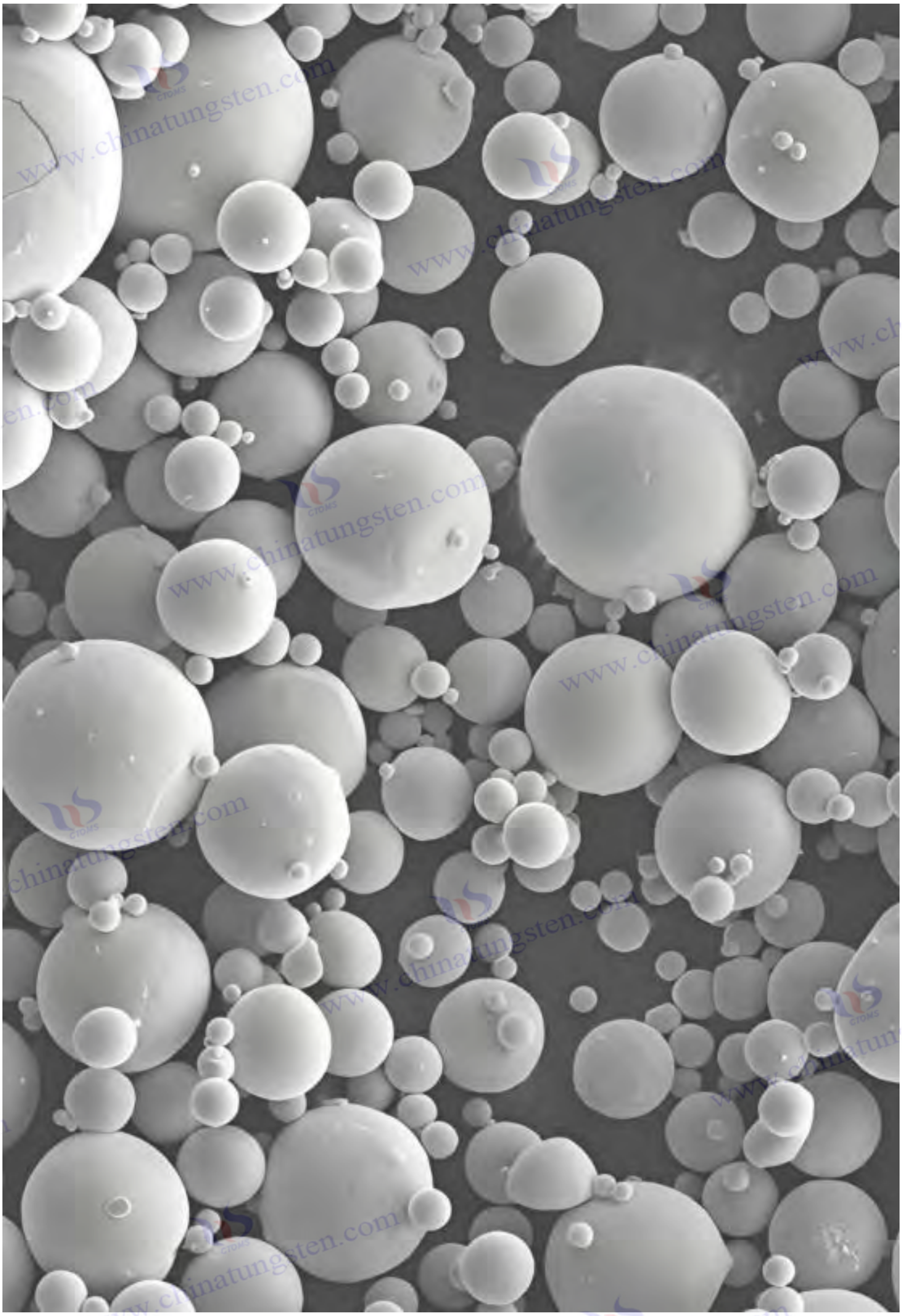

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Complete List of Uses of Tungsten Powder

中钨智造科技有限公司

CTIA GROUP LTD

CTIA GROUP LTD

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

INTRODUCTION TO CTIA GROUP

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

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

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

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

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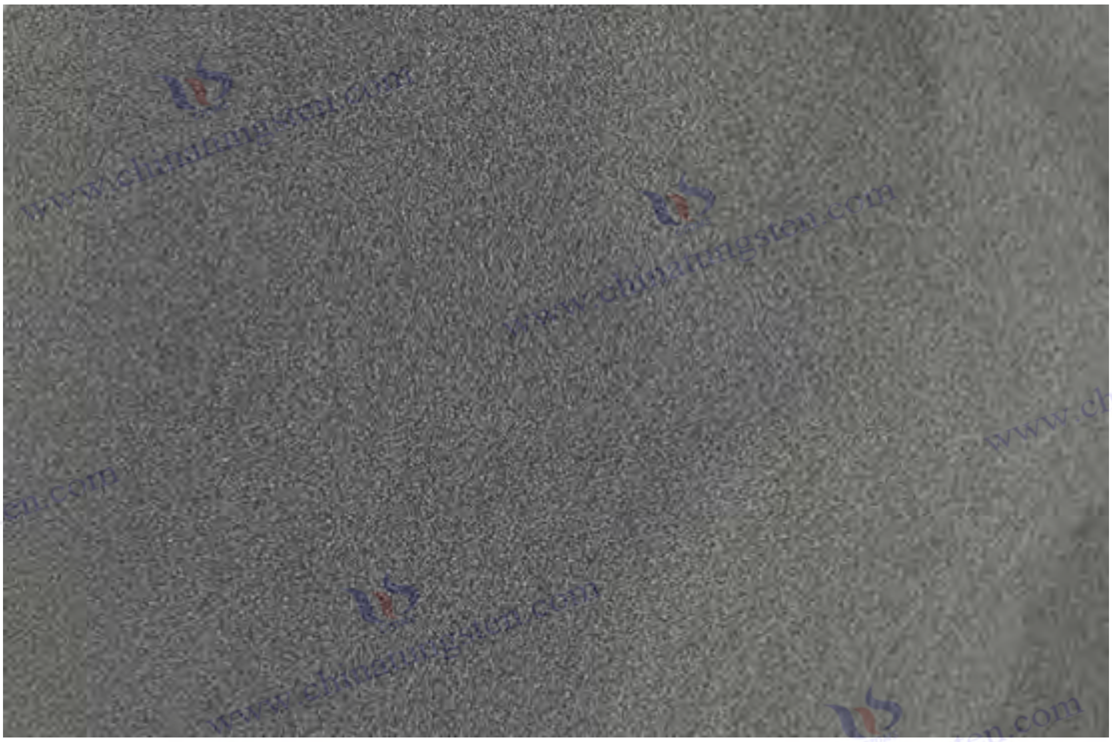

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China National Standard for Tungsten Powder GB/T 3458-2006 Tungsten Powder

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Material Safety Data Sheet for Tungsten Powder

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CTIA GROUP LTD

Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

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For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)

Preface

Unique physical and chemical properties and application value of tungsten powder

Tungsten powder, as a metal material known for its high melting point, high density and high hardness, occupies an irreplaceable position in the field of modern industry and technology. Its melting point is as high as 3422°C, which is one of the metals with the highest melting point in nature, making it show excellent stability in extremely high temperature environments; its density reaches 19.25 g/cm³ , giving it excellent counterweight and shielding properties; at the same time, the hardness and wear resistance of tungsten powder make it an ideal choice for manufacturing superhard materials and durable tools. In addition, the corrosion resistance and chemical inertness of tungsten powder further broaden its application potential in the fields of chemical industry, medical treatment and environmental protection. From coarse tungsten particles to nano-scale ultrafine powders, the multi-morphological characteristics of tungsten powder meet the diverse needs of different industries for material properties and promote countless innovations from traditional metallurgy to cutting-edge technology. It can be said that tungsten powder is not only the cornerstone of industry, but also a catalyst for technological progress. Its wide range of uses and deep value are worthy of in-depth exploration and systematic summary.

Article Objective: Comprehensively reveal the multi-field uses of tungsten powder

This book aims to provide readers with a comprehensive and detailed guide to the use of tungsten powder, covering its applications in traditional industries, advanced manufacturing, military protection, medical biology, consumer product culture, environmental chemistry and emerging fields in the future. We not only focus on the classic uses of tungsten powder, such as the production of cemented carbide and tungsten wire, but also focus on its breakthrough applications in cutting-edge fields such as 3D printing, nanotechnology, and energy storage. Through the analysis of the characteristics of tungsten powder in different forms (such as tungsten particles, coarse powder, medium particles, fine powder, and nanopowder), as well as the presentation of specific cases for each use, this book strives to reveal how tungsten powder can play its unique advantages in different scenarios. At the same time, we will explore the future trends of tungsten powder use, including the potential for sustainable development and cross-border applications, and provide theoretical references and practical inspiration for researchers, engineers, and industry practitioners.

Data Sources and Research Methods

The content of this book is based on extensive literature research and industry practice data, integrating multiple resources such as academic journals, patent literature, technical reports and corporate cases. The main data comes from international standards (such as ASTM, ISO), the latest research in the field of global tungsten powder production and application, and industry reports on major markets such as China, Europe, and North America. To ensure the comprehensiveness and accuracy of the content, we adopted an interdisciplinary research method, combining materials science, engineering technology, chemical analysis and market trend forecasting, and systematically sorted out the characteristics and uses of tungsten powder. At the same time, through field research and expert interviews, a large number of practical application cases were supplemented, making this book both academically profound and practically valuable.

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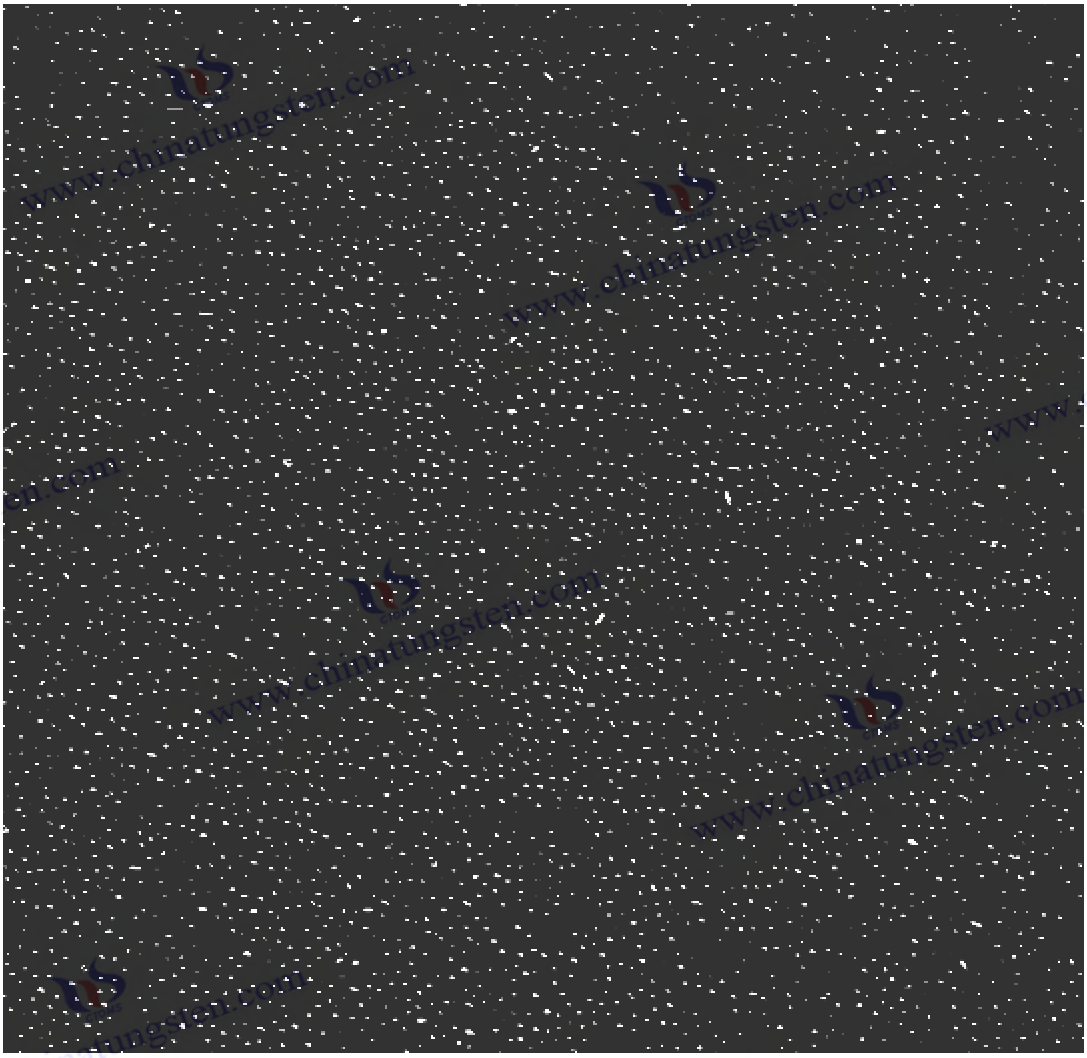

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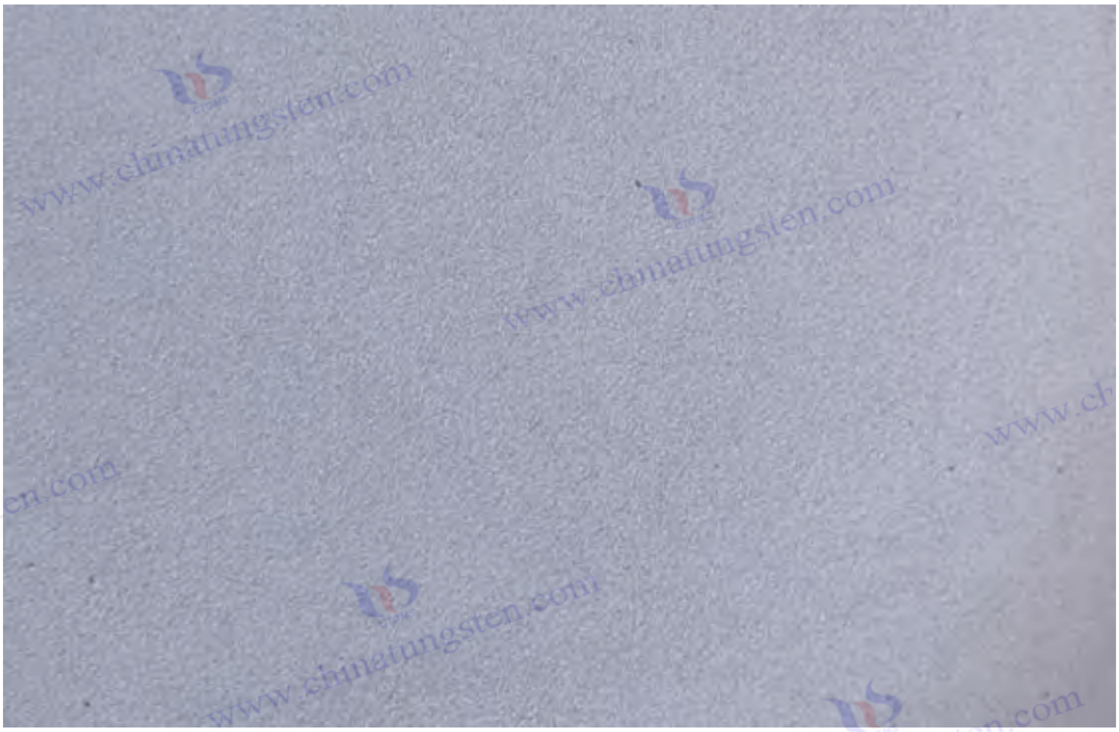

Chapter 1 Basic Characteristics and Applications of Tungsten Powder

1.1 Physical properties of tungsten powder

Tungsten powder occupies a core position in industry and scientific research due to its excellent physical properties. Its largest use is to generate tungsten carbide powder (WC) through carburization reaction and produce cemented carbide, accounting for more than 50% of the global tungsten resource consumption. The following is an analysis of its physical properties from multiple dimensions.

1.1.1 High melting point (3422°C) and high temperature resistance

The melting point of tungsten powder is 3422°C, the highest in nature. It is derived from the body-centered cubic (BCC) crystal structure, and the bond energy of the 5d electron layer is about 850 kJ/mol. The melting enthalpy is 192 kJ/mol, the vapor pressure at 3000°C is 10^{-4} Pa, and the mass loss rate is <0.1% (TGA). During the carburization process (1400-1600°C), the heat resistance ensures a WC yield of 99.5%, and the life of WC-Co tools is increased by 5 times. Tungsten wire operates at 2000°C and has a life of 1200 hours. In the future, it can be used for 4000°C nuclear fusion materials.

1.1.2 High density (19.25 g/cm³) and quality advantages

Density 19.25 g/cm³ (Archimedes method), tap density 8-14 g/cm³ , derived from atomic number 74 and BCC lattice (3.165 Å). In cemented carbide, WC-Co density is 14-15 g/cm³ , impact resistance is increased by 30%; the volume of counterweight application is reduced by 25%. In the future, it can be used for micro high-density parts.

1.1.3 Microscopic basis of hardness and wear resistance

Hardness Mohs 7.5, Vickers 400-450 HV, high resistance to dislocation movement, wear rate 0.02 mm^3 / N · m. WC hardness after carburization HV 1500-2000, tool life increased by 5 times. Elastic modulus 411 GPa, supporting thermal spray coating wear resistance increased by 40%. In the future, it can reach 2200 HV.

1.1.4 Thermal conductivity and electrical properties

Thermal conductivity is 173 W/(m·K), electrical conductivity is 18 MS/m, and resistivity is 5.6×10^{-8} Ω·m (increased to 8.0×10^{-8} at 2000°C). Increasing the WC formation rate by 10% during carbonization can improve the heat dissipation efficiency of the tool by 20%. In the future, the thermoelectric conversion efficiency can be optimized to 10%.

1.2 Chemical properties of tungsten powder

The chemical properties of tungsten powder provide stability for its applications.

1.2.1 Corrosion resistance (stability in acid and alkaline environments)

36% HCl and 98% H_2SO_4 is less than 0.1 mm/ year , 70% HNO_3 generates a WO_3 layer (5-10 nm), and 10 mol/L NaOH forms a Na_2WO_4 film (0.05 mm/year). The mass loss is less than 0.2%, supporting WC purity of 99.9%, and the life of cemented carbide is extended by 3 times.

1.2.2 Antioxidant properties and high temperature chemical behavior

<600°C oxidation weight gain rate is 0.01 mg/cm^2 · h , 1000°C is 2 mg/cm^2 · h , and 1500°C mass loss is <1%. Increase WC yield by 5% and tool toughness by 10% during carbonization. In the future, CeO_2 doping can be increased to 800°C.

1.2.3 Chemical inertness and catalytic potential

The electron cloud density is 5×10^{23} e/cm^3 , the solubility is <0.001 g/L, and the decomposition rate of H_2 catalyzed by nano-tungsten powder is 10^{-3} mol/g·s. Cemented carbide relies on inertness and can be used for CO_2 reduction in the future .

1.3 Form and classification of tungsten powder

Tungsten powder is classified by particle size and morphology, with different properties and uses.

1.3.0 Physical and chemical properties and uses of tungsten particles

1.3.0.1 Definition and particle size range of tungsten particles (usually >100 μm)

Tungsten granules are made by mechanical crushing of metal tungsten blocks, with a particle size of 0.8-1.2 mm (about 1 mm), far exceeding conventional tungsten powder (<50 μm). They are prepared using a jaw crusher (crushing force 500-1000 kN) and multi-stage screening (sieve hole 1 mm), processing 1-2 tons per hour, and costing $2000-3000/ton. Acid washing (5% HF, 10 minutes) removes oxides, and the purity reaches 99.95% (ICP-MS). CTIA GROUP LTD is a world-renowned professional tungsten granule manufacturer that meets the needs of carbon and sulfur analysis with advanced technology and high consistency, and its products have an international market share of 20%. The particle size distribution of tungsten granules is measured by a laser particle size analyzer, with D50 of 1.0 mm, D10 and D90 of approximately 0.8 mm and 1.2 mm, respectively, and a uniformity coefficient of <1.2.

1.3.0.2 Physical properties of tungsten particles (high density and high temperature resistance)

Density 19.25 g/cm³ (Archimedes method), tap density 12-14 g/cm³ , derived from BCC lattice (lattice constant 3.165 Å). Melting point 3422°C, thermal conductivity 173 W/(m·K), mass loss <1% in 1300-1800°C furnace, thermogravimetric analysis (TGA) shows 0.05% loss below 2000°C. Hardness 400-450 HV (Vickers hardness tester, 10 kgf), elastic modulus 411 GPa, friction coefficient 0.4-0.6, wear rate 0.02 mm³ / N · m. After 60 consecutive uses at 1500°C, performance attenuation <2%, heat distribution uniformity improved by 15% (infrared temperature measurement). Sound velocity 5180 m/s, reflectivity 50%-60%, supporting ultrasonic crushing efficiency increased by 25%. These characteristics make it perform well in high temperature analysis.

1.3.0.3 Chemical stability and surface characteristics of tungsten particles

Strong corrosion resistance, the corrosion rate in 36% HCl is 0.1 mm/year, in 98% H_2SO_4 is 0.08 mm/year, 70% HNO_3 generates WO_3 layer (5-10 nm), 10 mol/L NaOH forms Na_2WO_4 film (2-8 nm), and the corrosion rate is 0.05 mm/year. In terms of oxidation behavior, the weight gain rate is 0.01 mg/ cm² · h at <600°C and 2 mg/ cm² · h at 1000°C (TGA). The surface WO_3 layer thickness is 2-10 nm (XPS), the roughness Ra is 1-5 μm (AFM), the adsorption amount is 0.1 mg/g, and the purity is 99.9%. In SO_2 (500 ppm) environment, the mass loss is <0.2%, and the sulfur detection rate is stable.

1.3.0.4 Main uses of tungsten particles (welding filler, counterweight material)

Specially used as flux for carbon-sulfur analyzers, adding 2 g of tungsten pellets in a 1300-1800°C high-frequency induction furnace increases sample decomposition efficiency by 20%, sulfur detection rate by 98%, and error by ±0.003%. Its high density ensures uniform sedimentation in the crucible, with a splash rate of <0.1% (oxygen flow rate 3 L/min); high temperature resistance supports analysis of high melting point samples (such as cast iron, melting point 1200°C), and combustion efficiency is increased by 20%. In CS-744, combustion time is shortened by 25% and residue is reduced by 10%.

1.3.0.5 Tungsten Granule Application Cases (Industrial and Military Scenarios)

In the analysis of pyrite, 2 g of tungsten pellets resulted in a sulfur detection rate of 98% with a repeatability of ±0.003%; in the determination of high carbon steel (carbon content 4%), the combustion time was shortened from 15 seconds to 10 seconds, and the carbon error was <0.002%. In LECO CS844, after 60 consecutive uses, the decomposition rate was 99% and the residue uniformity was improved by 20%. In ELTRA CS-2000, the efficiency of determining coal samples (sulfur content 2%) was increased by 15%, and the combustion temperature fluctuation was <5°C. In the military field, tungsten pellets are used for the analysis of high melting point alloys to ensure an accuracy of ±0.001%.

