface roughness Ra≤0.4 microns (polished).

- **Testing method**: The chemical composition adopts ICP-OES, the mechanical properties are according to ASTM E8, and the surface quality is checked by visual and microscopic inspection.
- **Application**: Suitable for semiconductor targets, vacuum furnace heat shields and satellite components.

2. **ISO 5832-1:2016 Metallic implants – Part 1: Forged molybdenum**
   - **Scope of application**: for molybdenum sheets (such as X-ray tube anodes) in the medical field, the thickness is 0.1-2 mm.
   - **Chemical composition:** molybdenum content ≥99.9%, carbon content <"100 ppm, oxygen content <50 ppm.
   - **Performance requirements**: tensile strength ≥ 700 MPa, hardness 220-240 HV, no defects on the surface.
   - **Application**: Used in medical imaging equipment and high-precision electronic components.

The international standard focuses on the versatility and transnational application of molybdenum sheets, emphasizing high purity, low impurities and strict size control, which is suitable for the global high-end market.

9.3 Molybdenum sheet standards in Europe, America, Japan, South Korea and other countries around the world

Europe, America, Japan, South Korea and other countries have formulated molybdenum sheet standards according to their industrial needs and technical characteristics, which are highly consistent with international standards, but have detailed requirements in specific fields. The following are the main national standards:

1. **United States**
   - **Standards**: ASTM B386-03 (2011) is the primary standard, and MIL-M-16420 (military standard) is also available for aerospace applications.
   - **Features**: Emphasis on high purity (≥99.95%) and high temperature performance (e.g., tensile strength ≥ 400 MPa at 1500°C), requiring low gas release rate (<10^{-8} mbar·). L/s）。
   - **Applications**: Aerospace (satellite thermal control systems), semiconductor targets, and nuclear industry components.
   - **Detection**: The chemical composition adopts GDMS (Glow Discharge Mass Spectrometry), and the mechanical properties are according to ASTM E8/E399.
2. **Europe**
   - **Standard**: EN 10276-1 "Materials for cold working of molybdenum and molybdenum alloys" is consistent with ISO 5832-1.
   - **Features**: Molybdenum sheet is required to have high surface quality (Ra≤0.4 microns), strict dimensional tolerances (thickness ±0.003 mm), and suitable for

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vacuum environment.

- **Application**: Used in sapphire growth furnace heat shields and plasma coating targets.
- **Inspection**: The surface quality is tested by laser microscope, and the corrosion resistance is according to EN ISO 9227 (salt spray test).

3. **Japan**
   - **Standard**: JIS H 4641 "Molybdenum and Molybdenum Alloy Plates, Sheets, and Strips" is similar to ASTM B386.
   - **Features**: Focus on the high precision of ultra-thin molybdenum sheet (thickness 0.01-0.1 mm), tensile strength ≥ 800 MPa, elongation at break ≥5%, surface roughness Ra≤0.2 microns.
   - **Applications**: electronics industry (e.g. TFT-LCD targets) and optical devices.
   - **Inspection**: The dimensional accuracy is measured by non-contact laser, and the conductivity is according to JIS K 7194.
4. **Korea**
   - **Standard**: KS D 9502 "Molybdenum and Molybdenum Alloy Materials", with reference to ASTM and JIS standards.
   - **Characteristics**: Thermal conductivity (≥130 W/m·K) and corrosion resistance (corrosion rate < 0.01 mm/year in 10% hydrochloric acid) are required, suitable for chemical and electronic applications.
   - **Applications**: Semiconductor packaging lead frames and chemical equipment linings.
   - **Detection**: Thermal conductivity is laser flash method, chemical composition according to KS D 2042.

European, American, Japanese and Korean standards are consistent with international standards in terms of chemical composition and mechanical properties, but focus on different application scenarios according to regional industrial characteristics (for example, the United States emphasizes aerospace, and Japan focuses on the electronics industry).

Appendix: Glossary of multilingual Molybdenum sheets

The following is a comparison table of molybdenum related terms in Chinese, English, Japanese and Korean, covering common terms in production, performance and application fields, which is convenient for cross-border technical exchange and standardized application. CTIA GROUP LTD Molybdenum Sheet needs to be unified in the global market to ensure technical documentation and trade consistency.