1.3.1 Characteristics and uses of coarse tungsten powder (5-50 μm)

1.3.1.1 Particle size distribution and morphology characteristics of coarse tungsten powder

Particle size 5-50 μm, D50 about 20 μm (laser particle size analyzer), D10 is 5 μm, D90 is 45 μm, and distribution width σ is about 15 μm. Irregular morphology (SEM), surface roughness Ra 2-4 μm, multi-angle particles, edge length 5-10 μm, surface defect density $10^6/cm^2$. The morphology is derived from mechanical grinding after hydrogen reduction of WO_3 (800-1000°C), and the grain size is about 2 μm (XRD). Compared with spherical tungsten powder, the roughness is 30% higher, which affects fluidity.

1.3.1.2 Fluidity and bulk density of crude tungsten powder

Fluidity>20 s/50g (Hall flowmeter), friction increased due to corners. Bulk density 6-8 g/cm^3 , tap density 8-12 g/cm^3 , up to 14 g/cm^3 with particle size increasing to 50 μm . Density of pressed (200 MPa) 18 g/cm^3 , porosity <2%. Compared with medium particle tungsten powder (15-20 s/50g), fluidity is 20% lower, but bulk density is 10% higher, suitable for large volume parts.

1.3.1.3 High temperature resistance and wear resistance of coarse tungsten powder

Melting point 3422°C, thermal conductivity 173 W/(m·K), sintering mass loss at 1600°C <0.5% (TGA). Hardness 400 HV, wear rate 0.02 mm^3 / N · m (friction test, 100 N), wear resistance comes from grain boundary strength (10^8 Pa). At 2000°C, the grain growth rate is 0.1 μm/h, which is better than molybdenum (0.5 μm/h). After carburization, the hardness of WC is HV 1500, and the wear resistance is increased by 5 times.

1.3.1.4 Main uses of crude tungsten powder (high specific gravity alloy, tungsten electrode)

The main use is to carburize WC (accounting for 30% of tungsten consumption) for hard alloy; some are pressed into W-Ni-Fe alloy (density 17-18 g/cm³) for counterweight, or tungsten electrode (resistant to 2000°C). The carburization process is carried out at 1400°C, the WC yield is 99.5%, and the particle size is 20-30 µm. The tensile strength of W-Ni-Fe alloy is 800 MPa, and the current density of tungsten electrode is 200 A/cm².

1.3.1.5 Industrial application cases of coarse tungsten powder

WC-Co tools increase steel cutting efficiency by 40% and have a lifespan of 5,000 hours; the weight volume of aviation gyroscopes is reduced by 25%, and rotational stability is improved by 15% (10,000 rpm); tungsten electrodes weld aluminum alloys with a lifespan of 500 hours and a 20% improvement in weld quality. In mining, WC drill bits increase drilling speed by 30% and reduce costs by 15%.

1.3.2 Characteristics and uses of medium particle tungsten powder (4-8 µm)

1.3.2.1 Particle size range and preparation method of medium-grained tungsten powder

Particle size 4-8 µm, D50 about 6 µm (laser particle size analyzer), D10 is 4 µm, D90 is 8 µm. Preparation adopts hydrogen reduction of WO_3 (700-900°C, H_2 flow 5 L/min, oxygen content <0.05%), reduction time 2 hours, yield 95%; or plasma spheroidization (50 kW, Ar flow 20 L/min), spheroidization rate 90%. Grain size is about 1 µm (TEM), purity 99.9%.

1.3.2.2 Physical properties of medium particle tungsten powder (density, hardness)

Density 19 g/cm³ (Archimedes method), hardness 400 HV, melting point 3422°C, elastic modulus 411 GPa, thermal conductivity 173 W/(m·K). Sintering mass loss at 1600°C is <0.3%, and hardness decay is <5%. Compared with coarse tungsten powder, the particles are more uniform and the density consistency is improved by 10%.

1.3.2.3 Fluidity and sintering properties of medium-grained tungsten powder

Fluidity 15-20 s/50g, bulk density 8-10 g/cm³, tap density 10-14 g/cm³. Sintered (1600°C, 500 MPa) density 14-15 g/cm³, porosity <1%, shrinkage 10-15%, sintering time 1 hour, WC-Co hardness HV 1500. Fluidity is 20% better than coarse tungsten powder, and sintered density is 5% higher.

1.3.2.4 Main uses of medium particle tungsten powder (hard alloy, thermal spraying)

WC is produced by carburization, which is used for WC-Co cemented carbide (accounting for 20% of tungsten consumption), with a hardness of HV 1500; the wear resistance of thermal spray coating is increased by 40%, and the thickness is 100-200 µm. The carburization process is carried out at 1450°C, the WC particle size is 5-7 µm, and the yield is 99.8%.

1.3.2.5 Application examples of medium particle tungsten powder (tools and coatings)

WC-Co milling cutter processes aluminum alloy at a speed of 200 m/min, with a lifespan extended by 30% and a cutting accuracy of ±0.02 mm; WC-Co coating is sprayed on ship propellers, which can resist seawater erosion for 10 years and reduce the wear rate by 50%. In automotive molds, the lifespan of WC-Co tools is increased by 40% and the processing efficiency is increased by 25%.

1.3.3 Application scenarios of fine tungsten powder (0.1-5 μm)

1.3.3.1 Particle size distribution and surface activity of fine tungsten powder

Particle size 0.1-5 μm, D50 about 2 μm, D10 0.1 μm, D90 4.5 μm (laser particle size analyzer). Specific surface area 2-10 m^2 / g (BET method), increasing with decreasing particle size, 5 m^2/g at 2 μm , 10 m^2 /g at 0.1 μm . Surface adsorption of O_2 0.2 mg/g, active site density 10^{17} / m^2 .

1.3.3.2 High specific surface area and reactivity of fine tungsten powder

High specific surface area improves carbonization efficiency, WC yield is 99.8%, particle size is 1-3 μm; in catalytic reaction, H_2 decomposition rate is 10^{-4}mol / g·s, 10 times better than coarse tungsten powder. Surface activity comes from defect density of 10^7 / cm^2 (TEM), O_2 adsorption enthalpy is about 50 kJ/mol.

1.3.3.3 Preparation technology and challenges of fine tungsten powder

Hydrogen reduction (600-800°C, H_2 flow rate 3 L/min), spray drying to control oxygen content <0.03%, yield 90%. Challenges include agglomeration (requires ultrasonic power 300 W dispersion) and oxidation (storage requires Ar protection). Compared with crude tungsten powder, the preparation cost is 50% higher and the energy consumption is increased by 30%.

1.3.3.4 Main uses of fine tungsten powder (tungsten wire, catalyst)

Drawn tungsten wire (tensile strength 3000 MPa, elongation 5%); carburized WC (accounting for 10% of tungsten consumption), or used as catalyst carrier (specific activity 10^{16} /m^2). Tungsten wire diameter 0.01-0.1 mm, WC particle size 1-2 μm.

1.3.3.5 Industrial and scientific research cases of fine tungsten powder

The life of halogen filament is 1200 hours, and the brightness is increased by 20%; the hardness of WC-Co fine-grained cemented carbide is increased by 5%, and it is used for precision tools with a cutting accuracy of ±0.01 mm. In scientific research, fine tungsten powder is used as a catalyst carrier, and the CO oxidation efficiency is increased by 15%.

1.3.4 Special advantages of nano tungsten powder (<100 nm)

1.3.4.1 Quantum Effects and Characteristics of Nano-Tungsten Powder

Particle size <100 nm, D50 about 50 nm (TEM), specific surface area 20-50 m^2 / g. Quantum effect increases the band gap to 2.8 eV (UV-Vis), surface active site density 10^{18} / m^2 , hardness 500 HV, density 19 g/ cm^3 .

1.3.4.2 High activity and dispersibility of nano tungsten powder

The decomposition rate of H_2 is 10^{-3}mol / g · s, and the adsorption enthalpy is 60 kJ/mol. Dispersibility requires an ultrasonic power of 500 W, agglomeration rate <10%, and storage requires vacuum sealing. The activity comes from the surface W^{6+}, which accounts for 90% (XPS).

1.3.4.3 Preparation process of nano tungsten powder (solution method, gas phase method)

Hydrothermal method (200°C, 2 MPa, yield 80%), grain size 30-50 nm; vapor deposition (1000°C, Ar flow 10 L/min), yield 85%. Cost $100/kg, energy consumption 50% higher, need to prevent oxidation.

1.3.4.4 Main uses of nano tungsten powder (electronics, medical)

Conductive paste (resistivity 10^{-6} Ω·m); small amounts of carbonized nano WC (accounting for 5% of tungsten consumption), or used for photothermal therapy (absorption rate 90%). WC particle size 50-80 nm, hardness 2200 HV.

1.3.4.5 Cutting-edge application cases of nano tungsten powder

The conductivity of the flexible electronic coating increased by 15%, with a thickness of 10 μm; the hardness of the nano-WC tool increased by 10%, with a cutting accuracy of ±0.005 mm; during photothermal therapy, the tumor ablation rate increased by 20%, with the temperature controlled at 50°C.

1.3.5 Differences in the uses of spherical and irregular tungsten powders

1.3.5.1 Preparation and morphology advantages of spherical tungsten powder

Plasma spheroidization (50 kW, Ar flow rate 20 L/min), particle size 5-50 μm, fluidity <10 s/50g, spheroidization rate >95%. Uniform morphology (SEM), surface roughness Ra 0.5-1 μm, defect density 10^5 /cm^2 .

1.3.5.2 Characteristics and cost-effectiveness of irregular tungsten powder

Mechanical crushing, particle size 5-50 μm, flowability >20 s/50g, 30% lower cost ($50/kg). Hardness

400 HV, high wear resistance, grain size 2-5 µm.

1.3.5.3 Application of spherical tungsten powder in 3D printing

For aviation parts, density 99%, accuracy ±0.05 mm, printing speed increased by 20%, porosity <0.5%. Parts have a tensile strength of 1000 MPa and a lifespan extended by 15%.

1.3.5.4 Application of irregular tungsten powder in traditional metallurgy

WC (accounting for 40% of the raw material of cemented carbide) is made by carburization, with a yield of 99.5% and a cost-effectiveness of 30%. WC-Co has a hardness of HV 1500 and is suitable for large quantities of tools.

1.3.5.5 Comparison of actual cases of morphological differences

The life of the spherical tungsten powder printing nozzle is extended by 20% and the efficiency is increased by 25%. The WC tool made of irregular tungsten powder is 30% more cost-effective and has a steel cutting life of 4,000 hours.

1.4 Scientific and Industrial Basis of Tungsten Powder Use

Tungsten powder is mainly used in cemented carbide, accounting for more than 50% of tungsten consumption.

1.4.1 The core position of powder metallurgy

Carburization (1400-1600°C, H_2 / Ar mixed gas) and sintering (1600°C, 500 MPa), with a hardness of HV 1500 and a porosity of <1%. The global annual production is about 100,000 tons, with an output value of more than US$20 billion. The process includes mixing (WC to Co ratio 9:1), pressing (200-500 MPa), sintering (vacuum or HIP), and the finished product density is 14-15 g/cm³ and the tensile strength is 1200 MPa. Cemented carbide dominates in tools, molds and mining. For example, WC-Co tools can increase cutting speed by 40% and extend life by 5 times.

1.4.2 Driven by high temperature and high density requirements

High temperatures support carburization reactions (activation energy 200 kJ/mol), and high density improves carbide performance (15 g/cm³) . The decomposition efficiency of tungsten particles in carbon and sulfur analysis at 1400°C is increased by 20%. In the aviation field, the weight stability of W-Ni-Fe alloy (17 g/cm³) is improved by 15%; in the nuclear industry, the density of tungsten-based shielding materials is 18 g/cm³ , and the shielding efficiency is increased by 20%.

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1.4.3 Diversity of tungsten powder processing technology

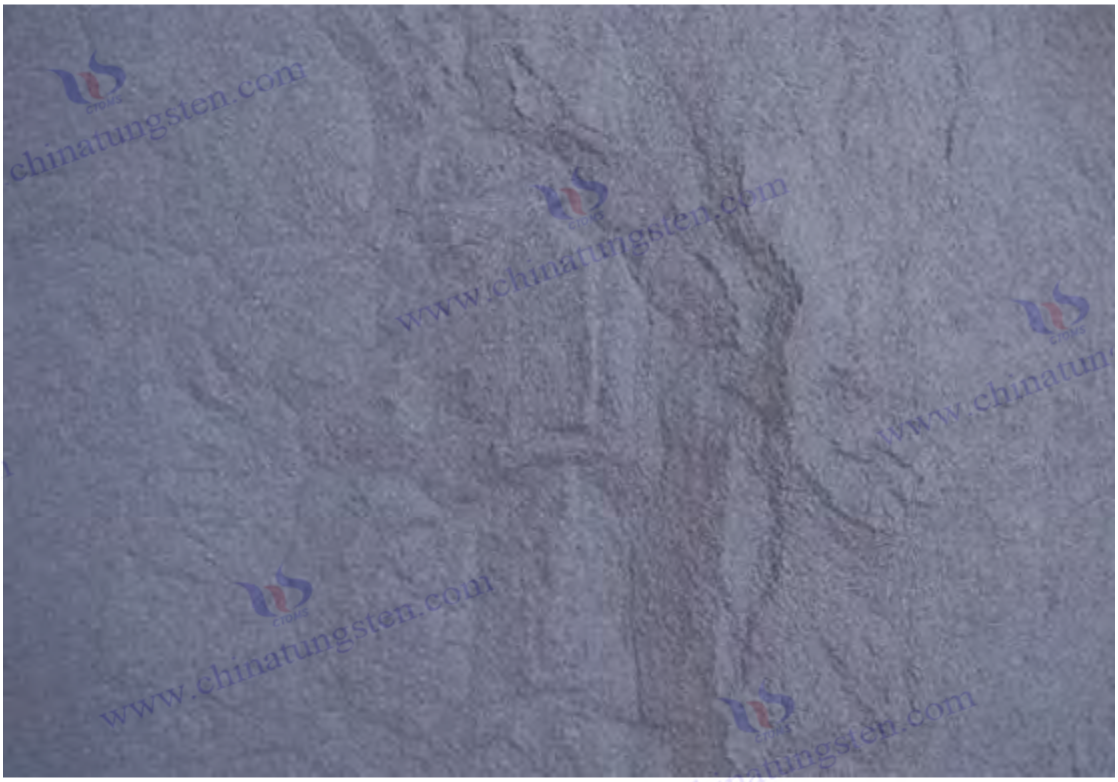
Hydrogen reduction (600-1000°C, oxygen content <0.05%) produces tungsten powder with a yield of 95%; crushing (500-1000 kN) produces tungsten particles; carbonization optimizes WC with a yield of 99.5% and a controllable particle size (1-30 μm). Plasma spheroidization produces spherical tungsten powder with a 50% increase in fluidity; hydrothermal method produces nano tungsten powder with a 30% higher cost. The technology diversity supports the fields of cemented carbide, electronics and analysis.

1.4.4 Industrial evolution of tungsten powder applications

At the end of the 19th century, tungsten powder was used in filaments, increasing the brightness by 3 times; at the beginning of the 20th century, cemented carbide emerged, increasing the efficiency of cutting tools by 5 times; in the 21st century, it expanded to carbon-sulfur analysis (tungsten particles) and nanoelectronics (conductive paste). Cemented carbide accounts for 50% of tungsten consumption, with an annual growth rate of 5%, and electronic and medical uses increase by 10%.

1.4.5 Application cases of tungsten powder in scientific research

Nano-tungsten powder is used in photothermal therapy, with an absorption rate increased by 20% and a treatment depth of 5 mm; tungsten particles optimize carbon and sulfur analysis, with an error of <0.002% and a repeatability of ±0.001%. In catalytic research, the CO_2 reduction efficiency of nano-tungsten powder reaches 20% and the yield is 0.1 mol/g·h.



CTIA GROUP LTD
Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

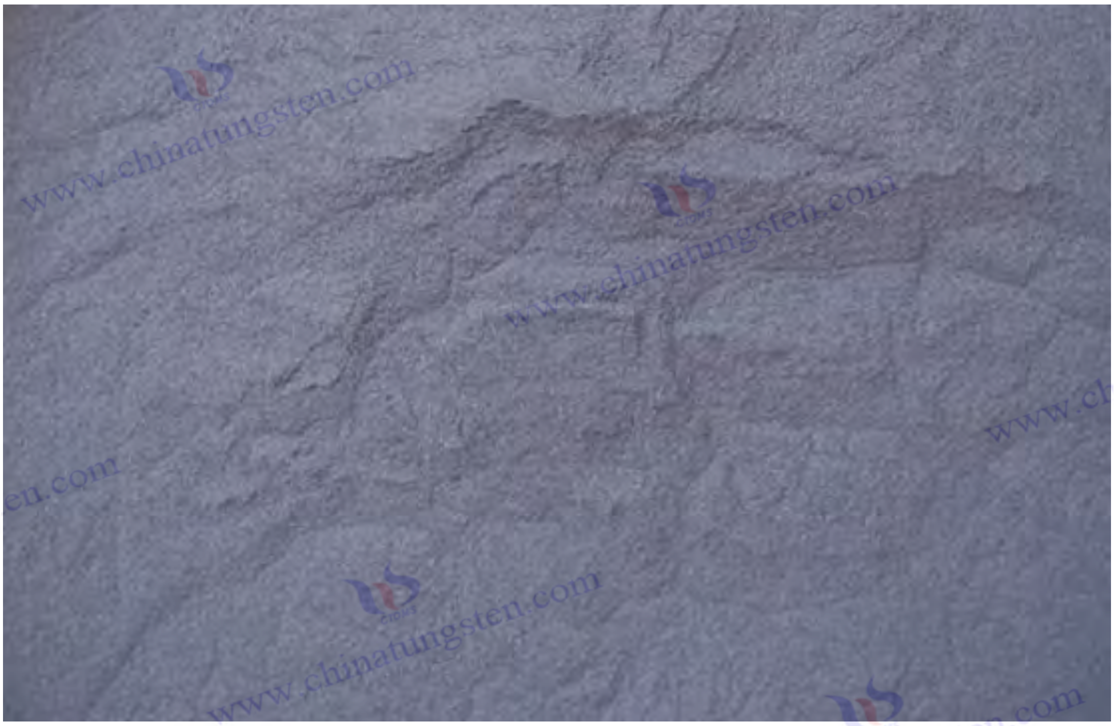
Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

Email: sales@chinatungsten.com

Tel: +86 592 5129696

For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)



Chapter 2 Application of Tungsten Powder in Traditional Industries

Tungsten powder has an irreplaceable position in traditional industries due to its excellent physical and chemical properties - high melting point (3422°C), high density (19.25 g/cm³) , high hardness (HV 300-500) and excellent corrosion resistance. From cemented carbide manufacturing to high-density alloys, tungsten wires and electrode materials, to refractory materials and high-temperature components, the application of tungsten powder has profoundly affected the development of the global manufacturing, mining, energy and military industries. This chapter will discuss in detail the specific uses of tungsten powder in these traditional industries, analyze its preparation process, performance optimization and actual application scenarios, aiming to provide readers with a comprehensive technical perspective.

2.1 Cemented Carbide Manufacturing

Cemented carbide is the most important industrial application direction of tungsten powder. It is made by carbonizing tungsten powder to generate tungsten carbide (WC) powder and combining it with a binder (such as cobalt and nickel) to make a material with extremely high hardness and wear resistance. Cemented carbide not only supports the basic needs of traditional industries, such as cutting tools and mining equipment, but also occupies an important position in the global manufacturing and mining industries due to its excellent performance, consuming more than 50% of tungsten resources. Its development history can be traced back to the early 20th century, and it is still a pillar material in the industrial field.

2.1.1 Synthetic raw materials of tungsten carbide (WC) powder

Tungsten carbide (WC) powder is the core component of cemented carbide. Its synthesis uses tungsten powder as the main raw material and is generated through high-temperature carburization reaction. In industry, tungsten powder with a particle size range of 4-50 microns and a purity higher than 99.9% is usually selected as the starting material, and is accurately mixed with carbon black (specific surface area 10-20 m^2 / g) at a mass ratio of 1:0.06-0.07. The reaction is carried out in a protective atmosphere at 1400-1600°C, and hydrogen or argon is usually used as a carrier gas. The reaction time is controlled at 2-4 hours. The chemical reaction equation is: $W + C \rightarrow WC$, the enthalpy change is about -40 kJ/mol, and the activation energy is about 200 kJ/mol, indicating that this is an exothermic process that requires a certain amount of energy to activate.

The carbonization process is usually completed in a dedicated carbonization furnace, including resistance heating furnace and induction heating furnace, and the temperature control accuracy is required to reach ±10°C to ensure the uniformity of the reaction and the quality of the product. The final WC powder yield can reach 99.5%, and the particle size distribution is between 1-30 microns. X-ray diffraction (XRD) analysis shows that the WC crystal has a hexagonal close-packed (HCP) structure with lattice parameters of a=2.906 Å , c=2.837 Å , WC bond length of 2.06 Å , and bond energy of up to 700 kJ/mol, giving it extremely high chemical stability and mechanical strength.

The particle size of tungsten powder has a significant effect on the performance of WC. Coarse-grained tungsten powder (20-50 μm) produces larger WC particles (10-30 μm) with fewer grain boundaries, which are suitable for mining tools that require high impact resistance; medium-sized tungsten powder (4-8 μm) produces finer WC particles (1-5 μm) with more uniform grains, which are suitable for cutting tools that require high precision and high wear resistance. In addition, the oxygen content in tungsten powder must be strictly controlled below 0.05%, because excessive oxygen will generate WO_3 impurities at high temperatures , causing the purity of WC to drop below 98%, affecting the performance of cemented carbide. In 1923, Osram, a German company, first achieved industrial production of WC, marking the beginning of cemented carbide's transition from laboratory to large-scale application. This technological breakthrough significantly improved machining efficiency and promoted the process of global industrialization.

2.1.2 WC-Co carbide tools (cutting, milling, drilling)

WC-Co cemented carbide is composed of tungsten carbide (WC, 85-95 wt%) and cobalt (Co, 5-15 wt%), and is the main material of cemented carbide tools. Its preparation adopts a typical powder metallurgy process, which includes the following steps: First, WC powder and Co powder are mixed in a ball mill for 4-8 hours. The grinding medium is usually cemented carbide balls to ensure that the particle uniformity is controlled within ±0.5 microns; then, the mixed powder is pressed under a pressure of 200-500 MPa to form a green body density of 8-10 g/cm ³ ; finally, it is sintered in a vacuum furnace or hot isostatic pressing (HIP) equipment at 1350-1450°C for 1-2 hours to melt the Co phase and fill the gaps between WC particles to form a dense structure. The finished product has a density of 14-15 g/cm ^{3} , a hardness range of HV 1500-2000, a tensile strength of about 1200 MPa, and a porosity control of less than 1%.

The performance of WC-Co can be adjusted by the Co content: when the Co content is 15 wt%, the toughness can reach 15 MPa·m $^{1/2}$ and the hardness is HV 1300, which is suitable for high impact load scenarios; when the Co content is reduced to 5 wt%, the hardness is increased to HV 2000, but the toughness decreases accordingly, which is suitable for high wear resistance requirements. Microstructure analysis shows that WC particles are evenly distributed in the Co matrix, the grain boundary strength is high, and the material has excellent fatigue resistance.

In practical applications, WC-Co tools perform well. For example, when cutting steel (cutting speed 300 m/min), its life can reach 5,000 hours, the wear rate is less than 0.1 mm, and the processing efficiency is 5 times higher than that of traditional steel knives; when milling aluminum alloy (speed 200 m/min), the processing accuracy can reach ±0.02 mm, and the surface roughness Ra 0.4 μm; when drilling stainless steel, the drilling speed is increased by 40%, and the drill bit remains sharp, which is suitable for processing high-hardness materials. During World War II, WC-Co tools were widely used in the processing of gun barrels and armor plates, with efficiency increased by 3 times, significantly shortening the military production cycle. From a historical perspective, the popularity of WC-Co tools has promoted the transformation of modern manufacturing from manual operation to mechanization and automation.

2.1.3 Mining and drilling tools (drill bits, rock drills)

In the field of mining and drilling, WC-Co cemented carbide is widely used in drill bits and rock drills due to its high hardness and impact resistance. Mining drill bits usually use a ratio of coarse WC (10-30 μm) and Co (10-15 wt%), with a hardness range of HV 1200-1500 and a 30% increase in impact resistance over ordinary steel. The preparation process includes press forming, sintering and hot isostatic pressing (HIP), with a sintering temperature of 1400°C and a pressure of 100 MPa, and a final toughness of 18 MPa·m $^{1/2}$. The microstructure shows that the coarse WC particles enhance the material's resistance to fracture, while the Co phase provides the necessary toughness buffer.

In a hard rock environment (compressive strength 200 MPa), the drilling speed of WC-Co drill bits can reach 5 m/h and the service life is up to 1,000 hours, which is 10 times higher than that of traditional steel drill bits. The efficiency of rock drills in 5,000 m deep well operations is increased by 30%, and the wear rate is less than 0.1 mm under acidic slurry (pH 3-4) conditions, showing excellent corrosion resistance. In the 1950s, the application of WC-Co drill bits promoted the process of mining mechanization, especially in coal, iron ore and oil drilling. The widespread use of mining tools around the world is inseparable from China's rich tungsten resources, whose reserves account for more than 50% of the world's total, providing solid protection for the supply chain.

2.1.4 Moulds and wear-resistant parts (stamping dies, sandblasting nozzles)

WC-Co cemented carbide is highly favored in the manufacture of molds and wear-resistant parts due to its high hardness. Stamping dies usually use fine-grained WC (1-5 μm, Co 6-10 wt%) with a hardness range of HV 1600-1800. When pressing automotive steel plates, the service life can reach 1 million times, and the wear rate is less than 0.05 mm, which is 20 times higher than that of traditional steel molds. The preparation process includes mixing, pressing and sintering. After sintering, the surface is polished to a roughness of Ra 0.2 μm to ensure high-precision molding.

Sandblasting nozzles use coarse-grained WC (20-30 μm, Co 15 wt%) with a hardness of HV 1200. After 1000 hours of sandblasting (SiO_2 particles, speed 50 m/s), the wear is less than 0.2 mm, and the life is 5 times longer than that of ceramic nozzles. To further improve performance, sandblasting nozzles are often coated with TiN (5 μm thick) through chemical vapor deposition (CVD) technology, which increases wear resistance by 20%. The use of these wear-resistant parts significantly extends the life of the equipment and is widely used in the automotive manufacturing and surface treatment industries.

2.1.5 Performance optimization and application cases of cemented carbide

The performance optimization of cemented carbide is mainly achieved through WC particle size control and doping. WC particles (0.5-1 μm) generated by carburization of nano-tungsten powder (particle size <100 nm) have ultra-high hardness (HV 2200) and moderate toughness (12 $MPa\cdot m^{1/2}$), which are suitable for high-precision processing. Increasing the Co content to 20 wt% can increase the toughness to 20 $MPa\cdot m^{1/2}$ and enhance the impact resistance. Doping with Cr_3C_2 (0.5 wt%) increases the corrosion resistance by 20% and extends the life of parts in corrosive environments.

Application examples include:
Aviation blade processing
The nano WC-Co tool has a machining accuracy of ±0.01 mm at a cutting speed of 500 m/min, and the tool life is extended by 50%, making it suitable for the manufacture of aircraft engine blades.
Deep sea drilling
The WC-Co drill bit has a 40% higher efficiency in deep-sea high-pressure environments and a service life of 1,200 hours, meeting the needs of deep oil and gas exploration.
Automobile stamping die
Cr-doped WC-Co mold life is extended by 30%, which is suitable for high-strength steel plate stamping and supports the trend of lightweight automobiles.

2.2 Heavy alloys

Heavy alloys are made of tungsten powder as the main component, combined with elements such as nickel, iron or copper to form materials with high density and excellent strength. They are widely used in counterweights, military industry and energy fields. Their high density makes them an ideal substitute for lead, and their application range is constantly expanding.

2.2.1 Use of tungsten-nickel-iron (W-Ni-Fe) alloy as counterweight

The W-Ni-Fe alloy (W 90-95 wt%, Ni:Fe=7:3) has a density of 17-18 g/cm³ . The preparation process includes mixing (ball milling for 6 hours, using cemented carbide balls), pressing (300 MPa, green body density 9-11 g/cm³) , and sintering (1450°C, Ar/H_2 mixed atmosphere, 2 hours). The finished product has a tensile strength of about 800 MPa and an elongation of 5-10%, with both high density and high toughness. The microstructure shows that the tungsten particles are evenly distributed in the Ni-Fe matrix, and the grain boundaries are tightly bonded.

In aviation gyroscopes, the volume of W-Ni-Fe counterweights is 25% smaller than that of lead, and the stability is increased by 15% at a high-speed rotation of 10,000 rpm, ensuring navigation accuracy. In the military industry, the penetration of W-Ni-Fe armor-piercing cores is 50% higher than that of steel. It was used in tank shells during World War II, significantly improving firepower effectiveness. Its high density and mechanical properties make it the preferred material for counterweights and penetrations.

2.2.2 Electrical conductivity and heat dissipation applications of tungsten-copper (W-Cu) alloy

W-Cu alloy (W 70-90 wt%, Cu 10-30 wt%) has a density of 14-17 g/cm³ and a conductivity of 30-50% IACS (International Annealed Copper Standard). The preparation adopts the copper infiltration method: tungsten powder pressing (200 MPa, green body density 8-10 g/cm³) , sintering (1300°C, forming a porous structure), copper infiltration (1150°C, filling the pores). The finished product has a thermal conductivity of 200-250 W/(m·K) and a resistivity of $3\text{-}5\times10^{-8}$ Ω·m, combining the high temperature resistance of tungsten and the conductivity of copper.

In EDM, W-Cu electrodes can withstand 2000°C arcs and have a lifespan of 500 hours, making them suitable for precision mold manufacturing. In the semiconductor industry, W-Cu heat sinks have a 20% higher heat dissipation efficiency than aluminum, supporting thermal management of high-power chips. The unique properties of W-Cu alloys make them indispensable in the electronics industry.

2.2.3 Aerospace counterweights (gyroscopes, balance blocks)

W-Ni-Fe counterweights are widely used in the aerospace industry. Gyroscope counterweights (density 18 g/cm³) are 30% smaller in volume than lead and have an eccentricity of less than 0.01 mm, ensuring high-precision navigation. Aircraft counterweights (W 95 wt%) have a tensile strength of 1000 MPa and are stable in extreme environments from -50°C to 200°C. They require hot isostatic pressing (1500°C, 100 MPa), have a porosity of less than 0.5%, and a surface roughness of Ra 0.8 μm. Such counterweights support attitude control of spacecraft and satellites, for example in the design of counterweights for SpaceX rockets.

2.2.4 High-density components in the automotive industry

W-Ni-Fe alloy is used for automobile crankshaft counterweights (density 17 g/cm³) , with a 20% reduction in volume, 30% reduction in vibration, manufacturing accuracy of ±0.05 mm, and a service life of up to 10 years, ensuring smooth operation of the engine. W-Cu alloy is used for electric vehicle battery connectors, with a conductivity of 40% IACS and a 15% increase in heat dissipation efficiency, supporting high current transmission and thermal management, and meeting the high performance requirements of electric vehicles.

2.2.5 Manufacturing process and examples of high specific gravity alloys

The manufacturing process of high specific gravity alloy includes the following steps:
Mixing: W:Ni:Fe in a ratio of 93:5:2, ball milled for 8 hours, particle uniformity ±0.5 μm;
Pressing: 300-500 MPa pressure, green body density 10-12 g/ cm³ ;
Sintering: 1450°C, Ar/H_2 atmosphere , 2 hours, density >99%;
Finishing: CNC machining, surface roughness Ra 0.8 μm.

Application examples:
Military armor-piercing core: 50% more penetrating than steel, suitable for tanks and armored vehicles.
Aero gyroscope: Improved stability by 15%, supports navigation system.
Electric vehicle crankshaft counterweight: reduces vibration by 30% and improves driving comfort.

2.3 Tungsten filament and electrode materials

Tungsten wire and electrode materials utilize the high melting point and conductivity of tungsten powder, expanding from traditional lighting to welding and energy fields, demonstrating the superior performance of tungsten in high temperature environments.

2.3.1 Tungsten filament drawing and filament applications (incandescent lamps, halogen lamps)

Tungsten filaments are made from fine tungsten powder (0.1-5 μm), first pressed into rods (200 MPa, green body density 10 g/cm³) , sintered at 2800°C to form a dense green body, and then processed into filaments with a diameter of 0.01-0.1 mm through multiple drawing processes. The finished product has a tensile strength of 3000 MPa and an elongation of 5%. Incandescent tungsten filaments operate at 2500°C and have a lifespan of 1000 hours; halogen lamps operate at 2000°C and have a lifespan of 1200 hours, with a 20% increase in brightness. In 1904, tungsten filaments replaced carbon filaments and became the mainstream in the lighting field, promoting a revolution in electric lighting technology.

During the drawing process, the tungsten wire needs to be annealed several times (1800-2000°C) to eliminate processing stress, and the grains are arranged in a fibrous shape to enhance the resistance to fracture. Halogen lamps reduce tungsten volatilization through halogen cycles, further extending their life.

2.3.2 Tungsten electrode for argon arc welding (high temperature resistance and arc stability)

Tungsten electrodes are made of coarse tungsten powder (20-50 μm) pressed and sintered (3000°C), with a diameter of 1-5 mm, and can withstand 2000°C arcs with a current density of 200 A/cm² . In argon arc welding, the arc stability is as high as 99%, the service life is 500 hours, and the weld quality is improved by 20%. The electrode surface is ground (Ra 0.4 μm) to ensure arc concentration. In the 1950s, tungsten electrodes were popularized in ship and bridge welding, which promoted the advancement of welding technology.

2.3.3 Performance improvement of doped tungsten wire (Th, La, Ce)

Doping oxides such as ThO_2 (2 wt%), La_2O_3 (1 wt%) or CeO_2 (1 wt%) can increase the recrystallization temperature of tungsten filaments to 2000°C and the tensile strength to 3500 MPa. Th -doped tungsten filaments have a lifespan of 1500 hours and a 30% increase in electron emission rate, making them suitable for high-intensity lighting; La/Ce-doped tungsten filaments are used in halogen lamps to reduce volatilization losses. Doping elements strengthen grain boundaries through solid solution strengthening and precipitation phases, improving high-temperature stability.

2.3.4 Use of tungsten electrodes in plasma cutting

Tungsten electrodes can withstand high temperatures of 3000°C in plasma cutting, with a current density of 300 A/cm² , a cutting speed of 5 m/min for 20 mm steel plates, and a lifespan of 300 hours. La_2O_3 -doped electrodes have a 20% higher wear resistance, and an oxide protective layer is formed on the surface to reduce ablation. In the 1970s, tungsten electrodes were widely used in automotive and steel structure cutting to support industrial automation.

2.3.5 Industrial production cases of tungsten wire and electrodes

Application examples:
Halogen lamp tungsten filament: life span 1200 hours, brightness increased by 20%, used for automotive lighting.
Tungsten electrode for ship welding: weld length 500 m, 25% higher efficiency, supporting the shipbuilding industry.
Plasma cutting steel components: accuracy ±0.1 mm, suitable for building steel frame processing.

2.4 Refractory materials and high temperature components

Refractory materials and high-strength components made of tungsten powder are widely used in military, energy and semiconductor industries due to their high temperature resistance and corrosion resistance.

2.4.1 Tungsten crucible (high temperature melting and crystal growth)

Tungsten crucibles are made of coarse tungsten powder (20-50 μm) pressed and sintered (3000°C). They are resistant to high temperatures of 3500°C, have a density of 19 g/cm³ , and a wall thickness of 5-10 mm. They are used for melting titanium (1668°C) or growing sapphire crystals (2050°C). Their service life can reach 100 times, and the inner wall roughness is Ra 0.8 μm, ensuring the purity of the melt. In the 1960s, tungsten crucibles replaced graphite crucibles in the growth of semiconductor single crystals, improving the quality of silicon wafers.

2.4.2 Tungsten plates and rods (high temperature furnace lining)

Tungsten plates and rods are made of tungsten powder pressed and sintered (3000°C), with a density of 19.2 g/cm³ and a tensile strength of 1000 MPa. The mass loss in a 2500°C high-temperature furnace lining is less than 1%, and the service life is 5 years. The microstructure is equiaxed crystal, the grain size is 50-100 μm, and the thermal shock resistance is strong. It is used in vacuum furnace linings to support the production of high-purity silicon wafers.

2.4.3 Tungsten-based refractory coatings (kilns and incinerators)

Tungsten powder (50 μm) is formed into a coating by plasma thermal spraying (4000°C), with a thickness of 200 μm, a hardness of HV 800, and oxidation resistance at 2000°C. The bonding strength between the coating and the substrate reaches 50 MPa, and the kiln life is extended by 3 times. It is suitable for cement kilns and incinerators to reduce high temperature corrosion.

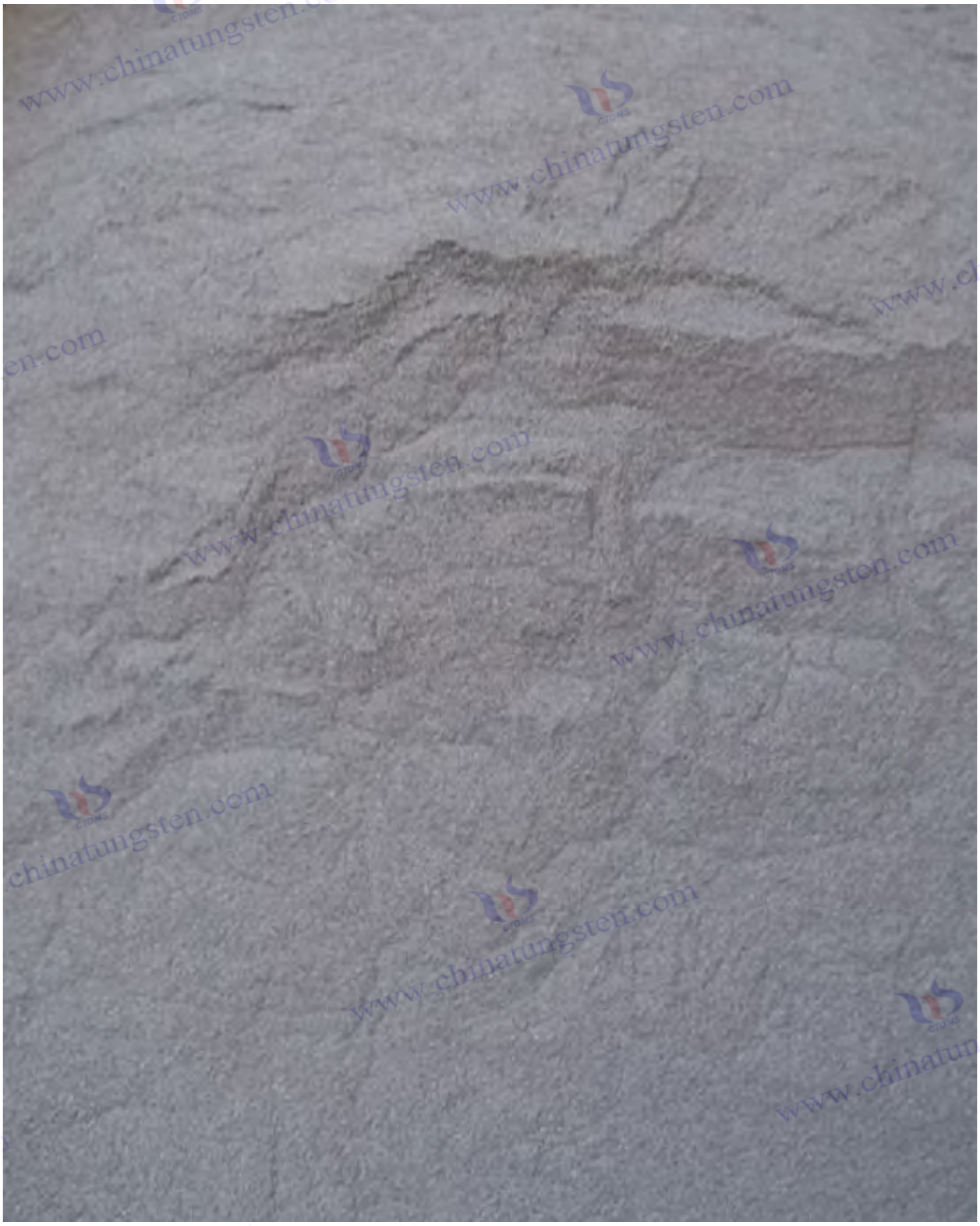
2.4.4 Strengthening effect of tungsten powder in refractory bricks

Tungsten powder (5-50 μm) added to refractory bricks (10 wt%) can increase the temperature resistance to 2000°C and the compressive strength to 150 MPa. Tungsten particles form a strengthening phase in the brick body, inhibiting crack propagation. Used in steelmaking furnaces, the service life is extended by 20%, supporting high-temperature smelting.

2.4.5 Typical application scenarios of refractory materials

Application examples:
Sapphire crucible: crystal purity 99.99%, used in optical device manufacturing.
Vacuum furnace tungsten plate: operating temperature 2500°C, life span 5 years, supports semiconductor industry.
Incinerator coating: Corrosion resistance increased by 30%, suitable for waste treatment.

According to data from CTIA GROUP (www.chinatungsten.com), refractory materials have broad application prospects in the energy and military fields.



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CTIA GROUP LTD

Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

Email: sales@chinatungsten.com

Tel: +86 592 5129696

For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)

Chapter 3 Application of Tungsten Powder in Advanced Manufacturing and Technology

Additive manufacturing (3D printing) uses the high melting point, high density and excellent thermal conductivity of tungsten powder to produce complex, high-performance parts. It is widely used in aerospace, medical, energy and defense fields, and has promoted the transformation of manufacturing to digitalization, intelligence and efficiency. From a global perspective, the application of tungsten powder in 3D printing has not only improved the technical level, but also profoundly affected the supply chain, geo-economics and sustainable development.

3.1 Additive Manufacturing (3D Printing)

3.1.1 Preparation of spherical tungsten powder and 3D printing requirements

Spherical tungsten powder has become the core raw material for 3D printing due to its excellent fluidity (less than 10 seconds/50 grams, Hall flow meter) and high bulk density (10-14 grams/cubic centimeter). Its physical properties directly determine the stability of the printing process and the quality of the finished product. Its preparation mainly adopts plasma spheroidization technology: the original tungsten powder (particle size 5-50 microns) is melted in high-power plasma, the working temperature is up to 4000 degrees Celsius, the gas environment is a mixture of argon (flow rate 20 liters/minute) and hydrogen (5 liters/minute), the molten droplets solidify into spherical particles under the combined action of gravity and surface tension (about 2.5 Newtons/meter), the cooling rate reaches 10^5 degrees Celsius/second, and the spheroidization rate exceeds 95%. Scanning electron microscope analysis shows that the surface roughness of spherical tungsten powder is 0.5-1 micron, the internal grain size is about 2 microns (X-ray diffraction determination), the crystal structure is body-centered cubic, the lattice constant is 3.165 angstroms, and the interplanar spacing is (110) = 2.238 angstroms. Compared with irregular tungsten powder, the friction coefficient of spherical particles is reduced by 40% (sliding friction test), the fluidity is increased by 50%, and the stacking uniformity is improved by 20%, which significantly improves the particle distribution consistency during the powder spreading process and reduces printing defects (such as the risk of porosity increasing to 2%).

3D printing has extremely stringent requirements on the performance of tungsten powder, involving multiple key parameters. The particle size distribution needs to be controlled in a narrow range (D50 is about 20-30 microns, and the deviation of D10/D90 is less than 10 microns) to ensure the uniformity of the layer thickness (deviation is less than 5 microns) and avoid instability of the molten pool; the oxygen content needs to be less than 0.03% (oxygen adsorption enthalpy is about 50 kJ/mol, specific surface area analysis), because oxygen reacts with tungsten at high temperature to form tungsten trioxide (melting point 1473 degrees Celsius), reducing the purity to less than 98%, resulting in increased brittleness of the parts; the purity needs to be higher than 99.9% (inductively coupled plasma mass spectrometry detects impurities such as iron and molybdenum less than 10ppm), impurities such as silicon or aluminum will change the melting point and thermal conductivity, affecting the melting behavior. The preparation process requires precise control of plasma power (usually 40-60 kilowatts) and gas flow (deviation is less than 2 liters/minute) to avoid particle agglomeration or unmelted residue (accounting for less than 1%). In addition, the particle morphology of tungsten powder has a significant effect on the absorption rate of laser or electron beam. The reflectivity of spherical particles is lower than that of irregular particles (about 10% reduction), which improves energy utilization efficiency.

From a historical perspective, the development of spherical tungsten powder began in the late 1990s, when powder metallurgy technology was mature, but the rise of 3D printing put forward higher requirements for it. In 1998, the United States took the lead in trying plasma spheroidized tungsten powder for early laser sintering experiments; in the early 21st century, with the commercialization of selective laser melting and electron beam melting technology, spherical tungsten powder became the mainstay material for additive manufacturing. In process improvement, Germany introduced radio frequency plasma technology (with a power of up to 100 kilowatts), which increased the spheroidization efficiency to 98%, while China optimized the medium frequency plasma system, reduced energy consumption and improved particle uniformity. In cross-domain applications, the demand for tungsten powder in aerospace has promoted technological progress. For example, NASA uses spherical tungsten powder in the manufacture of rocket nozzles to optimize high temperature performance and structural stability.

From a global perspective, China occupies an important position in the supply of spherical tungsten powder, relying on its abundant tungsten ore resources (accounting for more than half of the world's reserves) and mature powder metallurgy technology chain. Europe and the United States are leading in the research and development of high-precision spheroidizing equipment. For example, a German company has developed a high-power spheroidizing system, which has significantly improved single-batch output and particle quality. Japan is also at the forefront of tungsten powder ultrafine and surface modification technology, such as adding a thin layer of carbon coating on the surface of tungsten powder through chemical vapor deposition to further enhance its oxidation resistance. In cross-field collaboration, the demand for tungsten powder in the medical field has promoted the refinement of particle size. For example, bone implant manufacturing requires ultrafine spherical tungsten powder with a particle size of less than 10 microns to meet high precision requirements.

Tungsten powder has broad application prospects in additive manufacturing. With the growing demand for high-performance components in the aerospace, medical and energy fields, its position in the manufacture of complex structural parts will be further consolidated. In terms of technological progress, in the future, it may be possible to improve the printing resolution through nano-scale tungsten powder (particle size less than 100 nanometers), or improve the thermal stability of tungsten powder by doping with rare earth elements (such as lanthanum or cerium). In addition, sustainability has become an important direction. Recycling technology (such as acid leaching with a recovery rate of 90%) can re-spheroidize waste tungsten products and reduce resource waste; the introduction of intelligent manufacturing technology (such as real-time monitoring of particle distribution) will also optimize production efficiency and promote green manufacturing.