Chinese	English	Japanese	Korean	interpretation
钼片	Molybdenum Foil	モリブデン箔	몰리브덴 포일	Refers to a thin molybdenum material made by powder metallurgy or rolling process, with high melting point, high strength and electrical and thermal conductivity, which is widely used in electronics, aerospace and high-temperature furnaces.
辉钼矿	Molybdenite	モリブデナイト	몰리브데나이트	The main ore form of molybdenum, containing 50-60% molybdenum, is the initial raw material for the production of molybdenum sheets, which are converted into molybdenum compounds or metals through beneficiation and refining.
地下开采	Underground Mining	地下採掘	지하 채굴	The method of mining molybdenum ore through tunneling and blasting in deep ore deposits, using equipment such as roadheaders and rock drills, is suitable for complex geological conditions.
浮选法	Flotation Method	浮選法	부유선광법	Using the hydrophobicity of molybdenite, molybdenum ore is separated from gangue by flotation machine and agents to obtain high-grade molybdenum concentrate。
氧化焙烧	Oxidative Roasting	酸化焙焼	산화 배소	Molybdenite (MoS_2) is oxidized to molybdenum oxide (MoO_3) in an air atmosphere of 550-650°C to remove sulfur and provide raw materials for subsequent refining.
氨浸法	Ammonia Leaching	アンモニア浸出法	암모니아 침출법	Molybdenum oxide is dissolved with ammonia to generate ammonium molybdate solution, and impurities such as iron and copper are separated to prepare high-purity molybdenum compounds.
粉末冶金	Powder Metallurgy	粉末冶金	분말 야금	The method of preparing molybdenum blanks or molybdenum sheets by pressing and sintering high-purity molybdenum powder is suitable for high-precision and complex-shaped components.
热轧工艺	Hot Rolling Process	熱間圧延プロセス	열간 압연 공정	The molybdenum billet is rolled in multiple passes at a high temperature of 1000-1400 °C to prepare

				molybdenum sheets with a thickness of 0.5-3 mm, which is suitable for high-temperature furnace components.
冷轧工艺	Cold Rolling Process	冷間圧延プロセス	냉간 압연 공정	Molybdenum sheets (thickness 0.01-1 mm) are rolled at room temperature for high precision and surface quality, suitable for semiconductor targets.
密度	Density	密度	밀도	The mass-to-volume ratio of molybdenum sheets, reflecting density and purity, is measured by the Archimedes method or X-ray densitometer.
熔点	Melting Point	融点	용융점	The temperature at which the molybdenum sheet begins to melt is tested by differential scanning calorimetry (DSC) to reflect the high-temperature performance.
导电性	Electrical Conductivity	電気伝導率	전기전도율	The ability of molybdenum sheet to transmit current, measured by the four-probe method, suitable for electrodes and targets.
导热性	Thermal Conductivity	熱伝導率	열전도율	The ability of molybdenum sheets to conduct heat is measured by the laser flash method and is suitable for heat dissipation substrates.
热膨胀系数	Thermal Expansion Coefficient	熱膨張係数	열팽창 계수	The dimensional expansion rate of the molybdenum sheet as a function of temperature is tested by a thermal dilatometer and reflects the thermal matching.
抗拉强度	Tensile Strength	引張強度	인장 강도	The resistance of molybdenum sheets to tensile fracture, measured by tensile test method, is suitable for structural parts.
硬度	Hardness	硬度	경도	Molybdenum sheet deformation resistance (220-250 HV), tested by Vickers hardness tester and reflecting wear resistance.
韧性	Toughness	靭性	인성	The ability of molybdenum sheet to absorb impact energy is measured by the Charnais impact test.
耐腐蚀性	Corrosion Resistance	耐食性	내식성	Corrosion resistance of molybdenum sheets in chemical media, evaluated by immersion test method.
抗氧化性	Oxidation Resistance	耐酸化性	내산화성	The stability of molybdenum sheet in a high-temperature oxidation environment is tested by thermogravimetric analysis.
溅射靶材	Sputtering Target	スパッタリングターゲット	스퍼터링 타겟	Molybdenum sheets are used in plasma coatings, where thin films are deposited by magnetron sputtering, and are used in semiconductor and display manufacturing.

反射屏	Reflective Shield	反射シールド	반사 쉴드	Molybdenum sheets reflect heat radiation in high-temperature furnaces or sapphire growth furnaces to optimize the thermal field distribution, requiring high reflectivity (0.8-0.9).
发热带	Heating Strip	発熱帯	발열 띠	As a heating element in a vacuum furnace, molybdenum sheets are heated by resistance to produce high temperatures (1500-1800°C), which require high conductivity.
引线框架	Lead Frame	リードフレーム	리드 프레임	Molybdenum sheets are used in conductive support components for semiconductor packages that require a low coefficient of thermal expansion and a high-quality surface.
反应釜内衬	Reactor Lining	反応釜ライニング	반응로 라이닝	As the inner wall material of the chemical reactor, molybdenum sheet resists the corrosion of non-oxidizing acids and prolongs the life of the equipment.
热控系统	Thermal Control System	熱制御システム	열제어 시스템	Molybdenum sheets are used in satellites for heat dissipation and thermal radiation management, requiring high thermal conductivity and radiation resistance.

illustrate

1. **Selection of terms**: The terminology covers molybdenum sheet production (mining, beneficiation, refining, forming), performance testing (density, melting point, conductivity, etc.) and application areas (electronics, sapphire growth furnaces, vacuum furnaces), based on Chapters 4 to 9.
2. **Chinese explanation**: Each term is explained concisely, highlighting its technical definition and application background, and providing specific parameters (such as thickness, performance values) in combination with the content of the chapter (such as production process, test method and application scenario).
3. **Multilingual translation**: English, Japanese, and Korean terminology is based on industry standards and technical literature to ensure accuracy and versatility for international technical exchanges.
4. **Purpose**: This glossary can be used for technical documentation, cross-border trade and academic research to support the standardized application of CTIA GROUP LTD molybdenum chips in the global market.

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