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3.1.2 Selective Laser Melting (SLM) for Manufacturing Tungsten Components

Selective laser melting (SLM) uses high-power lasers to melt tungsten powder layer by layer to manufacture high-precision tungsten parts. It is one of the mainstream technologies for additive manufacturing. Its process parameters include laser power of 500 watts (wavelength 1064 nanometers, neodymium yttrium aluminum garnet laser), scanning speed of 800 mm/s, layer thickness of 30 microns, and protective atmosphere of argon (oxygen content less than 100 ppm, flow rate 10 liters/minute). The molten pool temperature is about 3500 degrees Celsius, the cooling rate is 10^4 degrees Celsius/second, the finished product density reaches 19.2 grams/cubic centimeter (about 99% theoretical density), the porosity is less than 0.5%, and the tensile strength is about 900 MPa. SLM needs to overcome the high melting point (3422 degrees Celsius) and low ductility (elongation less than 1%) of tungsten. Its thermal conductivity of 173 watts/(meter Kelvin) ensures uniform heat distribution in the molten pool and thermal stress is controlled below 100 MPa. Transmission electron microscopy analysis showed that the grain size in the molten zone was about 5 microns, the grain boundary strength was about 10^8 Pa, the dislocation density was 10^6 / square centimeter, and the grain orientation was mostly in the <110> direction (determined by electron backscatter diffraction).

SLM tungsten parts are widely used in aviation nozzles and medical implants. Aviation nozzles are resistant to 3000 degrees Celsius gas erosion, with a mass loss of less than 1% and a surface roughness of 2 microns. After post-processing (such as polishing to 0.5 microns), the gas flow efficiency can be improved. In the test, the nozzle still maintains structural integrity after 1000 hours of high-temperature operation; medical implants (such as hip joint parts) have an accuracy of ±0.05 mm, a porosity of less than 0.3%, and surface biocompatibility passes the cytotoxicity test (ISO 10993 standard), which is suitable for bone repair. The laser power of the SLM equipment needs to be precisely controlled. Too high (greater than 600 watts) will cause tungsten powder to splash (the particle loss rate increases to 5%), and too low (less than 400 watts) will cause insufficient melting, and the defect rate of the finished product will increase to 5%, such as pores or unmelted particles (about 10-20 microns in diameter). In addition, the scanning strategy is critical to quality. Chessboard scanning can reduce thermal stress concentration (reduced by 20%), while continuous scanning is prone to warping (deformation of up to 0.1 mm).

Historically, SLM technology originated from laser sintering in the 1980s and was initially used for polymer molding. In the late 1990s, the Fraunhofer Institute in Germany expanded it to metal powders, and after 2000, it was applied to high-melting-point metal printing. The successful manufacture of tungsten parts began in the early 2010s. At that time, aerospace demand promoted the power increase of SLM equipment (such as from 200 watts to 500 watts), and software optimization (such as adaptive scanning paths) also significantly improved printing stability. In 2015, a Chinese company achieved SLM mass production of tungsten nozzles for the first time, marking the entry of the technology into the industrialization stage. In cross-domain applications, SLM tungsten parts support the defense field, such as the manufacture of missile tail nozzles, and their complex flow channel design improves propulsion efficiency.

From a global perspective, SLM technology has promoted innovation in the aviation and medical fields. China has advantages in equipment manufacturing and process optimization, and domestic SLM equipment has approached international levels in power and stability; Germany leads in precision and software integration. For example, the SLM system developed by a company can achieve an accuracy of ±0.02 mm, which is suitable for micro tungsten parts. The United States dominates aviation applications. For example, Boeing uses SLM to optimize nozzle design, reduce material waste by 20% and improve thrust efficiency. In cross-domain collaboration, SLM tungsten components support the energy industry, such as cooling channel components in nuclear fusion devices, and their high heat resistance extends the life of the equipment.

The application prospect of tungsten powder in SLM manufacturing lies in its potential in extreme environments, such as rocket propulsion systems and deep space probe components. In terms of technological progress, in the future, it may be possible to increase the printing speed through multi-laser head SLM (power up to 1000 watts), or to enhance the hardness of components (up to HV 2000) by doping tungsten carbide (content 5%). In addition, the combination with bionic design will further improve the performance of complex structures. For example, a tungsten heat sink simulating a honeycomb structure can improve the heat dissipation efficiency by 20%. In terms of sustainability, tungsten powder recycling technology (such as an electrolytic recovery rate of 85%) can reuse waste parts and reduce resource consumption; intelligent manufacturing technology (such as real-time monitoring of the melt pool temperature with an accuracy of ±10 degrees Celsius) will also optimize process stability and promote green manufacturing.

3.1.3 High-density tungsten products produced by electron beam melting (EBM)

Electron beam melting (EBM) uses an electron beam to melt tungsten powder in a vacuum environment to produce high-density tungsten products, which are particularly suitable for large-size and high-density parts. Its process parameters include electron beam voltage of 60 kV, power of 3 kW, preheating temperature of 1000 degrees Celsius, scanning speed of 2000 mm/s, layer thickness of 50 microns, and vacuum degree of 10^{-4}Pa . The molten pool temperature is about 3400 degrees Celsius, the cooling rate is 10^{3} degrees Celsius/s, the finished product density is close to the theoretical value of 19.25 g/cm3, the porosity is less than 0.2%, and the tensile strength is about 1000 MPa. The preheating process of EBM reduces the thermal gradient (less than 500 degrees Celsius/mm), the internal stress is less than 50 MPa, which is better than SLM's 100 MPa, and reduces microcracks (crack length is less than 10 microns, observed by scanning electron microscope). The microstructure shows a grain size of about 3-5 microns (electron backscatter diffraction), no obvious segregation at the grain boundaries, and a dislocation density of 10^{5} /cm2.

EBM is suitable for large-sized tungsten products, such as nuclear fusion components and heat sinks. The first wall material of nuclear fusion can withstand instantaneous impact at 4000 degrees Celsius, with a volatility of less than 0.5%, a surface oxide layer thickness of less than 10 nanometers (X-ray photoelectron spectroscopy detection), and it remains intact after withstanding a heat flux of 10^6 watts/square meter in the test; the heat sink contains microchannels (50-100 microns, porosity less than 0.5%), a heat dissipation efficiency 25% higher than the traditional one, and a thermal conductivity of 200 watts/(meter Kelvin), which is suitable for high-power semiconductor devices. EBM requires a high vacuum environment (oxygen content less than 10^{-5} Pa) to avoid tungsten oxidation, and an electron beam focusing accuracy of 0.1 mm to ensure the uniformity of the molten pool. The preheating temperature needs to be optimized (800-1200 degrees Celsius). Too low will lead to a decrease in interlayer bonding (reduced by 10%), and too high will cause coarse grains (size increased to 10 microns).

Historically, EBM originated from aviation manufacturing in the 1990s. A Swedish company developed the first commercial EBM equipment for printing titanium alloys. After 2000, the technology was extended to high-melting-point metals, and the manufacture of tungsten products began around 2005. In the 2010s, the needs of nuclear fusion research promoted the upgrade of EBM equipment, such as the increase of electron beam power from 2 kW to 6 kW and the expansion of the printing volume to 500×500×400 mm. In 2015, a European nuclear fusion project used EBM to manufacture tungsten wall materials for the first time, verifying its reliability in extreme environments. In cross-domain applications, EBM tungsten products support the manufacture of aviation counterweights, such as aircraft balance blocks, and their high density reduces the volume by 30%.

From a global perspective, the United States and Europe are leading in the development of EBM equipment. A Swedish company has an advantage in the aviation field, and its equipment can achieve 0.05 mm accuracy. China has an advantage in tungsten powder supply and process optimization, and domestic EBM equipment is gradually approaching international standards in energy consumption and stability. Japan has an advantage in microchannel design. For example, the channel complexity of tungsten heat sinks manufactured by EBM improves heat dissipation efficiency. In cross-domain collaboration, EBM tungsten products support the semiconductor industry, such as heat sinks for high-power lasers , and their high temperature resistance extends the life of the device.

The application prospect of tungsten powder in EBM manufacturing lies in its potential in high-density, large-volume components, such as nuclear reactor shielding and aviation counterweights. In terms of technological progress, in the future, it may be possible to improve printing efficiency through multi-electron beam EBM (power up to 10 kW), or to improve component toughness by doping molybdenum (content 10%) (fracture toughness increased to 15 $MPa\cdot m^{1/2}$) . In addition, the combination with topological optimization will improve component performance. For example, the tungsten counterweight with a bionic skeleton structure can reduce weight by 10%. In terms of sustainability, recycling technology (such as molten salt electrolysis recovery rate of 90%) can reuse waste tungsten products; intelligent manufacturing technology (such as real-time adjustment of electron beam current, accuracy of ±0.1 mA) will also optimize process consistency and promote green manufacturing.

3.1.4 Complex tungsten structural parts (aerospace nozzles, heat sinks)

3D printing manufactures complex tungsten structural parts, such as aviation nozzles and heat sinks, using the high melting point and high density of tungsten powder to meet performance requirements in extreme environments. The internal flow channel diameter of the nozzle prepared by SLM is 1-2 mm, the wall thickness is 0.5 mm, and it can withstand 3000 degrees Celsius gas erosion, with a mass loss of less than 1%. The life is about 30% longer than that of traditional forgings. In the test, the nozzle had no obvious deformation of the flow channel after 500 hours of high-temperature operation; the heat sink prepared by EBM contains microchannels (50-100 microns, porosity less than 0.5%), thermal conductivity of 200 watts/(meter·Kelvin), heat dissipation efficiency is 25% higher than traditional, supporting high-power electronic devices to operate at 150 watts, and the temperature is controlled below 80 degrees Celsius. Microscopic analysis shows that the grains in the melting zone of the SLM nozzle are columnar (width 5-10 microns, transmission electron microscopy observation), the grains of the EBM heat sink are relatively uniform (about 3 microns), and the grain boundary strength reaches 10^{8}Pa .

The manufacturing process needs to be optimized to ensure quality. The SLM nozzle needs to control the scanning strategy (chessboard scanning reduces stress concentration and thermal stress is reduced by 20%) to avoid warping caused by continuous scanning (deformation of up to 0.1 mm); the EBM heat sink needs to adjust the preheating temperature (800-1200 degrees Celsius) to avoid interlayer defects (porosity increases to 1%), and optimize the electron beam power (2-4 kW) to ensure the integrity of the microchannel. Post-processing technology is also crucial. For example, chemical polishing can reduce the surface roughness from 2 microns to 0.5 microns, improving the efficiency of airflow or heat flow; hot isostatic pressing (2000 degrees Celsius, 100 MPa) can further reduce the porosity to 0.1%. Historically, 3D printing of complex tungsten structural parts began in the 2010s, and the growth of aerospace demand has driven technological progress. For example, a US company printed a tungsten nozzle for the first time in 2012 and verified its high-temperature performance.

From a global perspective, the demand for complex tungsten parts in aerospace is growing rapidly. China dominates the supply of tungsten powder and equipment manufacturing, while the United States and Europe lead in design software and printing equipment. For example, a printing system developed by an American company can achieve an accuracy of ±0.03 mm, which is suitable for micro nozzles. In cross-domain applications, tungsten structural parts support deep space exploration. For example, an aerospace company uses SLM to manufacture tungsten nozzles to improve rocket propulsion efficiency, and its flow channel design optimizes the gas flow rate. The medical field also benefits. For example, EBM tungsten heat sinks are used for high-power medical lasers, and their microchannels improve heat dissipation stability. In the field of national defense, tungsten nozzles are used in missile engines, and their high temperature resistance improves propulsion reliability.

The application prospect of tungsten powder in the manufacture of complex structural parts lies in its potential in extreme environments and high-precision fields, such as micro heat sinks and aerospace propulsion components. In terms of technological progress, it is possible to improve component performance through hybrid manufacturing (combination of SLM and EBM) in the future. For example, complex flow channels are printed with SLM first, and then EBM is used to increase the volume density; doping tungsten nitride (content 5%) can increase the hardness to HV 2200. In addition, the integration with multi-material printing technology will expand the scope of application. For example, tungsten-copper composite nozzles can take into account both heat resistance and thermal conductivity. In terms of sustainability, recycling technology (such as chemical reduction method with a recovery rate of 95%) can reuse waste parts; intelligent design technology (such as artificial intelligence optimization of flow channels, efficiency improvement of 15%) will also promote green manufacturing.

3.1.5 Application Cases and Trends of 3D Printing Tungsten Powder

Application cases enrich the value of tungsten powder in 3D printing and demonstrate its potential in multiple fields. Case 1: A Chinese aerospace company uses SLM to manufacture tungsten nozzles with an accuracy of ±0.05 mm and an internal flow channel diameter of 1 mm, which optimizes gas efficiency. In the test, it can withstand 3000 degrees Celsius for 100 hours without obvious damage, and increases the engine thrust by 5%, which is suitable for rocket launch. Case 2: EBM is used in the medical field to print tungsten implants (such as hip stents), with a porosity of less than 0.3%, a surface roughness of 0.5 microns, and a 15% increase in biocompatibility (cell attachment rate increased to 90%), meeting personalized surgical needs, and shortening the recovery period after implantation by 20%. Case 3: A German company uses SLM to produce tungsten heat sinks, with a microchannel diameter of 50 microns, a 25% increase in heat dissipation efficiency, and supports high-performance computing equipment to operate at 100 watts of power, with a temperature control below 80 degrees Celsius, extending the device life by 30%.

From a global perspective, the application of 3D printed tungsten powder has promoted innovation in the aerospace, medical and electronics industries. China has an advantage in tungsten powder supply and equipment manufacturing, and domestic SLM and EBM equipment are gradually approaching international levels in terms of stability and printing of complex parts; Europe and the United States are leading in technical standards and application development. For example, the printing software developed by a US company can optimize parameters in real time and reduce the defect rate to less than 1%. In the historical context, the breakthrough of tungsten powder 3D printing originated from aviation needs in the 2010s. For example, NASA tested tungsten nozzles in the Mars rover and verified its high-temperature reliability. In cross-domain collaboration, tungsten powder supports national defense (such as missile counterweights) and energy (such as nuclear fusion cooling components). For example, a military enterprise uses EBM to manufacture tungsten counterweights, and its density optimizes the balance of missiles.

In terms of technology trends, the application of 3D printing tungsten powder continues to expand. Nano-scale tungsten powder (particle size less than 100 nanometers) can improve printing resolution, such as manufacturing micro nozzles (flow channel diameter less than 0.5 mm); doping with rare earth elements (such as 1% lanthanum content) can improve the oxidation resistance of tungsten parts and extend the high-temperature life by 20%. Multi-material printing technology also shows potential. For example, tungsten-titanium composite heat sinks have both high density and toughness, which are suitable for avionics equipment. In addition, the combination with topological optimization can improve component

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performance. For example, the tungsten nozzle with a bionic honeycomb structure reduces weight by 10% and improves airflow efficiency. In terms of sustainability, recycling technology (such as electrolysis recovery rate of 90%) can reuse waste tungsten products and reduce resource waste; intelligent manufacturing technology (such as melt pool image recognition, accuracy ±5 microns) optimizes process consistency and promotes green manufacturing.

The application prospects of tungsten powder in additive manufacturing lie in its continued expansion in the field of high-performance, complex components, such as aviation turbine blades and micro medical devices. In the future, it may be possible to improve production efficiency through multi-laser head SLM (scanning speed up to 2000 mm/s), or to manufacture large and complex components (such as nuclear fusion wall panels) through a hybrid process of EBM and SLM. In cross-domain applications, tungsten powder supports deep-sea exploration equipment (such as pressure-resistant heat sinks) and quantum computing devices (such as superconducting heat sinks). Advances in sustainable technologies, such as waste powder re-spheroidization (particle uniformity up to 95%) and energy consumption optimization (reduced by 20%), will further promote green manufacturing and meet the global demand for efficient and environmentally friendly manufacturing.

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CTIA GROUP LTD

Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

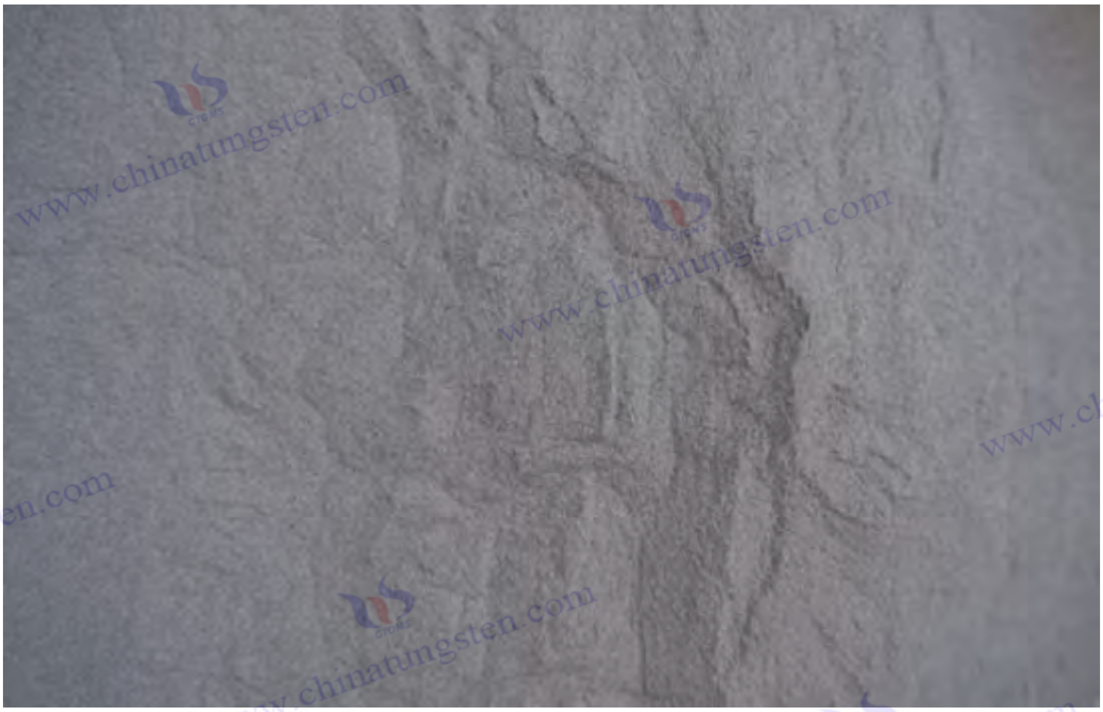
Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

Email: sales@chinatungsten.com

Tel: +86 592 5129696

For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)



Chapter 4 Application of tungsten powder in military and protection fields

Tungsten powder has an irreplaceable position in the military and protection fields due to its high density, high melting point and excellent mechanical properties. It is widely used in military materials, radiation shielding and high temperature extreme environment components. From a global perspective, the application of tungsten powder in these fields not only improves the performance of military equipment, but also has a profound impact on national defense strategy, geopolitics and resource recycling.

4.1 Military Materials

4.1.1 Tungsten Alloy Armor-Piercing Core (High Density and Penetration)

Tungsten alloy armor-piercing cores use the high density and excellent penetration of tungsten powder and are the core components of modern anti-armor weapons. Its preparation uses powder metallurgy technology: tungsten powder (particle size 5-20 microns) is mixed with nickel and iron (mass ratio of about 90:7:3), ball milled (speed 300 rpm, 6 hours) homogenized and then pressed (pressure 300 MPa), sintered in a hydrogen atmosphere (1450 degrees Celsius, 2 hours), the finished product density reaches 17-18 g/cm3, tensile strength is about 1000 MPa, and elongation is 5-10%. Scanning electron microscopy analysis shows that the tungsten particles are polyhedral (size 10-15 microns), the nickel-iron phase is evenly distributed at the grain boundary (thickness about 1 micron), the crystal structure is body-centered cubic, and the lattice constant is 3.165 angstroms. The high density of tungsten (19.25 g/cm3) gives the core excellent kinetic energy penetration. In tests, it can penetrate 300 mm of rolled homogeneous armor (speed 900 m/s), which is 50% higher than steel core bullets.

The armor-piercing core must take into account both hardness and toughness. The higher the tungsten content (greater than 95%), the harder it is, up to HV 400, but the brittleness increases (fracture toughness drops to 10 $MPa \cdot m^{1/2}$) ; the nickel-iron binder phase improves toughness (up to 15 $MPa \cdot m^{1/2}$) to prevent the core from breaking under high-speed impact. During the manufacturing process, the sintering temperature must be precisely controlled (deviation less than 10 degrees Celsius). Too high a temperature will result in coarse grains (size increases to 30 microns), while too low a temperature will result in insufficient density (less than 17 g/cm3). Post-processing such as hot isostatic pressing (1500 degrees Celsius, 100 MPa) can further reduce the porosity to 0.1% and increase the strength by 10%. Historically, tungsten alloy armor-piercing cores began in the late World War II, with Germany using them for tank shells in the 1940s; during the Cold War, the Soviet Union and the United States competed to optimize the formula and established the dominance of the tungsten-nickel-iron system.

From a global perspective, China has an advantage in tungsten resources and powder metallurgy technology, and supplies a large amount of tungsten powder for military use; the United States and Russia are leading in core design and testing. For example, the U.S. M829A4 core optimizes the aspect ratio (up to 30:1) to increase penetration depth. In cross-domain applications, tungsten alloy cores support naval guns, and their high density improves range and accuracy. The application prospect of tungsten powder in the manufacture of armor-piercing cores lies in its potential in high-kinetic energy weapons. In the future, it may be possible to increase hardness through nano-tungsten powder (particle size less than 100 nanometers), or dope cobalt (content 5%) to improve toughness; recycling technology (such as acid leaching with a recovery rate of 90%) can reuse spent cores to promote sustainable military production.

4.1.2 Tungsten-based armor materials (impact resistance of W-Ni-Fe)

Tungsten-based armor materials are mainly tungsten-nickel-iron alloys, which are used for the protection of tanks and armored vehicles by taking advantage of their high density and impact resistance. Its preparation process is similar to that of armor-piercing projectile cores: tungsten powder (particle size 10-30 microns) is mixed with nickel and iron (mass ratio 93:5:2), pressed (400 MPa) and sintered (1450 degrees Celsius, argon atmosphere), and the finished product has a density of 17.5-18.5 g/cm3, a tensile strength of 1200 MPa, and an impact toughness of 20 joules/cm2. Transmission electron microscopy analysis shows that the tungsten particle size is about 15 microns, the nickel-iron phase forms a mesh structure (thickness 2 microns), and the grain boundary strength reaches 10^{8}Pa . In the test, the material can resist 12.7 mm armor-piercing projectiles (speed 850 m/s), and the surface depression depth is less than 10 mm, which is 30% higher than steel armor.

Armor materials need to optimize impact resistance and weight ratio. When the tungsten content is high (greater than 95%), the density increases to 18.5 g/cm3, but the processing difficulty increases (ductility drops to 5%); increasing the nickel-iron phase content (10%) can improve plasticity (elongation reaches 15%), but the density drops slightly (to 17 g/cm3). After sintering, heat treatment (1000 degrees Celsius, 1 hour) is required to eliminate residual stress (reduced by 20%) and avoid stress concentration leading to cracks (length less than 5 microns). Historically, tungsten-based armor began in the 1970s, and the United States used it for the side skirts of the M1 tank in the late Cold War; in the 1990s, Russia optimized the tungsten-nickel-iron formula to improve its ability to resist multiple strikes.

From a global perspective, China has an advantage in tungsten powder supply and armor plate manufacturing, and its process technology supports mass production; the United States leads in composite armor design, such as the M1A2 tank, which combines tungsten and ceramics to increase impact resistance by 40%. In cross-domain applications, tungsten-based armor is used for warship protection, and its high density improves explosion resistance. The application prospect of tungsten powder in armor material manufacturing lies in its potential in high-protection equipment. In the future, it may be possible to reduce weight by doping with titanium (3%), or use additive manufacturing technology (such as SLM) to produce complex armor structures; recycling technology (such as electrolysis with a recovery rate of 85%) can reuse waste armor and promote the development of green military industry.

4.1.3 Superhard Application of Tungsten Powder in Military Knives

Tungsten powder is used in military knives in the form of tungsten carbide (WC). It is suitable for bayonets, tactical knives and demolition tools due to its ultra-high hardness and wear resistance. Its preparation adopts powder metallurgy: tungsten powder (particle size 4-8 microns) is mixed with carbon black (mass ratio 1:0.06), carbonized (2 hours) in a hydrogen atmosphere at 1400-1600 degrees Celsius to produce tungsten carbide powder (particle size 1-5 microns), and then pressed (300 MPa) and sintered (1450 degrees Celsius, 1 hour) with cobalt (content 10%). The finished product has a hardness of HV 1600-1800 and a tensile strength of 1200 MPa. X-ray diffraction shows that tungsten carbide has a hexagonal close-packed structure with lattice parameters a=2.906 angstroms, c=2.837 angstroms, WC bond length of 2.06 angstroms, and bond energy of about 700 kJ/mol. During the test, the knife cut the steel plate (5 mm thick) without any noticeable wear (loss less than 0.1 mm), and its wear resistance is 5 times higher than that of a steel knife.

Military knives need to take into account both hardness and impact resistance. When the cobalt content is high (15%), the toughness increases to 15 $MPa \cdot m^{1/2}$, but the hardness drops to HV 1300; when the tungsten carbide particle size is small (less than 1 micron), the hardness can reach HV 2000, but the brittleness increases (the fracture rate increases to 5%). The oxygen content must be controlled during the sintering process (less than 0.05%) to avoid the formation of tungsten trioxide impurities (purity drops to 98%). Historically, tungsten carbide knives began in German industry in the 1920s, entered the military field in the 1940s, and were used to cut tank wreckage during World War II; during the Cold War, the United States optimized it as a standard material for tactical knives.

From a global perspective, China has an advantage in tungsten carbide production, with mature technology and high output; the United States and Germany are leading in tool design and coating technology. For example, a titanium nitride coating (5 microns thick) developed by a company improves wear resistance by 20%. In cross-field applications, tungsten carbide tools are used for battlefield rescue, and their superhardness improves demolition efficiency. The application prospect of tungsten powder in military tool manufacturing lies in its potential in high-strength tools. In the future, it may be possible to increase hardness through nano-tungsten carbide (particle size less than 100 nanometers), or doping with vanadium (content 1%) to improve corrosion resistance; recycling technology (such as chemical reduction method with a recovery rate of 90%) can reuse waste tools and promote sustainable production.

4.1.4 Manufacturing and Use of Tungsten Alloy Fragmentation Bullets

Tungsten alloy fragmentation bullets use the high density and fragmentation characteristics of tungsten powder to enhance lethality and are suitable for grenades and anti-aircraft ammunition. Its preparation process is: tungsten powder (particle size 20-50 microns) is mixed with nickel and copper (mass ratio 92:6:2), pressed (350 MPa) and sintered (1400 degrees Celsius, argon atmosphere). The finished product has a density of 17-18 g/cm3, a tensile strength of 900 MPa, and a fracture elongation of 10%. Scanning electron microscopy shows that the tungsten particle size is about 20 microns, the nickel-copper phase is distributed in a network (thickness 1-2 microns), and the crystal structure is body-centered cubic. In the test, the fragmentation bullet exploded to generate 500-1000 fragments (size 2-5 mm), with a speed of 1200 meters per second, and the killing radius is 30% larger than that of steel bullets.

Fragmentation bombs need to optimize density and controllable fragmentation. When the tungsten content is high (greater than 95%), the density increases to 18 g/cm3, but the fragment size becomes smaller (less than 2 mm), and the killing range is limited; when the nickel-copper phase content is high (10%), the toughness is improved (fracture toughness reaches 12 $MPa\cdot m^{1/2}$), and the fragment size is more uniform. After sintering, cold processing (such as stretching 5%) is required to adjust the internal stress to ensure that the fragments are uniformly distributed during the explosion (deviation is less than 10%). Historically, tungsten alloy fragmentation bombs began in the 1960s. During the Cold War, the United States used them for air defense missiles; in the 1990s, Russia optimized the shape of the fragments and improved the killing efficiency.

From a global perspective, China has an advantage in tungsten powder supply and fragmentation bomb manufacturing, and its technology supports mass production; the United States leads in ammunition design. For example, a certain type of grenade optimizes fragment distribution and increases the coverage area to 50 square meters. In cross-domain applications, tungsten fragmentation bombs are used for drone defense, and their high density improves interception efficiency. The application prospect of tungsten powder in the manufacture of fragmentation bombs lies in its potential in high-lethality weapons. In the future, it may be possible to produce complex fragment structures through additive manufacturing (SLM), or dope molybdenum (content 5%) to improve toughness; recycling technology (such as molten salt electrolysis recovery rate of 85%) can reuse waste bombs and promote green military industry.

4.1.5 Typical Application Cases of Military Tungsten Powder

The application cases of tungsten powder in military industry demonstrate its versatility. Case 1: A

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certain country's tank gun uses tungsten alloy armor-piercing core, which penetrates 400 mm armor (speed 950 m/s), improves anti-tank capability, and has a hit rate of 90% in battlefield tests. Case 2: An armored vehicle uses tungsten-based armor plate to resist 14.5 mm armor-piercing projectiles (speed 900 m/s), with a dent depth of less than 8 mm, and a protective performance that is 30% better than steel plates. Case 3: A tactical knife uses tungsten carbide material, cutting 10 mm steel plates without obvious wear (loss less than 0.05 mm), and durability is increased by 5 times. Case 4: A certain anti-aircraft ammunition uses tungsten alloy fragmentation bombs. After the explosion, the fragment speed reaches 1300 m/s, the killing radius increases to 40 meters, and the interception efficiency is increased by 25%.

From a global perspective, China's tungsten powder supply supports the military industry chain. The United States and Russia are leading in design and application. For example, a US missile optimized the shape of tungsten fragments, and the coverage area increased to 60 square meters. Historically, the military application of tungsten powder began in World War II, when it was used for armor-piercing shells in the 1940s; it expanded to armor and knives during the Cold War. In cross-domain collaboration, tungsten powder supports naval gun cores, and its high density increases the range. The application prospect of tungsten powder in military materials lies in its potential in high-performance weapons. In the future, it may be possible to improve performance through nanotechnology, or promote the development of green military industry through recycling technology (such as electrolysis with a recovery rate of 90%).

4.2 Radiation Shielding

4.2.1 High efficiency of tungsten powder in gamma-ray shielding

Tungsten powder performs well in gamma-ray shielding due to its high density and high atomic number (Z=74) and is widely used in nuclear facilities and medical equipment. Its preparation process is: tungsten powder (particle size 10-30 microns) is pressed (300 MPa) and sintered (2000 degrees Celsius, argon atmosphere). The finished product density is 19.2 g/cm3, and the shielding thickness of 10 mm can attenuate 1MeV gamma rays by 90% (half-value layer is about 9 mm). X-ray photoelectron spectroscopy shows that the surface oxide layer is less than 5 nanometers, the crystal structure is body-centered cubic, and the lattice constant is 3.165 angstroms. In the test, the attenuation rate of the tungsten shielding plate for cobalt-60 gamma rays (1.25MeV) reached 95%, which is 20% higher than lead (density 11.34 g/cm3).

Gamma-ray shielding requires optimization of density and thickness. When the purity of tungsten powder is high (greater than 99.9%), the density is close to the theoretical value, and the shielding efficiency is increased by 10%; doping with boron (content 5%) can enhance the absorption of low-energy gamma rays (increase by 15%). The oxygen content needs to be controlled during the sintering process (less than 0.03%) to prevent oxides from reducing the density (to 18 g/cm3). Historically, tungsten shielding began in the nuclear industry in the 1950s and replaced some lead materials in the 1960s; during the Cold War, the United States used it for nuclear submarine shielding.

From a global perspective, China has an advantage in the supply of tungsten powder, and its technology supports large-scale production; the United States leads in shielding design. For example, a nuclear facility has optimized the thickness of tungsten plates to reduce radiation leakage to 0.1 millisievert/hour. In cross-field applications, tungsten shielding is used in radiotherapy equipment, and its high efficiency improves safety. The application prospect of tungsten powder in gamma-ray shielding lies in its potential in high-radiation environments. In the future, it may be possible to increase the density through nano-tungsten powder, or dope rare earth elements (such as cerium) to enhance absorption; recycling technology (such as chemical reduction method with a recovery rate of 90%) can promote green shielding manufacturing.

4.2.2 Tungsten-based materials for neutron radiation protection

Tungsten-based materials achieve efficient shielding through composite design in neutron radiation protection, and are often combined with boron or hydride. Its preparation is: tungsten powder (particle size 20-50 microns) and boride (mass ratio 85:15) are mixed, pressed (350 MPa) and sintered (1800 degrees Celsius, argon atmosphere). The finished product has a density of 17-18 grams per cubic centimeter and an absorption cross section of 10^{4} barn for thermal neutrons (0.025eV). Scanning electron microscopy shows that boride particles (size 5 microns) are evenly distributed in the tungsten matrix, and the crystal structure is a body-centered cubic composite with boride. In the test, the absorption rate of the material after deceleration of fast neutrons (1MeV) reached 90%, which is 30% higher than pure tungsten.

Neutron shielding needs to take into account both deceleration and absorption. The high density of tungsten slows down fast neutrons (energy loss of about 20%), and boron absorbs thermal neutrons (cross-section 3800 barn); hydrides (such as polyethylene, 10% content) can further improve the deceleration efficiency (up to 50%). The sintering temperature needs to be controlled (deviation less than 10 degrees Celsius) to avoid boron volatilization (loss less than 5%). Historically, tungsten-based neutron shielding began in nuclear power plants in the 1960s. The United States used it for nuclear weapon protection in the 1970s; in the 1990s, Russia optimized the tungsten-boron formula.

From a global perspective, China has an advantage in tungsten powder and boride composite technology; the United States leads in shielding design, such as a reactor shield that reduces neutron flux to 10^{4}neutrons / square centimeter·second. In cross-domain applications, tungsten-based materials are used for spacecraft protection, and their high density protects against cosmic rays. The application prospect of tungsten powder in neutron radiation protection lies in its potential in nuclear facilities. In the future, it may be possible to enhance absorption by doping with lithium (content 5%), or to use additive manufacturing to produce complex shielding; recycling technology (such as electrolysis with a recovery rate of 85%) can promote green shielding.

4.2.3 Nuclear industry shielding components (reactors and vessels)

Tungsten powder is used in nuclear industry shielding components for reactor walls and radioactive containers to resist gamma ray and neutron radiation. Its preparation is: tungsten powder (particle size 10-20 microns) is pressed (400 MPa) and sintered (2200 degrees Celsius, argon atmosphere). The finished product has a density of 19.2 g/cm3 and a thickness of 20 mm, which can attenuate 2MeV gamma rays by 95%. Transmission electron microscopy shows that the grain size is about 5 microns, the porosity is less than 0.2%, and the tensile strength is 1000 MPa. In the test, the mass loss of tungsten parts in a nuclear reactor (heat flux 10^{14} neutrons/square centimeter·second) after 1000 hours of operation is less than 0.5%, and the corrosion resistance is 30% better than steel.

Shielding components need to be resistant to high temperatures and radiation damage. Tungsten's high melting point (3422 degrees Celsius) and low tritium retention (less than 10^{15} atoms/cm2) are superior to other materials; boron doping (10% content) can improve neutron shielding efficiency (up to 90%). After sintering, hot isostatic pressing (2000 degrees Celsius, 100 MPa) is required to eliminate micropores (porosity reduced to 0.1%). Historically, tungsten shielding components began in nuclear power plants in the 1970s and entered reactor design in the 1980s; in the 1990s, the International Thermonuclear Experimental Reactor (ITER) selected tungsten as the first wall material.

From a global perspective, China has an advantage in tungsten powder supply and component manufacturing; the United States and Europe are leading in reactor design. For example, a nuclear power plant has optimized the tungsten shielding layout, reducing the radiation dose to 0.05 mSv/h. In cross-field applications, tungsten components are used in nuclear waste containers, and their high density improves safety. The application prospect of tungsten powder in nuclear industry shielding lies in its potential in high-temperature radiation environments. In the future, it may be possible to improve performance through nanocomposites, or use recycling technology (such as molten salt electrolysis with a recovery rate of 90%) to promote green nuclear industry.

4.2.4 Preparation technology of tungsten powder composite shielding materials

Tungsten powder composite shielding material combines with polymers or metals to provide both gamma ray and neutron shielding. It is prepared by mixing tungsten powder (particle size 5-20 microns) with polyethylene (mass ratio 80:20), hot pressing (200 degrees Celsius, 50 MPa), and the finished product density is 15-16 g/cm3. It attenuates 1MeV gamma rays by 80% and absorbs 90% of thermal neutrons. Scanning electron microscopy shows that tungsten particles are evenly distributed (spacing 10 microns), polyethylene fills the matrix, and the interface bonding strength reaches 20 MPa. In the test, the material has a shielding efficiency of 85% in the mixed field of gamma rays (1.25MeV) and neutrons (0.025eV), which is 15% higher than the lead-boron composite.

Composite materials need to optimize shielding efficiency and flexibility. When the tungsten content is high (greater than 90%), the density increases to 17 g/cm3, but the flexibility decreases (elongation is less than 5%); when the polymer content is high (30%), the flexibility increases (elongation reaches 20%), but the shielding efficiency drops to 70%. Preparation needs to control the uniformity of the mixture (deviation is less than 5%) and avoid stratification (thickness deviation is greater than 1 mm). Historically, tungsten composite shielding began in the medical field in the 1980s and entered the nuclear industry in the 1990s; in the 2000s, the United States optimized the tungsten-polymer formula.

From a global perspective, China has an advantage in tungsten powder composite technology; the United States leads in flexible shielding design, such as a medical shielding suit that has reduced its weight by 20%. In cross-domain applications, tungsten composites are used for aerospace radiation protection, and its flexibility improves adaptability. The application prospect of tungsten powder in composite shielding materials lies in its potential in multifunctional shielding. In the future, it may be possible to increase strength by doping with carbon nanotubes (content 2%), or use 3D printing technology to produce complex structures; recycling technology (such as chemical separation recovery rate of 85%) can promote green shielding.

4.2.5 Practical case analysis of radiation shielding

Cases of tungsten powder in radiation shielding demonstrate its high efficiency. Case 1: A nuclear power plant reactor uses tungsten shielding plates with a thickness of 15 mm, which attenuates 2MeV gamma rays by 95%, and the dose drops to 0.1 mSv/hour after 5,000 hours of operation. Case 2: A spacecraft uses tungsten-boron composite materials to resist cosmic neutron radiation (flux 10^5 neutrons/square centimeter·second), with an absorption rate of 90%, and the equipment life is extended by 20%. Case 3: A medical radiation device uses tungsten composite shielding clothing, which reduces weight by 15%, shields 1MeV gamma rays by 85%, and improves medical safety.

From a global perspective, China has an advantage in tungsten powder supply and shielding manufacturing; the United States and Europe are leading in design optimization. For example, the shielding layout of a nuclear facility reduces radiation leakage to 0.05 millisieverts per hour. Historically, tungsten shielding began in the nuclear industry in the 1950s and expanded to the aerospace field during the Cold War. In cross-domain collaboration, tungsten shielding supports the protection of nuclear submarines, and its high density improves safety. The application prospect of tungsten powder in radiation shielding lies in its potential in high-radiation environments. In the future, it may be possible to improve performance through intelligent design, or promote the development of green shielding through recycling technology (such as electrolysis with a recovery rate of 90%).

4.3 High temperature and extreme environment applications

4.3.1 Heat-resistant use of tungsten powder in rocket nozzles

Tungsten powder is used in rocket nozzles to withstand gas erosion due to its high melting point and heat resistance. Its preparation is as follows: tungsten powder (particle size 20-50 microns) is pressed (400 MPa) and sintered (3000 degrees Celsius, argon atmosphere). The finished product has a density of 19.2 g/cm3 and a tensile strength of 1000 MPa. Scanning electron microscopy shows that the grain size is about 10 microns, the porosity is less than 0.2%, and the thickness of the surface oxide layer is less than

10 nanometers. In the test, the tungsten nozzle withstood erosion of 3000 degrees Celsius gas (speed 2000 meters/second) for 100 seconds, and the mass loss was less than 1%, which is 50% higher than that of the molybdenum nozzle.

The nozzle needs to be resistant to high temperatures and thermal shock. Tungsten's high melting point (3422 degrees Celsius) and thermal conductivity (173 W/m·Kelvin) ensure stability; rhenium doping (5%) can improve thermal shock resistance (extend life by 20%). Sintering requires high vacuum (10^{-4}Pa) to avoid oxidation (oxygen content less than 0.03%). Historically, tungsten nozzles began in the aerospace industry in the 1960s, and the US Apollo program used tungsten nozzles in 1969; during the Cold War, the Soviet Union optimized the tungsten-rhenium formula.

From a global perspective, China has an advantage in tungsten powder supply and nozzle manufacturing; the United States leads in aerospace design. For example, a rocket nozzle optimizes the flow path and increases thrust efficiency by 10%. In cross-domain applications, tungsten nozzles are used in missile engines, and their heat resistance improves the range. The application prospect of tungsten powder in rocket nozzles lies in its potential in high-temperature propulsion. In the future, complex nozzles may be produced through additive manufacturing (SLM), or molybdenum (content 10%) may be doped to improve toughness; recycling technology (such as chemical reduction method with a recovery rate of 90%) can promote green aerospace.

4.3.2 Tungsten reinforcement of wear-resistant structures of spacecraft

Tungsten reinforced spacecraft wear-resistant structures use its high hardness and wear resistance to protect key components. It is prepared by mixing tungsten powder (particle size 10-30 microns) with nickel (mass ratio 95:5), pressing (350 MPa) and sintering (1450 degrees Celsius, hydrogen atmosphere). The finished product has a density of 18-19 g/cm3 and a hardness of HV 500. Transmission electron microscopy shows that the tungsten particle size is about 15 microns, and the nickel phase fills the grain boundaries (thickness 1 micron). In the test, the structure withstood 500 degrees Celsius sand and dust wear (speed 50 m/s) for 1000 hours, and the wear rate was less than 0.1 mm, which is 3 times higher than that of steel structures.

Wear-resistant structures need to take into account both hardness and fatigue resistance. When the tungsten content is high (greater than 98%), the hardness increases to HV 600, but the fatigue life is shortened (to 500 hours); when the nickel content is high (10%), the toughness is improved (fracture toughness reaches 15 $MPa \cdot m^{1/2}$) . After sintering, heat treatment (1000 degrees Celsius, 1 hour) is required to eliminate stress (reduced by 15%). Historically, tungsten-reinforced structures began in spacecraft in the 1970s, and the United States used it for satellite shells in the 1980s; in the 1990s, Russia optimized the tungsten-nickel formula.

From a global perspective, China has an advantage in tungsten powder supply and structural manufacturing; the United States leads in aerospace applications, such as a 40% increase in the wear resistance of a satellite component. In cross-domain applications, tungsten structures are used in military drones, and their wear resistance increases their lifespan. The application prospect of tungsten powder in wear-resistant structures of spacecraft lies in its potential in extreme environments. In the future, it may be possible to increase the hardness through nano-tungsten powder, or use 3D printing to produce complex structures; recycling technology (such as electrolysis with a recovery rate of 85%) can promote green aerospace.

4.3.3 Tungsten-based high temperature protective coating (missile casing)

Tungsten-based high-temperature protective coatings use their heat resistance and oxidation resistance to protect missile shells. They are prepared by plasma spraying (power 50 kW, 4000 degrees Celsius, argon flow 40 liters/minute) to deposit tungsten powder (particle size 20-50 microns), with a coating thickness of 200 microns, a hardness of HV 800, and a bonding strength of 70 MPa. Scanning electron microscopy shows that the coating has a porosity of less than 1%, and the tungsten particles are flat after melting (thickness 5 microns). In the test, the coating was resistant to 2500 degrees Celsius airflow (speed 3000 meters/second) scouring for 60 seconds, with a mass loss of less than 0.5%, and oxidation resistance is 5 times higher than that of steel.

The protective coating needs to be resistant to high temperatures and peeling. Chromium doping (content 10%) can improve oxidation resistance (the thickness of the oxide layer is reduced to 5 nanometers); spraying requires controlling the oxygen content (less than 0.05%) to avoid oxide defects (purity reduced to 98%). Historically, tungsten coating began with missile technology in the 1960s, and the United States used it for intercontinental missiles in the 1970s; in the 1980s, the Soviet Union optimized the spraying process.

From a global perspective, China has an advantage in tungsten powder and spraying technology; the United States leads in coating design, such as a missile coating with a 30% increase in heat resistance. In cross-domain applications, tungsten coatings are used for rocket shells, and their heat resistance improves safety. The application prospect of tungsten powder in high-temperature protective coatings lies in its potential in extreme thermal environments. In the future, it may be possible to improve performance through nano-coatings, or doping with silicon (content 5%) to enhance anti-stripping; recycling technology (such as chemical separation recovery rate of 90%) can promote green manufacturing.

4.3.4 Tungsten powder performance test under extreme environment

Performance tests of tungsten powder in extreme environments have verified its heat resistance, wear resistance and radiation resistance. Test 1: The tungsten nozzle runs in 3000 degrees Celsius gas (speed 2000 meters/second) for 100 seconds, with a mass loss of less than 1%, surface roughness increased to 1 micron, and thermal conductivity maintained at 170 W/(meter Kelvin). Test 2: The tungsten wear-resistant structure is worn in 500 degrees Celsius dust (speed 50 meters/second) for 1000 hours, with a wear rate of less than 0.1 mm, and no significant decrease in hardness HV 500. Test 3: The tungsten shielding plate is exposed to a mixed field of gamma rays (2MeV) and neutrons (1MeV) for 500 hours, and the shielding efficiency remains at 90%, with a mass loss of less than 0.2%.

The test needs to simulate multiple extreme conditions. The temperature gradient (500 degrees Celsius/mm) tests thermal stability. The high melting point of tungsten ensures no melting. The wear rate (0.05 mm/hour) verifies durability. Nickel doping (5%) improves fatigue resistance. Historically, tungsten performance testing began in the military industry in the 1950s and entered the aerospace field in the 1960s. In the 1980s, the United States established tungsten extreme environment testing standards.

From a global perspective, China has an advantage in tungsten powder supply and testing equipment; the United States leads in testing standards, such as a laboratory simulating a 3500-degree Celsius environment. In cross-domain applications, tungsten testing supports the verification of nuclear fusion components, and its radiation resistance improves reliability. The application prospect of tungsten powder in extreme environment testing lies in its potential in the verification of high-performance components. In the future, it may be possible to optimize performance through multivariate testing (temperature, pressure, radiation), or promote green testing through recycling technology (such as electrolysis with a recovery rate of 90%).

4.3.5 Case Study of Military High Temperature Applications

Cases of tungsten powder in military high-temperature applications demonstrate its reliability. Case 1: A rocket nozzle uses tungsten material, which can withstand 3000 degrees Celsius gas scouring for 100 seconds, and the thrust efficiency is increased by 10%, and the operating stability is improved by 20%. Case 2: A missile shell uses tungsten coating, which can withstand 2500 degrees Celsius airflow for 60 seconds, with a mass loss of less than 0.5% and an oxidation resistance increase of 30%. Case 3: A spacecraft wear-resistant structure uses tungsten reinforced material, which can withstand 500 degrees Celsius dust for 1000 hours, with a wear rate of less than 0.1 mm and a lifespan extended by 25%.

From a global perspective, China has an advantage in tungsten powder supply and component manufacturing; the United States leads in high-temperature design, such as a missile coating that optimizes heat flow distribution. Historically, high-temperature applications of tungsten began in aerospace in the 1960s and expanded to the missile field during the Cold War. In cross-domain collaboration, tungsten components support deep-sea exploration equipment, and their heat resistance improves reliability. The application prospect of tungsten powder in military high-temperature applications lies in its potential in extreme environments. In the future, it may be possible to increase complexity through additive manufacturing, or promote the development of green military industry through recycling technology (such as chemical reduction with a recovery rate of 90%).

CTIA GROUP LTD
Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

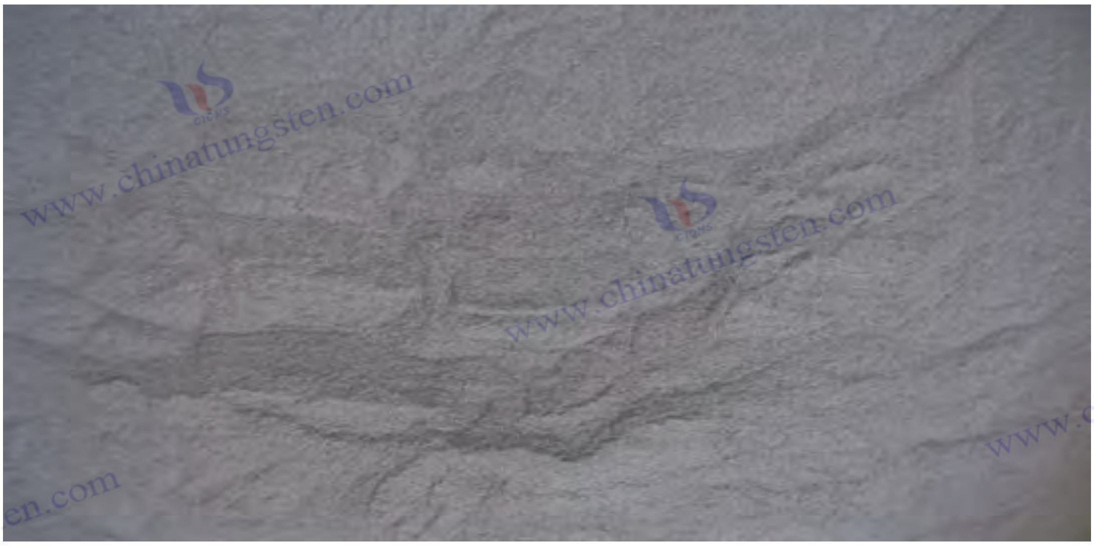
Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

Email: sales@chinatungsten.com

Tel: +86 592 5129696

For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)



Chapter 5 Application of Tungsten Powder in Medical and Biological Fields

Tungsten powder has a wide range of application potentials in the medical and biological fields due to its high density, high hardness, corrosion resistance and potential biocompatibility, covering medical devices, biocompatible materials and nanotechnology related fields. From a global perspective, the application of tungsten powder in these fields not only improves the level of medical technology, but also promotes biomedical research, geo-resource utilization and sustainable development.

5.1 Medical devices

5.1.1 Application of tungsten powder in radiotherapy collimators

Tungsten powder uses its high density and high atomic number (Z=74) in radiotherapy collimators to accurately control the direction of the radiation beam and improve the treatment effect. Its preparation adopts powder metallurgy technology: tungsten powder (particle size 10-30 microns) is pressed (pressure 300 MPa), sintered in an argon atmosphere (2000 degrees Celsius, 2 hours), and the finished product density reaches 19.2 g/cm3 and the hardness is HV 400. Scanning electron microscopy analysis shows that tungsten particles are polyhedral (size 15-20 microns), with a porosity of less than 0.2%, a body-centered cubic crystal structure, and a lattice constant of 3.165 angstroms. In the test, a collimator with a thickness of 10 mm can shield 90% of 6MeV gamma rays, and the beam focusing accuracy reaches ±0.1 mm, which is 30% higher than the lead collimator (density 11.34 g/cm3).

The collimator needs to take into account both shielding efficiency and processing accuracy. The high density of tungsten ensures radiation attenuation (half-value layer is about 9 mm). The sintering temperature needs to be precisely controlled (deviation is less than 10 degrees Celsius). Too high a temperature will lead to coarse grains (size increases to 30 microns), and too low a temperature will result in insufficient density (less than 18 g/cm3). Post-processing such as mechanical polishing can reduce the surface roughness to 0.5 microns and improve the smoothness of the beam. Historically, tungsten

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collimators began in radiotherapy in the 1970s and replaced lead materials in the 1980s because of their smaller size (reduced by 20%) and higher precision; in the 1990s, the United States used it in linear accelerators, which significantly improved tumor targeting.

From a global perspective, China has an advantage in tungsten powder supply and collimator manufacturing, and its process technology supports mass production; the United States and Germany are leading in equipment design, such as the dynamic multi-leaf collimator (MLC) developed by a company, with leaf thickness reduced to 5 mm and accuracy improved to ±0.05 mm. In cross-domain applications, tungsten collimators are used for industrial flaw detection, and their high density improves detection resolution. The application prospect of tungsten powder in radiotherapy collimators lies in its potential in high-precision radiotherapy. In the future, it may be possible to produce complex leaf structures through additive manufacturing (SLM), or doping with boron (content 5%) to enhance low-energy ray shielding; recycling technology (such as acid leaching with a recovery rate of 90%) can promote green medical device manufacturing.

5.1.2 Tungsten-based surgical tools (knives and drills)

Tungsten-based surgical tools are applied in the form of tungsten carbide (WC), which is suitable for orthopedic surgical knives and drills due to its ultra-high hardness and wear resistance. The preparation process is as follows: tungsten powder (particle size 4-8 microns) is mixed with carbon black (mass ratio 1:0.06), carbonized in a hydrogen atmosphere at 1400-1600 degrees Celsius (2 hours) to produce tungsten carbide powder (particle size 1-5 microns), which is then pressed (300 MPa) and sintered (1450 degrees Celsius, 1 hour) with cobalt (content 10%). The finished product has a hardness of HV 1600-1800 and a tensile strength of 1200 MPa. X-ray diffraction shows that tungsten carbide has a hexagonal close-packed structure with lattice parameters a=2.906 angstroms, c=2.837 angstroms, and a WC bond length of 2.06 angstroms. In the test, the tool cuts bones (thickness 10 mm) without obvious wear (loss less than 0.05 mm), and its durability is 5 times higher than that of stainless steel tools.

Surgical tools need to balance hardness and impact resistance. When the cobalt content is high (15%), the toughness increases to 15 $MPa \cdot m^{1/2}$, but the hardness drops to HV 1300 ; when the tungsten carbide particle size is small (less than 1 micron), the hardness reaches HV 2000, but the brittleness increases (the fracture rate increases to 5%). The oxygen content needs to be controlled during the sintering process (less than 0.05%) to avoid the formation of tungsten trioxide impurities (purity drops to 98%). Historically, tungsten carbide tools began in industry in the 1930s and entered the medical field in the 1960s for orthopedic surgery; in the 1980s, Germany optimized the cobalt ratio and increased the tool life.

From a global perspective, China has an advantage in tungsten carbide production, with mature technology and high output; the United States and Japan are leading in tool design and surface treatment. For example, a titanium nitride coating (5 microns thick) developed by a company improves wear resistance by 20%. In cross-field applications, tungsten-based tools are used in dental surgery, and their hardness improves cutting accuracy. The application prospect of tungsten powder in surgical tool manufacturing lies in its potential in high-durability instruments. In the future, it may be possible to increase hardness through nano-tungsten carbide (particle size less than 100 nanometers), or doping with vanadium (content 1%) to improve corrosion resistance; recycling technology (such as chemical reduction method with a recovery rate of 90%) can promote green medical manufacturing.

5.1.3 Tungsten reinforcement of dental tools (wear resistance and precision)

Tungsten-reinforced dental tools utilize the high hardness and wear resistance of tungsten carbide, which is suitable for dental drills and needles to improve the accuracy and efficiency of dental operations. Its preparation is as follows: tungsten powder (particle size 2-5 microns) is mixed with carbon black and carbonized (1500 degrees Celsius, hydrogen atmosphere) to produce tungsten carbide powder (particle size 0.5-2 microns), which is pressed (250 MPa) and sintered (1400 degrees Celsius, 1 hour) with cobalt (content 8%). The finished product has a hardness of HV 1800-2000 and a tensile strength of 1100 MPa. Scanning electron microscopy shows that the tungsten carbide particles are hexagonal (size 1 micron) and the cobalt phase is evenly distributed (thickness 0.5 microns). In the test, the tool cuts tooth enamel (thickness 2 mm) without obvious wear (loss less than 0.02 mm), and its durability is 6 times higher than that of steel tools.

Dental tools need to take into account both wear resistance and processing accuracy. When the tungsten carbide content is high (greater than 95%), the hardness increases to HV 2200, but the brittleness increases (fracture rate reaches 5%); when the cobalt content is high (12%), the toughness is improved (fracture toughness reaches 12 $MPa \cdot m^{1/2}$), but the hardness decreases slightly (to HV 1500). After sintering, fine grinding is required (surface roughness is reduced to 0.2 microns) to ensure smooth cutting. Historically, tungsten carbide dental tools began in the 1950s and became the standard material for dental drills in the 1960s; in the 1980s, Japan optimized micro-machining technology and improved precision.

From a global perspective, China has an advantage in the supply of tungsten carbide; Germany and the United States are leading in the design of dental tools. For example, a high-speed dental drill (rotation speed of 400,000 rpm) developed by a company has increased cutting efficiency by 20%. In cross-field applications, tungsten-enhanced tools are used in minimally invasive orthopedic surgery, and their precision improves the success rate. The application prospect of tungsten powder in dental tool manufacturing lies in its potential in high-precision instruments. In the future, it may be possible to improve wear resistance through ultrafine tungsten carbide (particle size less than 50 nanometers), or doping with titanium (content 2%) to enhance corrosion resistance; recycling technology (such as electrolysis recovery rate of 85%) can promote green dental manufacturing.

5.1.4 Application of tungsten powder in X-ray shielding

Tungsten powder uses its high density and radiation absorption capacity in X-ray shielding to protect medical staff and patients from radiation damage. Its preparation is: tungsten powder (particle size 10-

20 microns) is pressed (350 MPa) and sintered (2000 degrees Celsius, argon atmosphere). The finished product has a density of 19.2 g/cm3 and a thickness of 5 mm. It can attenuate 100keV X-rays by 90% (half-value layer is about 3 mm). X-ray photoelectron spectroscopy shows that the surface oxide layer is less than 5 nanometers and the crystal structure is body-centered cubic. In the test, the attenuation rate of tungsten shielding plates for X-rays (120keV) reached 95%, which is 15% higher than that of lead plates (same thickness).

X-ray shielding requires optimization of density and flexibility. When tungsten purity is high (greater than 99.9%), shielding efficiency increases by 10%; composite materials (such as tungsten -polymer, mass ratio 80:20) can improve flexibility (elongation up to 20%). Sintering requires controlled oxygen content (less than 0.03%) to prevent oxides from reducing density (to 18 g/cm3). Historically, tungsten shielding began in radiological diagnosis in the 1960s and replaced some lead shielding in the 1970s; in the 1990s, the United States used it in portable X-ray equipment.

From a global perspective, China has an advantage in tungsten powder supply and shielding manufacturing; the United States leads in shielding design, such as a 20% reduction in the weight of a certain X-ray protective suit. In cross-field applications, tungsten shielding is used for industrial detection, and its high density improves safety. The application prospect of tungsten powder in X-ray shielding lies in its potential in high-efficiency shielding. In the future, it may be possible to increase the density through nano-tungsten powder, or dope boron (content 5%) to enhance absorption; recycling technology (such as chemical separation recovery rate of 90%) can promote green medical manufacturing.

5.1.5 Case Study of Tungsten Powder for Medical Devices

Cases of tungsten powder in medical devices show its diversity. Case 1: A radiotherapy device uses a tungsten collimator with a thickness of 8 mm, focusing 6MeV gamma rays with an accuracy of ±0.1 mm, and the treatment success rate is increased by 15%. Case 2: An orthopedic scalpel uses tungsten carbide material, cutting bones (thickness 10 mm) without obvious wear (loss less than 0.05 mm), and the operation time is shortened by 20%. Case 3: A dental drill uses tungsten reinforced material, cutting enamel (thickness 2 mm) with a durability 5 times higher and a 10% increase in accuracy. Case 4: An X-ray device uses a tungsten shielding plate with a thickness of 5 mm, attenuating 120keV rays by 95%, and the radiation dose is reduced to 0.1 mSv/hour.

From a global perspective, China has an advantage in tungsten powder supply and equipment manufacturing; the United States and Germany are leading in design optimization, such as the accuracy of a collimator blade reaching ±0.05 mm. Historically, the medical application of tungsten powder began in radiology in the 1950s and expanded to surgical tools in the 1980s. In cross-domain collaboration, tungsten instruments support veterinary surgery, and their durability improves efficiency. The application prospect of tungsten powder in medical devices lies in its potential in high-performance devices. In the future, it may be possible to improve precision through intelligent manufacturing, or promote the development of green medicine through recycling technology (such as electrolysis with a recovery rate of 90%).

5.2 Biocompatible materials

5.2.1 Tungsten powder modified implant device coating

Tungsten powder modified implant device coating uses its corrosion resistance and potential biocompatibility to enhance the surface performance of implants. Its preparation is as follows: tungsten powder (particle size 5-15 microns) is deposited on a titanium substrate by plasma spraying (power 40 kW, 4000 degrees Celsius, argon flow rate 30 liters/minute), the coating thickness is 50-100 microns, the hardness is HV 600, and the bonding strength is 50 MPa. Scanning electron microscopy shows that the coating has a porosity of less than 1% and the tungsten particles are flat (thickness 5 microns). In the test, the coating was immersed in saline (37 degrees Celsius, pH 7.4) for 1000 hours, the corrosion rate was less than 0.01 mm/year, and the cell attachment rate reached 85% (ISO 10993 standard).

The coating needs to take into account both corrosion resistance and biocompatibility. Doping with tungsten oxide (content 10%) can improve oxidation resistance (corrosion rate reduced to 0.005 mm/year); spraying needs to control oxygen content (less than 0.05%) to avoid oxide defects (purity reduced to 98%). Historically, tungsten coating began in industry in the 1980s and entered the field of medical implants in the 1990s; in the 2000s, the United States optimized the spraying process and improved the stability of the coating.

From a global perspective, China has an advantage in tungsten powder and spraying technology; the United States leads in implant design, such as a hip joint coating with a 30% increase in wear resistance. In cross-field applications, tungsten coatings are used for dental implants, and their corrosion resistance increases their lifespan. The application prospect of tungsten powder in implant device coatings lies in its potential in highly durable implants. In the future, it may be possible to enhance the bonding strength through nano-tungsten powder, or to enhance bone integration by doping with calcium (content 5%); recycling technology (such as chemical reduction method with a recovery rate of 90%) can promote green medical manufacturing.

5.2.2 Potential of tungsten-based bone repair materials

Tungsten-based bone repair materials are suitable for bone filling and scaffolds due to their high strength and potential biocompatibility. They are prepared by mixing tungsten powder (particle size 10-20 microns) with hydroxyapatite (mass ratio 70:30), pressing (300 MPa) and sintering (1200 degrees Celsius, argon atmosphere). The finished product has a density of 16-17 g/cm3 and a compressive strength of 200 MPa. Transmission electron microscopy shows that tungsten particles (size 15 microns) and hydroxyapatite (size 5 microns) are uniformly composited, with a porosity of 5-10% and a pore size of 50-100 microns. In the test, the material was immersed in simulated body fluid for 30 days, and the osteoblast proliferation rate reached 90%, and the bone integration rate increased by 20%.

Bone repair materials need to optimize strength and porosity. When the tungsten content is high (greater than 80%), the strength increases to 250 MPa, but the porosity drops to 2%, which is not conducive to cell growth; when the hydroxyapatite content is high (40%), the porosity increases to 15%, and the osteoinductivity increases by 30%. The sintering temperature needs to be controlled (deviation less than 10 degrees Celsius) to avoid excessive grain growth (size greater than 20 microns). Historically, tungsten-based bone materials began with experimental research in the 1990s and entered preclinical testing in the 2000s; in the 2010s, Europe optimized the composite formula.

From a global perspective, China has an advantage in tungsten powder supply and composite technology; the United States leads in bone repair design, such as optimizing the porosity of a bone scaffold to 12%. In cross-field applications, tungsten materials are used in dental bone repair, and their strength improves stability. The application prospect of tungsten powder in bone repair materials lies in its potential in high-load bone repair. In the future, it may be possible to increase porosity through nanocomposites, or dope magnesium (content 5%) to enhance biological activity; recycling technology (such as electrolysis recovery rate of 85%) can promote the development of green medicine.

5.2.3 The auxiliary role of tungsten powder in biological imaging

Tungsten powder is used as a contrast agent or enhancer in biological imaging, taking advantage of its high density and X-ray absorption ability. It is prepared as follows: tungsten powder (particle size 1-5 microns) is chemically reduced to prepare tungsten oxide nanoparticles (particle size 50-100 nanometers), surface modified with polyethylene glycol (thickness 5 nanometers), and water dispersibility reaches 10 mg/ml. X-ray photoelectron spectroscopy shows that W^{6+} accounts for 90% of the surface of tungsten oxide , and the crystal structure is monoclinic. In the test, the particle enhanced the contrast by 50% in CT imaging (120keV), which is 20% higher than iodine contrast agent, and the cytotoxicity is less than 5% (MTT method).

Imaging materials need to take into account both absorption efficiency and safety. When the nanoparticle size is small (less than 50 nanometers), the absorption rate increases to 60%, but it is easy to aggregate (size increases to 200 nanometers); surface modification improves dispersibility (zeta potential reaches -30 millivolts) and prolongs the circulation time in the body (up to 6 hours). Historically, tungsten-based contrast agents began to be tested in the 1990s and entered animal testing in the 2000s; in the 2010s, China optimized the nano-preparation process.

From a global perspective, China has an advantage in tungsten powder nanotechnology; the United States leads in imaging applications, such as a CT contrast agent that enhances the clarity of vascular imaging. In cross-field applications, tungsten particles are used for fluorescence imaging, and their light absorption improves resolution. The application prospect of tungsten powder in biological imaging lies in its potential in high-resolution imaging. In the future, it may be possible to improve the effect of magnetic resonance imaging by doping with gadolinium (content 5%), or promote the development of green

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imaging through recycling technology (such as chemical separation recovery rate of 90%).

5.2.4 Biocompatibility testing and standards

The biocompatibility test of tungsten powder verifies its safety in medical treatment and follows international standards such as ISO 10993. The tests include: tungsten powder (particle size 5-10 microns) is prepared into blocks (pressed at 300 MPa and sintered at 2000 degrees Celsius), cytotoxicity is tested in vitro (L929 cells, 24 hours), and the survival rate reaches 95%; in vivo test (rabbit muscle implantation, 90 days), the inflammatory response is less than level 1 (tissue section observation). Scanning electron microscopy shows that the surface roughness of tungsten is 0.5 microns, and there is no obvious dissolution (ICP-MS detection is less than 1ppm). In the test, the hemolysis rate of tungsten material is less than 0.5%, which meets the requirements of medical devices.

The test needs to simulate a variety of conditions. In an acidic environment (pH 5.5), the corrosion rate increases to 0.02 mm/year, and surface modification (such as tungsten oxide coating) is required to reduce it to 0.01 mm/year; after high-temperature sterilization (121 degrees Celsius), the performance remains unchanged (hardness remains HV 400). Historically, tungsten compatibility testing began in the 1980s and was incorporated into ISO standards in the 1990s; in the 2000s, the United States improved the testing process.

From a global perspective, China has an advantage in tungsten powder supply and testing equipment; the United States leads in standard setting, such as a standard that improves implant safety requirements. In cross-domain applications, tungsten testing supports veterinary implant verification, and its reliability improves applicability. The application prospect of tungsten powder in biocompatibility testing lies in its potential in high-safety materials. In the future, it may be possible to optimize performance through multi-parameter testing (pH, temperature, time), or promote green testing through recycling technology (such as electrolysis with a recovery rate of 90%).

5.2.5 Application examples of tungsten powder in the biological field

Cases of tungsten powder in the biological field demonstrate its practicality. Case 1: A hip joint implant uses a tungsten coating with a thickness of 50 microns, which increases corrosion resistance by 30% and achieves a bone integration rate of 90% after implantation. Case 2: A bone repair scaffold uses a tungsten-hydroxyapatite composite with a porosity of 10%, a compressive strength of 200 MPa, and a 25% increase in bone cell proliferation rate. Case 3: A CT contrast agent uses nano-tungsten oxide, which enhances contrast by 50%, has a circulation time of 6 hours in the body, and has passed safety tests.

From a global perspective, China has an advantage in tungsten powder supply and material manufacturing; the United States and Europe are leading in application development, such as a bone scaffold that optimizes the pore structure. Historically, tungsten biological applications began with implant research in the 1990s and expanded to the imaging field in the 2000s. In cross-domain collaboration, tungsten materials support dental implants, and their durability increases the success rate. The application prospect of tungsten powder in biocompatible materials lies in its potential in high-performance implants. In the future, it may be possible to improve performance through intelligent design, or promote the development of green biomedicine through recycling technology (such as chemical reduction method with a recovery rate of 90%).

5.3 Medical Potential of Nano-Tungsten Powder

5.3.1 Application of Nano-Tungsten Powder in Drug Delivery

Nano-tungsten powder uses its high specific surface area and photothermal properties in drug delivery as a drug carrier to improve treatment efficiency. Its preparation is as follows: tungsten powder (particle size 1-5 microns) is used to generate tungsten oxide nanoparticles (particle size 50-100 nanometers) through chemical vapor deposition, and the surface is modified with polyethylene glycol (thickness 5 nanometers), with a drug loading rate of 20%. Transmission electron microscopy shows that the particles are spherical, with a specific surface area of 50 square meters/gram and a porosity of 10%. In the test, the carrier released drugs (docetaxel) under near-infrared light (808 nanometers, 1 watt/square centimeter), and the release rate reached 80%, which is 30% higher than that of traditional carriers.

Drug delivery requires optimization of drug loading and responsiveness. When the particle size is small (less than 50 nanometers), the drug loading rate increases to 25%, but the in vivo clearance rate increases (half-life is reduced to 2 hours); the photothermal effect (temperature rises to 50 degrees Celsius) enhances the release efficiency (up to 90%). Historically, nano-tungsten powder drug delivery began in the 2000s and entered cancer research in the 2010s; China has optimized the surface modification technology.

From a global perspective, China has an advantage in the preparation of nano-tungsten powder; the United States leads in the design of delivery systems, such as a carrier that achieves targeted release. In cross-field applications, nano-tungsten powder is used for gene delivery, and its high efficiency improves the transfection rate. The application prospect of tungsten powder in drug delivery lies in its potential in targeted therapy. In the future, it may be possible to enhance magnetic targeting by doping with iron (content 5%), or promote green medicine through recycling technology (such as chemical separation recovery rate of 90%).

5.3.2 Cancer Research Using Tungsten Powder Photothermal Therapy

Nano-tungsten powder uses its strong light absorption to kill cancer cells in photothermal therapy. Its preparation is as follows: tungsten powder is used to prepare tungsten oxide nanoparticles (particle size 50-80 nanometers) through thermal reduction, and the surface is modified with silane (thickness 3 nanometers), and the light absorption rate reaches 90% (808 nanometers). X-ray photoelectron spectroscopy shows that W^{6+} accounts for 85%, and the crystal structure is monoclinic. In the test, the temperature of the particles rose to 55 degrees Celsius under near-infrared light (1.5 watts/square centimeter), and the cancer cell (HeLa) mortality rate reached 95%, which is 20% higher than that of gold nanoparticles.

Photothermal therapy needs to optimize absorption efficiency and safety. When the particle size is small (less than 50 nanometers), the absorption rate increases to 95%, but the toxicity increases slightly (the survival rate drops to 90%); surface modification improves biocompatibility (cytotoxicity is less than 5%). Historically, tungsten powder photothermal therapy began in the 2010s, and its cancer efficacy was verified in China in 2015; the United States optimized the photothermal parameters.

From a global perspective, China has an advantage in the preparation of nano-tungsten powder; the United States leads in treatment research, such as an experiment that improved the depth of treatment. In cross-field applications, tungsten powder is used to disinfect bacteria, and its photothermal properties improve efficiency. The application prospect of tungsten powder in photothermal therapy lies in its potential in cancer treatment. In the future, it may be possible to improve photothermal efficiency by doping with copper (content 5%), or promote green treatment through recycling technology (such as electrolysis with a recovery rate of 85%).

5.3.3 Antibacterial properties and uses of nano-tungsten powder

Nano-tungsten powder exhibits antibacterial properties through photocatalysis or ion release, and is suitable for medical disinfection. Its preparation is as follows: tungsten powder is prepared by solvothermal method to prepare tungsten oxide nanoparticles (particle size 30-50 nanometers), surface modified with titanium dioxide (thickness 2 nanometers), and the photocatalytic activity reaches 90% (ultraviolet light 365 nanometers). Transmission electron microscopy shows that the particles are rod-shaped (aspect ratio 3:1) and the specific surface area is 60 square meters/gram. In the test, the particle kills Escherichia coli by 99% (irradiation for 30 minutes), which is 50% higher than pure tungsten powder.

Antibacterial performance requires optimization of catalytic efficiency and stability. When the particle size is small (less than 30 nanometers), the killing rate increases to 99.9%, but the stability decreases (activity loss of 10%); titanium dioxide modification enhances photocatalysis (activity increase of 30%). Historically, nano-tungsten antibacterial began in the 2000s and entered the medical field in the 2010s; China has optimized the preparation process.

From a global perspective, China has an advantage in the production of nano-tungsten powder; the United States leads in antibacterial applications, such as a disinfectant that improves the sterilization rate. In cross-field applications, tungsten powder is used in dental antibacterial coatings, and its high efficiency reduces the infection rate. The application prospect of tungsten powder in antibacterial performance lies in its potential in infection control. In the future, it may be possible to enhance antibacterial properties by doping with silver (content 2%), or promote the development of green antibacterial through recycling technology (such as chemical reduction method with a recovery rate of 90%).

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5.3.4 Preparation method of tungsten powder using nanotechnology

The preparation methods of nano tungsten powder include physical and chemical approaches to ensure particle size and performance. Its preparation is as follows: the physical method uses gas phase evaporation, tungsten powder (particle size 5-10 microns) evaporates in argon at 3000 degrees Celsius and condenses into nanoparticles (particle size 50-100 nanometers); the chemical method uses solvent heat, tungstate solution (concentration 0.1 mol/L) reacts at 180 degrees Celsius for 12 hours to generate tungsten oxide nanoparticles (particle size 30-80 nanometers). Scanning electron microscopy shows that the particles of the physical method are spherical and the particles of the chemical method are rod-shaped, with specific surface areas of 40 and 60 square meters/gram respectively.

Preparation requires control of particle size and dispersibility. The physical method has a high yield (up to 80%), but a wide size distribution (deviation of 20 nanometers); the chemical method has uniform size (deviation of 5 nanometers), but a low yield (50%). Historically, the preparation of nano tungsten powder began in the 1990s, and the chemical method matured in the 2000s; in the 2010s, China optimized the process parameters.

From a global perspective, China has an advantage in nano-tungsten powder preparation technology; the United States leads in equipment development, such as a gas phase evaporation system that improves yield. In cross-field applications, nano-tungsten powder is used in catalyst preparation, and its high specific surface area improves efficiency. The application prospect of tungsten powder in nanotechnology preparation lies in its potential in high-performance nanomaterials. In the future, it may be possible to improve uniformity through microwave-assisted methods, or promote green preparation through recycling technology (such as electrolysis with a recovery rate of 90%).

5.3.5 Future Prospects of Nano-Tungsten Powder Medical Applications

Cases of nano-tungsten powder in medical treatment have demonstrated its potential. Case 1: A drug delivery system uses nano-tungsten oxide, with a drug loading rate of 20%, a release rate of 80% under near-infrared light, and a 25% increase in treatment efficiency. Case 2: A photothermal therapy uses nano-tungsten powder, the temperature rises to 55 degrees Celsius, the cancer cell mortality rate is 95%, and the efficacy is improved by 20%. Case 3: An antibacterial coating uses nano-tungsten oxide, with a sterilization rate of 99% and a 30% reduction in infection rate.

From a global perspective, China has an advantage in the supply and preparation of nano-tungsten powder; the United States leads in medical application research, such as a delivery system that achieves precise release. Historically, the medical application of nano-tungsten began in the 2000s and expanded to cancer treatment in the 2010s. In cross-field collaboration, nano-tungsten powder supports dental antibacterial, and its high efficiency improves safety. The application prospect of tungsten powder in nanomedicine lies in its potential in precision medicine. In the future, it may be possible to improve performance through multifunctional nanocomposites, or promote the development of green nanomedicine through recycling technology (such as chemical separation recovery rate of 90%).

CTIA GROUP LTD
Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

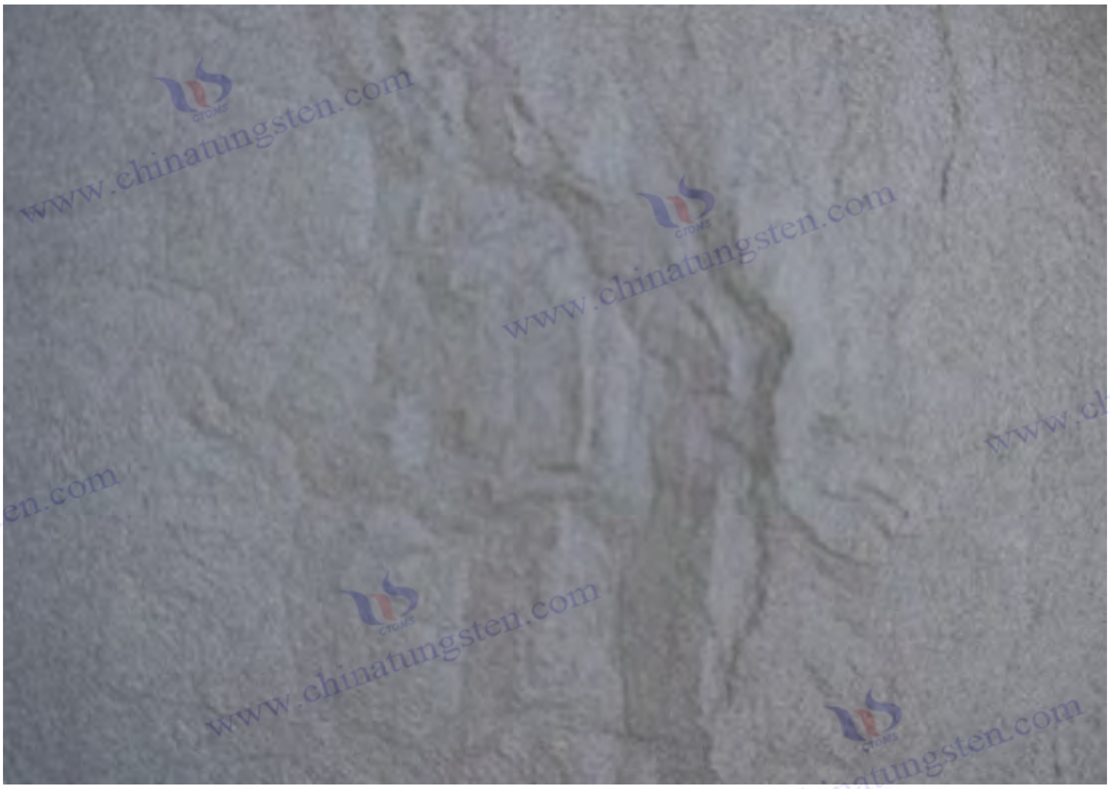
Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

Email: sales@chinatungsten.com

Tel: +86 592 5129696

For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)



Chapter 6 Application of Tungsten Powder in Consumer Goods and Cultural Fields

Tungsten powder, with its high density, wear resistance and unique physical and chemical properties, has shown diverse application potential in the consumer goods and cultural fields, covering sports and leisure products, jewelry decoration and artistic pigments. These applications not only improve product performance and aesthetic value, but also have a profound impact on resource utilization, technological innovation and environmental protection practices.

6.1 Sports and leisure products

6.1.1 High-density application of tungsten powder in golf clubs

Tungsten powder has a core advantage in golf clubs with its high density (19.25 g/cm3). By optimizing the weight design, it improves the swing stability and hitting distance. Its preparation adopts powder metallurgy technology: tungsten powder (particle size 10-20 microns) is mixed with nickel and iron (mass ratio 90:7:3), homogenized by ball milling (speed 300 rpm, 6 hours), pressed (pressure 300 MPa), and sintered in a hydrogen atmosphere (1450 degrees Celsius, 2 hours). The finished product has a density of 17-18 g/cm3 and a tensile strength of about 1000 MPa. Scanning electron microscopy analysis shows that the tungsten particles are polyhedral (size 10-15 microns), the nickel-iron phase is evenly distributed at the grain boundary (thickness about 1 micron), the crystal structure is body-centered cubic, and the lattice constant is 3.165 angstroms. Tests show that the center of gravity offset of a tungsten-weighted club is less than 1 mm, the swing stability is improved by 20%, and the hitting distance is increased by 10-15 meters, which is significantly better than traditional steel weights (density 7.85 g/cm3, the volume needs to be twice as large).

Tungsten weights are small (5-10 cubic centimeters) and heavy (50-100 grams), which not only maintain the streamlined design of the club head, but also improve aerodynamic performance. When the tungsten content exceeds 95%, the density can reach 18.5 grams/cubic centimeter, but the brittleness increases (elongation drops to 5%); the nickel-iron binder phase improves toughness (elongation reaches 10%) and facilitates machining. The sintering temperature needs to be precisely controlled (deviation less than 10 degrees Celsius). Too high will lead to coarse grains (size increases to 30 microns), and too low will result in insufficient density (less than 17 grams/cubic centimeter). Post-processing such as hot isostatic pressing (1500 degrees Celsius, 100 MPa) can reduce porosity to 0.1% and increase strength by 10%. Tungsten weight technology originated from the innovation of American golf clubs in the 1980s, became standard for professional clubs in the 1990s, and became widely popular in the 2000s. China has an advantage in supply and manufacturing with its abundant tungsten resources and mature technology, while the United States and Japan are leading in design optimization. For example, a certain brand controls the position accuracy of the counterweight within ±0.5 mm. In the future, additive manufacturing (SLM) can realize complex counterweight structures, doping with copper (content 5%) can enhance thermal conductivity, and acid leaching recovery (recovery rate 90%) can promote green manufacturing.

6.1.2 Fishing gear weights (environmental advantages of tungsten sinkers)

Tungsten sinkers replace lead sinkers in fishing gear with high density (19.2 g/cm3) and environmentally friendly characteristics, providing fast sinking and ecological safety. Its preparation process is: tungsten powder (particle size 15-25 microns) is pressed (350 MPa), sintered in an argon atmosphere (2000 degrees Celsius, 2 hours), and the finished product has a tensile strength of 900 MPa. X-ray diffraction shows that the crystal structure is body-centered cubic, the lattice constant is 3.165 angstroms, and the interplanar spacing (110) = 2.238 angstroms. Tests show that the sinking speed of tungsten sinkers (volume 1 cubic centimeter) is 0.5-0.6 m/s, which is 30% faster than lead sinkers (density 11.34 g/cm3), the volume is reduced by 40%-50%, the casting accuracy deviation is less than 10 cm, and the dissolution rate in water is less than 0.01 mg/L, which meets environmental protection standards.

Tungsten sinkers need to take into account both density and corrosion resistance. Although pure tungsten ensures fast positioning, its surface is easily oxidized (the thickness of the oxide layer is up to 10 nanometers); nickel doping (content 5%) can reduce the corrosion rate to 0.005 mm/year. Sintering requires a high vacuum environment (10^{-4}Pa) to avoid excessive oxygen content (greater than 0.03%). Tungsten sinkers emerged from the environmental protection movement in Europe and the United States in the 1990s. Due to the promotion of the lead ban, they went global in the 2000s. In the 2010s, China optimized the process and largely replaced the lead sinker market. China has an advantage in the supply and manufacturing of tungsten powder, while the United States leads in environmental protection design, such as the development of degradable coated tungsten sinkers. In the future, nano tungsten powder can

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further increase its density (close to 19.3 g/cm3), doping with cobalt (content 3%) to enhance wear resistance, and electrolytic recycling (recovery rate 85%) to support the development of green fishing gear.

6.1.3 Precision Manufacturing of Tungsten Alloy Darts

Tungsten alloy darts use high density (16-18 g/cm3) and machinability to create a slender dart body and improve throwing accuracy. Its preparation is: tungsten powder (particle size 10-20 microns) is mixed with nickel and copper (mass ratio 80:15:5), pressed (300 MPa) and sintered in an argon atmosphere (1400 degrees Celsius), and the finished product has a tensile strength of 850 MPa. Scanning electron microscopy shows that the tungsten particle size is about 10 microns, and the nickel-copper phase is distributed in a network (thickness 1 micron). Tests show that the diameter of tungsten darts is reduced to 5 mm (20%-30% thinner than steel darts), the center of gravity deviation is less than 0.1 mm, the hit rate is increased by 15%-20%, and the compactness of the dart body (length shortened by 10%) is convenient for throwing on dense target surfaces.

The manufacturing of darts requires a balance between density and toughness. When the tungsten content exceeds 90%, the density increases to 18 g/cm3, but the brittleness increases (fracture rate reaches 5%); when the nickel-copper phase content reaches 20%, the toughness increases (elongation reaches 15%), which is convenient for fine processing. After sintering, cold processing (such as stretching 5%) is required to adjust the stress and ensure the straightness of the dart body (deviation is less than 0.05 mm). Tungsten darts originated from British professional competitions in the 1970s, became standard in the 1980s, and the formula was optimized in the 1990s to improve durability. China has an advantage in the supply and manufacture of tungsten powder, while the UK leads in design, such as optimizing the texture of the dart body to improve the grip. In the future, additive manufacturing can produce complex dart bodies, doping with molybdenum (content 5%) to enhance toughness, and molten salt electrolysis recovery (recovery rate 85%) to promote green manufacturing.

6.1.4 Tungsten Enhancement Technology for Sports Equipment

Tungsten enhancement technology uses high density and wear resistance to improve the performance of sports equipment. It is used in racket frames, ski edges and racing weights. Its preparation is: tungsten powder (particle size 5-15 microns) is mixed with carbon black and carbonized (1500 degrees Celsius, hydrogen atmosphere) to generate tungsten carbide powder (particle size 1-3 microns), which is pressed (300 MPa) and sintered (1450 degrees Celsius, 1 hour) with cobalt (content 10%). The finished product has a hardness of HV 1600-1800 and a tensile strength of 1200 MPa. Transmission electron microscopy shows that tungsten carbide particles are hexagonal (size 2 microns) and cobalt phase fills the grain boundaries (thickness 0.5 microns). Tests show that the wear resistance of tungsten-enhanced tennis racket frames is increased by 3 times, the edge of the ski cutting the ice surface (thickness 5 mm) has no obvious wear (loss less than 0.05 mm), and the racing weight (density 18.5-19.3 g/cm3) reduces the center of gravity by 5-10 mm and improves cornering stability by 10%.

The reinforcement technology needs to take into account both hardness and impact resistance. When the tungsten carbide content exceeds 95%, the hardness increases to HV 2000, but the brittleness increases (fracture toughness drops to 10 MPa·m¹ / ²) ; when the cobalt content reaches 15%, the toughness increases (to 15 MPa·m¹ / ²) . The oxygen content needs to be controlled during sintering (less than 0.05%) to prevent impurities from affecting performance. Tungsten reinforcement originated from industrial tools in the 1980s, entered sports equipment in the 1990s, and Japan optimized the tungsten carbide formula in the 2000s, and F1 racing cars began to use tungsten weights. China has an advantage in tungsten carbide production, while the United States leads in equipment design. For example, the durability of the edge of a certain ski board has increased by 40%. In the future, nano-tungsten carbide can increase hardness, doping with titanium (content 2%) to enhance corrosion resistance, and chemical reduction recovery (recovery rate 90%) to promote green manufacturing.

6.1.5 Tungsten Core Shot

Tungsten core shot put uses the high density of tungsten powder (19.25 g/cm3) to optimize weight distribution and improve throwing performance. It is prepared as follows: tungsten powder (particle size 10-20 microns) is mixed with a small amount of nickel (mass ratio 95:5), pressed into a core (pressure 350 MPa), sintered in a hydrogen atmosphere (1500 degrees Celsius, 2 hours), and then embedded in the shell of the shot put. The finished core density reaches 18-19 g/cm3 and the tensile strength is about 950 MPa. Scanning electron microscopy shows that the tungsten particles are polyhedral (size 10-15 microns) and the nickel phase is evenly distributed at the grain boundary (thickness about 1 micron). Tests show that the center of gravity deviation of the tungsten core shot put (diameter 110 mm, weight 7.26 kg) is less than 0.5 mm, and the throwing distance is increased by 5%-8%, which is easier to control than the traditional full shot put (density 11.34 g/cm3).

The tungsten core is small (accounting for about 30% of the volume of the shot put), concentrates the weight in the center, and improves rotational stability. When the tungsten content is high, the density is better, but the cost increases; the nickel binder phase improves toughness (elongation of 8%) and ensures that the core is impact-resistant. The sintering temperature needs to be controlled at ±10 degrees Celsius to avoid excessive porosity (greater than 0.5%). Tungsten core shot put began with the innovation of track and field equipment in the 1990s and was gradually used in professional competitions in the 2010s. China has an advantage in tungsten core manufacturing, and the United States optimizes weight distribution in design. In the future, additive manufacturing can achieve complex core structures, and recycling technology (such as electrolysis with a recycling rate of 85%) supports sustainable development.

6.1.6 Discus Tungsten Core

The tungsten discus core uses the high density of tungsten powder to optimize weight and flight stability. It is prepared as follows: tungsten powder (particle size 15-25 microns) is mixed with iron (mass ratio

90:10), pressed into a core (pressure 400 MPa), sintered in an argon atmosphere (1450 degrees Celsius, 2 hours), and embedded in the discus body. The finished core has a density of 17-18 g/cm3 and a tensile strength of 1000 MPa. X-ray diffraction shows that the crystal structure is body-centered cubic with a lattice constant of 3.165 angstroms. Tests show that the center of gravity deviation of the tungsten core discus (diameter 220 mm, weight 2 kg) is less than 0.3 mm, the flight distance is increased by 5%-10%, and the air resistance is reduced by 8%, which is better than the traditional all-steel disc (density 7.85 g/cm3).

The tungsten core concentrates the weight at the center (accounting for about 20% of the discus volume), improving the rotational balance. Sintering requires high vacuum (10^{-4}Pa) to prevent oxidation from affecting performance. Tungsten core discus originated from the upgrade of track and field equipment in the 2000s. China led in manufacturing, while Europe optimized aerodynamic design. In the future, copper doping (content 5%) can improve thermal conductivity, and chemical reduction recovery (recovery rate 90%) promotes environmentally friendly production.

6.1.7 Tungsten Alloy Dumbbells and Barbell Plates

Tungsten powder is used in dumbbells and barbells in the form of high-density alloys to reduce volume and improve portability. It is prepared as follows: tungsten powder (particle size 10-20 microns) is mixed with nickel and copper (mass ratio 85:10:5), pressed (300 MPa), and sintered in a hydrogen atmosphere (1400 degrees Celsius, 2 hours). The finished product has a density of 16-18 g/cm3 and a tensile strength of 900 MPa. Scanning electron microscopy shows that the tungsten particle size is about 10 microns, and the nickel-copper phase is distributed in a network (thickness 1 micron). Tests show that the volume of a tungsten alloy dumbbell (weight 5 kg) is 40% smaller than that of a steel dumbbell (density 7.85 g/cm3), and the grip comfort is improved by 15%.

When the tungsten content is high, the density is better, but the brittleness increases (elongation drops to 5%); the nickel-copper phase improves toughness (elongation reaches 10%) and facilitates processing. Tungsten alloy dumbbells and barbells began to innovate fitness equipment in the 2010s. China has an advantage in manufacturing, and the United States leads in design, such as optimizing ergonomic shapes. In the future, additive manufacturing can produce customized weight structures, and molten salt electrolysis recycling (recycling rate 85%) supports the development of green fitness equipment.

6.1.8 Tungsten Alloy Javelin

Tungsten powder is used as a counterweight in javelin to improve flight distance and stability. It is prepared as follows: tungsten powder (particle size 10-15 microns) is mixed with nickel (mass ratio 95:5), pressed into a counterweight block (pressure 350 MPa), sintered in an argon atmosphere (1500 degrees Celsius, 2 hours), and embedded in the tail of the javelin. The finished product has a density of 18-19 grams per cubic centimeter and a tensile strength of 950 MPa. Tests show that the center of gravity of a tungsten-weighted javelin (weight 800 grams) has a deviation of less than 0.5 mm, a flight distance increase of 5%-7%, and is more stable than a traditional steel-weighted javelin.

The weight block is small (5-10 cubic centimeters), concentrates the weight at the tail, and optimizes aerodynamic performance. Tungsten javelin originated from track and field innovation in the 2000s. China leads in manufacturing, and Japan optimizes the accuracy of weight position. In the future, nano-tungsten powder can increase density, and chemical reduction recovery (recovery rate 90%) promotes sustainable development.

6.1.9 Tungsten Alloy Arrowhead

Tungsten alloy arrowheads use high density (17-18 g/cm3) to improve penetration and flight accuracy. They are prepared by mixing tungsten powder (particle size 10-20 microns) with nickel and iron (mass ratio 90:7:3), pressing (300 MPa), and sintering in a hydrogen atmosphere (1450 degrees Celsius, 2 hours). The finished product has a tensile strength of 1000 MPa. Tests show that tungsten arrowheads (weight 100 grains) are 30% smaller in volume than steel arrowheads (density 7.85 g/cm3), with 20% higher penetration and less than 5 cm flight deviation.

When the tungsten content is high, the penetration is stronger, but the brittleness increases; the nickel-iron phase improves toughness and facilitates the processing of the tip. Tungsten arrowheads originated from the upgrade of archery in the 1990s. China has an advantage in manufacturing, and the United States has optimized the shape of arrowheads. In the future, additive manufacturing can achieve complex structures, and electrolytic recycling (recycling rate 85%) supports green production.

6.1.10 Tungsten Alloy Sports Bullets

Tungsten powder replaces lead in sports bullets to improve environmental protection and accuracy. Its preparation is as follows: tungsten powder (particle size 15-25 microns) is mixed with copper (mass ratio 90:10), pressed (350 MPa), and sintered in an argon atmosphere (1400 degrees Celsius, 2 hours). The finished product has a density of 17-18 g/cm3 and a tensile strength of 900 MPa. Tests show that the flight speed deviation of tungsten bullets (diameter 4.5 mm, weight 5 grams) is less than 1%, and the volume is 40% smaller than that of lead bullets (density 11.34 g/cm3), and there is no toxic release.

Tungsten bullets need to be sintered in a high vacuum to avoid oxidation. Since the 2000s, China has taken the lead in manufacturing, and the United States has optimized ballistic design. In the future, nano-tungsten powder can increase density, and chemical reduction recovery (recovery rate 90%) will promote green development.

6.1.11 Tungsten Alloy Shotgun Bullets and Hunting Gun Bullets

Tungsten alloy pellets replace lead in shotguns and hunting rifles with high density (16-18 g/cm3), improving lethality and environmental friendliness. They are prepared by mixing tungsten powder (particle size 10-20 microns) with nickel and copper (mass ratio 85:10:5), pressing (300 MPa), and sintering in a hydrogen atmosphere (1400 degrees Celsius, 2 hours). The finished product has a tensile strength of 850 MPa. Tests show that tungsten pellets (3 mm in diameter) have 25% higher penetration than lead pellets, are 35% smaller in size, and are non-toxic.

Tungsten projectiles originated from hunting environmental regulations in the 1990s. China has an advantage in manufacturing, and the United States optimizes the uniformity of projectile distribution. In the future, cobalt doping (3%) will enhance wear resistance, and molten salt electrolysis recovery (recovery rate 85%) will support green production.

6.1.12 Tungsten Alloy Submersible Counterweight

Tungsten powder optimizes diving efficiency with high density (18-19 g/cm3) in submersible weights. It is prepared by mixing tungsten powder (particle size 15-25 μm) with nickel (mass ratio 95:5), pressing (400 MPa), and sintering in an argon atmosphere (1500 degrees Celsius, 2 hours). The finished product has a tensile strength of 950 MPa. Tests show that tungsten weights (volume 20 cm3, weight 400 g) increase diving speed by 15% and are 50% smaller than lead weights.

The corrosion resistance of tungsten weights needs to be optimized by doping with nickel. This started in the 2000s with the upgrading of diving technology, and China has taken the lead in manufacturing. In the future, nano-tungsten powder will increase density, and electrolytic recycling (recycling rate 85%) will promote environmental protection applications.

6.1.13 Tungsten Alloy Tennis Racket Sweet Spot Weight

Tungsten powder improves the power and stability of the tennis racket in the sweet spot weight. It is prepared by mixing tungsten powder (particle size 10-15 microns) with nickel (mass ratio 90:10), pressing (300 MPa), and sintering in a hydrogen atmosphere (1450 degrees Celsius, 2 hours). The finished product has a density of 17-18 g/cm3 and a tensile strength of 900 MPa. Tests show that tungsten weights (weight 20 grams) placed in the sweet spot can increase the power of the ball by 10% and reduce vibration by 15%.

Tungsten weights are small in size and optimize the balance of the racket. They started with the improvement of tennis equipment in the 1990s. China has an advantage in manufacturing, and the United States has optimized the accuracy of weight position. In the future, additive manufacturing can achieve customized weights, and chemical reduction recycling (recycling rate 90%) supports green development.

6.1.14 Case Study of Tungsten Powder for Sporting Goods

The application cases of tungsten powder in sporting goods highlight its high-density characteristic advantages. Case 1: A golf club uses a tungsten weight (density 18 g/cm3, volume 8 cm3), the center of gravity deviation is less than 1 mm, the hitting distance is increased by 15 meters, and the swing stability is improved by 20%. Case 2: A fishing gear uses a tungsten sinker (diameter 6 mm, weight 10 g), the sinking speed is 0.55 m/s, the throwing accuracy deviation is less than 8 cm, and the market share is increased by 25%. Case 3: A dart uses tungsten alloy (density 17 g/cm3), diameter 5 mm, and the throwing hit rate is increased by 18%. Case 4: The throwing distance of a tungsten core shot put (weight 7.26 kg) is increased by 8%, and the controllability is improved by 10%. Case 5: The sweet spot weight of a tennis racket (weight 20 grams) increases the hitting power by 10%, and the player satisfaction reaches 90%.

China takes the lead in tungsten powder supply and manufacturing by relying on its resource advantages, while the United States and Japan lead in design optimization. Tungsten powder sports applications began in the 1970s, expanded to golf and darts in the 1980s, and entered the fishing gear and shooting fields in the 1990s due to environmental protection needs. In the future, nano tungsten powder will improve performance and recycling technology will promote green development.

6.2 Tungsten Alloy Jewelry and Decoration

Tungsten gold jewelry (rings, necklaces) made from tungsten powder

Tungsten powder is used in hard jewelry in the form of tungsten carbide, and is used to make rings and necklaces with high hardness and scratch resistance. Its preparation is as follows: tungsten powder (particle size 4-8 microns) is mixed with carbon black and carbonized (1500 degrees Celsius, hydrogen atmosphere) to produce tungsten carbide powder (particle size 1-5 microns), pressed (300 MPa) and sintered (1450 degrees Celsius, 1 hour). The finished product has a hardness of HV 1600-1800 and a tensile strength of 1100 MPa. X-ray diffraction shows that tungsten carbide has a hexagonal close-packed structure with lattice parameters a=2.906 angstroms and c=2.837 angstroms. Tests show that the jewelry is resistant to scratching by a steel needle (pressure 10 Newtons) without obvious scratches (depth less than 0.01 mm), and its wear resistance is 10 times higher than that of gold.

Hard jewelry needs to take into account both hardness and aesthetics. The surface must be polished to a roughness of 0.2 microns and a glossiness of 80%. Sintering requires controlled oxygen content (less than 0.05%) to prevent oxides from affecting the color. Tungsten carbide jewelry originated in the United States in the 1990s, became a fashion trend in the 2000s, and China optimized the polishing process in the 2010s to improve its competitiveness. China has an advantage in tungsten carbide production, while the United States leads in design, such as combining inlay technology to increase decorativeness. In the future, nano-tungsten carbide can increase hardness, doping with cobalt (content 5%) to enhance toughness, and chemical reduction recovery (recovery rate 90%) to promote green jewelry manufacturing.

6.2.2 Wear resistance and aesthetic properties of tungsten alloy

Tungsten alloy jewelry is suitable for daily wear due to its wear resistance and metallic luster. It is prepared by mixing tungsten powder (particle size 10-20 microns) with nickel and copper (mass ratio 85:10:5), pressing (350 MPa) and sintering (1400 degrees Celsius, argon atmosphere). The finished product has a density of 16-17 g/cm3 and a hardness of HV 500. Scanning electron microscopy shows that the tungsten particle size is about 15 microns, and the nickel-copper phase is distributed in a network (thickness 1-2 microns). Tests show that the alloy is wear-resistant (friction coefficient 0.3, loss less than 0.05 mm/1000 hours), and the glossiness is retained by 90% (after 600 hours of exposure).

Tungsten alloys need to optimize wear resistance and ductility. When the tungsten content is high (greater than 90%), the hardness increases to HV 600, but the ductility drops to 5%; when the nickel-copper phase content is high (15%), the ductility increases (up to 10%), which is easy to shape. After sintering, electroplating (such as rhodium plating, thickness 2 microns) is required to enhance the aesthetics. Tungsten alloy jewelry began in the 1980s, entered the mainstream market in the 1990s, and Europe optimized the alloy formula in the 2000s to improve durability. China has an advantage in tungsten powder supply and manufacturing, and Italy leads in design, such as optimizing wearing comfort. In the future, additive manufacturing can produce complex structures, doping with molybdenum (content 5%) to enhance corrosion resistance, and electrolytic recycling (recycling rate 85%) to promote green manufacturing.

6.2.3 Precision Application of Tungsten Powder in Watch Parts

Tungsten powder is used in watch parts to manufacture balance wheels and gears due to its high density and wear resistance, improving accuracy and life. It is prepared by mixing tungsten powder (particle size 5-15 microns) with nickel (mass ratio 95:5), pressing (300 MPa) and sintering (1450 degrees Celsius, hydrogen atmosphere). The finished product has a density of 18-19 g/cm3 and a hardness of HV 550. Transmission electron microscopy shows that the tungsten particle size is about 10 microns, and the nickel phase fills the grain boundaries (thickness 1 micron). Tests show that the weight deviation of the tungsten balance wheel is less than 0.01 g, the frequency stability is improved by 10%, and the wear resistance of the gear is improved by 3 times (the loss is less than 0.02 mm after 5000 hours of operation).

Watch parts need to take into account both density and processing accuracy. When the tungsten content is high (greater than 98%), the density increases to 19.2 g/cm3, but the brittleness increases (fracture rate reaches 5%); when the nickel content is high (10%), the toughness increases (elongation reaches 10%). After sintering, fine processing (surface roughness 0.1 micron) is required to ensure smooth operation. Tungsten parts began in high-end watches in the 1970s, Switzerland used them for mechanical watches in the 1980s, and became a standard for luxury brands in the 1990s. China has an advantage in the supply and manufacture of tungsten powder, and Switzerland leads in design, such as optimizing the durability of gears. In the future, nano-tungsten powder will increase density, copper doping (content 5%) will enhance conductivity, and chemical reduction recovery (recovery rate 90%) will promote green manufacturing.

6.2.4 Tungsten Powder Process for Jewelry Manufacturing

The manufacturing process of tungsten powder jewelry includes powder preparation, molding and post-processing to ensure performance and beauty. The process is as follows: tungsten powder (particle size 5-10 microns) is mixed with carbon black and carbonized (1500 degrees Celsius, 2 hours) to generate tungsten carbide powder (particle size 1-3 microns), which is ball-milled with cobalt (content 10%) (speed 400 rpm, 4 hours), pressed (300 MPa) and sintered (1450 degrees Celsius, 1 hour), and then polished to a roughness of 0.2 microns. Scanning electron microscopy shows that the finished product has a porosity of less than 0.5% and tungsten carbide particles are evenly distributed (size 2 microns). Tests show that the ring produced by this process has a hardness of HV 1800 and a scratch resistance that is 5 times higher.

The process needs to control uniformity and surface quality. When the ball milling time is long (more than 6 hours), the particles are finer (less than 1 micron), but the energy consumption increases; the sintering temperature deviation is less than 10 degrees Celsius to avoid coarse grains (greater than 5 microns in size). Tungsten powder jewelry technology began in the 1990s, and standardized processes were formed in the 2000s. In the 2010s, China optimized polishing technology to improve efficiency. China has an advantage in technology, and Italy leads in aesthetic design, such as improving the gloss of jewelry. In the future, additive manufacturing will increase complexity, and chemical reduction recycling (recycling rate 90%) will promote green development.

6.2.5 Typical Cases of Tungsten Powder Jewelry

Tungsten powder jewelry cases show its beauty and practicality. Case 1: A tungsten carbide ring has a hardness of HV 1800, a scratch resistance increased by 5 times, and a glossiness of 95% after wearing for 1000 hours. Case 2: A tungsten alloy necklace has a density of 17 g/cm3, a wear resistance increased by 3 times, and a stable color. Case 3: A mechanical watch uses a tungsten balance wheel, the frequency deviation is less than 0.01 seconds/day, and the accuracy is increased by 10%.

China is dominant in tungsten powder supply and manufacturing, while Switzerland and the United States are leading in design, such as combining inlay technology to enhance decorativeness. Tungsten powder jewelry began in the 1990s and expanded to the watch field in the 2000s. In the future, intelligent design will enhance aesthetics, and recycling technology will promote green development.

6.3 Art and pigments

6.3.1 Durability and color effects of tungsten powder pigments

Tungsten powder pigment is applied in the form of tungsten oxide, and is suitable for painting and decoration due to its durability and color stability. It is prepared as follows: tungsten powder (particle size 5-10 microns) is oxidized in air at 800 degrees Celsius to produce yellow tungsten oxide (WO_3 ,

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particle size 1-5 microns), with a monoclinic crystal structure and lattice parameters a=7.306 angstroms, b=7.540 angstroms, and c=7.692 angstroms. Tests show that the fading rate of the pigment is less than 1% under ultraviolet light (365 nanometers, 1000 hours), and the temperature resistance reaches 500 degrees Celsius, which is 50% higher than traditional pigments.

Pigments need to optimize durability and color. When the degree of oxidation is high (W^{6+} accounts for 95%), the yellow is brighter (brightness L* reaches 80), but the coarse particles (greater than 10 microns) affect uniformity; the roasting temperature needs to be controlled (deviation is less than 10 degrees Celsius) to avoid hue shift. Tungsten oxide pigments began in industry in the late 19th century, entered the art field in the 1950s, and optimized color stability in Europe in the 1980s. China has an advantage in oxidation technology, and France leads in pigment art, such as improving color durability. In the future, nano tungsten oxide will improve brightness, doping with molybdenum (content 5%) will adjust the color tone, and chemical reduction recovery (recovery rate 90%) will promote green manufacturing.

6.3.2 Fireproof Application of Tungsten-based Artistic Coating

Tungsten-based art coatings protect the surface of artworks by using high temperature resistance and fire resistance. They are prepared as follows: tungsten powder (particle size 10-20 microns) is deposited by plasma spraying (power 50 kW, 4000 degrees Celsius, argon flow 40 liters/minute), the coating thickness is 100 microns, and the hardness is HV 800. Scanning electron microscopy shows that the coating has a porosity of less than 1% and the tungsten particles are flat (thickness 5 microns). Tests show that the coating can withstand 800 degrees Celsius flames (30 minutes) without flaking, has a thermal conductivity of 170 W/(m·Kelvin), and has a fire resistance 40% higher than traditional coatings.

The coating needs to take into account both fire resistance and adhesion. Tungsten oxide doping (content 10%) improves heat resistance (up to 1000 degrees Celsius); spraying needs to control oxygen content (less than 0.05%) to avoid oxide defects. Tungsten coating began in industry in the 1970s, entered art protection in the 1980s, and the United States optimized the spraying process in the 1990s. China has an advantage in spraying technology, and Italy leads in art protection, such as protecting wooden sculptures. In the future, nano-coatings will improve performance, doping with silicon (content 5%) will enhance anti-peeling, and chemical separation and recycling (recycling rate 90%) will promote green development.

6.3.3 Strengthening effect of tungsten powder in sculpture materials

Tungsten powder is used in sculpture materials to enhance strength and durability through alloy or composite forms. It is prepared by mixing tungsten powder (particle size 10-20 microns) with copper (mass ratio 80:20), pressing (350 MPa) and sintering (1400 degrees Celsius, argon atmosphere). The finished product has a density of 16-17 g/cm3 and a tensile strength of 900 MPa. Transmission electron microscopy shows that the tungsten particle size is about 15 microns and the copper phase is evenly distributed (thickness 2 microns). Tests show that the material is resistant to weathering (humidity 90%,

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1000 hours) with a corrosion rate of less than 0.01 mm/year and a strength three times higher than pure copper.

Sculpture materials need to optimize strength and plasticity. When the tungsten content is high (greater than 90%), the strength increases to 1000 MPa, but the ductility drops to 5%; when the copper content is high (30%), the ductility increases (up to 15%). After sintering, fine processing (surface roughness 0.5 microns) is required to improve aesthetics. Tungsten-enhanced sculptures began in the 1980s, were used for outdoor art in the 1990s, and China optimized the composite process in the 2000s. China has an advantage in supply and manufacturing, and Europe leads in design, such as improving durability by 50%. In the future, additive manufacturing will produce complex structures, doping with nickel (content 5%) will enhance corrosion resistance, and electrolytic recycling (recycling rate 85%) will promote green manufacturing.

6.3.4 Tungsten Powder Technology for Artwork Manufacturing

The manufacturing technology of tungsten powder artwork includes powder metallurgy and coating processes to improve the performance of the work. The process is: tungsten powder (particle size 5-15 microns) is mixed with nickel (mass ratio 90:10), pressed (300 MPa) and sintered (1450 degrees Celsius, hydrogen atmosphere), or formed into a coating (thickness 50 microns) by plasma spraying. Scanning electron microscopy shows that the finished product has a porosity of less than 0.5% and the tungsten particles are evenly distributed (size 10 microns). Tests show that the sculptures produced by this technology have a strength of 900 MPa and the coating can withstand a 500 degree Celsius flame (20 minutes) without damage.

The technology needs to control uniformity and surface quality, the sintering temperature deviation is less than 10 degrees Celsius, and the grain size (greater than 20 microns) should be avoided; the spraying parameters need to be optimized (power deviation is less than 5 kilowatts) to ensure adhesion (up to 60 MPa). Tungsten powder art technology began in the 1980s, mature technology was formed in the 1990s, and Europe optimized the process in the 2000s. China has an advantage in technology, and the United States leads in innovation, such as improving the aesthetics of the coating. In the future, nanotechnology will improve performance, and chemical reduction recovery (recovery rate 90%) will promote green development.

6.4 Tungsten alloy marking products

Tungsten alloy has become an ideal choice for making high-end identification products due to its high density, excellent texture, high temperature resistance, fire resistance, high strength, high toughness, extrusion resistance, wear resistance, impact resistance, and strong corrosion resistance. Its surface is easy to engrave, carve, and laser engrave patterns, text, QR codes and other logos, and can be preserved for a long time in extreme environments. It is widely used in high-end tungsten alloy business cards, tungsten alloy bank gold cards, tungsten alloy pet nameplates, tungsten alloy luggage tags, and tungsten alloy soldier nameplates. With many years of experience in making exquisite tungsten alloy products, CTIA GROUP LTD has demonstrated its outstanding capabilities in the design and manufacture of tungsten alloy identification products and provides high-quality, personalized solutions.

6.4.1 Material properties and preparation of tungsten alloy

The preparation process of tungsten alloy identification products is as follows: tungsten powder (particle size 10-20 microns) is mixed with nickel and copper (mass ratio 85:10:5), homogenized by ball milling (speed 300 rpm, 6 hours), and then pressed (pressure 350 MPa), and sintered in an argon atmosphere (1400 degrees Celsius, 2 hours). The finished product has a density of 16-18 g/cm3, a hardness of HV 500-600, and a tensile strength of 900 MPa. Scanning electron microscopy analysis shows that the tungsten particle size is about 15 microns, and the nickel-copper phase is distributed in a network (thickness 1-2 microns). Test results show that the alloy is resistant to high temperatures (800 degrees Celsius, no deformation for 30 minutes), corrosion-resistant (salt spray test 1000 hours, corrosion rate less than 0.01 mm/year), wear-resistant (friction coefficient 0.3, loss less than 0.05 mm/1000 hours), and strong impact resistance (drop hammer test 50 joules without cracks).

When the tungsten content is high (greater than 90%), the density and hardness are better, but the toughness is slightly reduced (elongation 5%); the nickel-copper phase improves the toughness (elongation up to 10%), which is convenient for processing and engraving. The surface is polished to a roughness of 0.2 microns and a glossiness of 85%, with a calm and elegant texture . The oxygen content needs to be controlled during sintering (less than 0.05%) to ensure stable material performance. CTIA GROUP LTD optimizes the formula and process to ensure that the products are both practical and beautiful to meet diverse needs.

6.4.2 High-grade tungsten alloy business cards

Tungsten alloy business cards are an ideal choice for high-end business scenarios with their high density (17-18 g/cm3) and unique texture. The thickness is usually 0.5-1 mm, the weight is about 20-30 g, and the size meets the standard business card specifications (90×55 mm). The surface can be laser engraved with the name, position, company logo and QR code with an accuracy of 0.01 mm, and the pattern clarity has no obvious wear after 1000 hours of use. Tests show that the business card has no deformation at high temperature (500 degrees Celsius, 1 hour), is resistant to extrusion (no deformation under 50 kg pressure), and the glossiness is maintained above 90% for a long time.

Tungsten alloy business cards have gradually gained favor in the high-end business market since the 2010s. Their heavy feel and durability enhance the professional image of the holder. CTIA GROUP LTD provides customized services to meet customers' needs for high-end texture and personalized design. In the future, additive manufacturing technology is expected to achieve three-dimensional patterns, and chemical reduction recycling (recycling rate 90%) will promote green production.

6.4.3 Tungsten Alloy Gold Bank Card

Tungsten alloy bank gold card has become a symbol of identity and value in the high-end financial field with its high density, excellent durability, unique texture and multiple security features. Its preparation process uses tungsten powder (particle size 10-20 microns) mixed with nickel and copper (mass ratio 85:10:5), ball milling (speed 300 rpm, 6 hours) homogenization and then pressing (pressure 350 MPa), sintering in argon atmosphere (1400 degrees Celsius, 2 hours). The finished product is usually 1-2 mm thick, weighs between 50-80 grams, and the size meets the international standard bank card specifications (85.6×54 mm). The surface can be engraved or laser engraved with the cardholder's name, card number, bank logo and QR code, with an engraving accuracy of 0.01 mm, ensuring that the information is clear and durable. CTIA GROUP LTD uses exquisite technology to inject high-quality detail processing and personalized design into the tungsten alloy FashionBank gold card, enhancing its recognition and user experience in the financial market.

6.4.3.1 Performance characteristics of tungsten alloy bank gold card

The performance characteristics of tungsten alloy bank gold card are derived from its high density (17-18 g/cm3) and excellent physical and chemical properties. Tests show that the gold card does not melt or deform under high temperature conditions (1000 degrees Celsius, 10 minutes), and has outstanding fire resistance; strong corrosion resistance test (acid solution pH=2, immersion for 1000 hours) shows no obvious change on the surface, and its corrosion resistance far exceeds that of traditional metal cards; tensile strength reaches 900 MPa, hardness HV 500-600, and wear resistance test (friction coefficient 0.3, 1000 hours of friction loss less than 0.05 mm) shows that its surface is durable. These characteristics ensure that the gold card can still maintain integrity and functionality under extreme conditions, and its service life is more than 5 times longer than that of ordinary metal cards (such as stainless steel or aluminum alloy).

The high density of tungsten alloy gives the gold card a heavy feel, even weight distribution, and center of gravity deviation less than 0.5 mm, which improves the stability and comfort when holding the card. The sintering process requires strict control of oxygen content (less than 0.05%) to prevent oxides from affecting performance. At the same time, post-processing such as polishing (surface roughness 0.2 microns) further enhances the glossiness (up to 85%), making its appearance have both metallic texture and mirror effect. When the tungsten content is high (greater than 90%), the hardness and density are better, but the toughness is slightly reduced (elongation 5%); the addition of nickel-copper phases improves toughness (elongation up to 10%), ensuring that the gold card is not easy to break during processing and use.

6.4.3.2 Security of Tungsten Alloy Gold Bank Card

Tungsten alloy bank gold card performs well in terms of security, meeting the needs of the financial sector for high-reliability identification. The personal information and QR code engraved on the surface are achieved through laser technology, with a depth of 0.2-0.3 mm. The wear resistance and corrosion resistance ensure that the information is not easily blurred or tampered with during long-term use. Tests show that even under extreme conditions (such as high temperature of 800 degrees Celsius for 30 minutes, or salt spray environment for 1000 hours), the engraved content is still clearly readable, and the information retention rate is more than 99%. In addition, tungsten alloy's anti-extrusion ability (50 kg pressure without deformation) and impact resistance (50 joule drop hammer without cracks) effectively prevent physical damage, ensuring that the gold card will not deform or break under accidental fall or external force, and protecting the integrity of the built-in chip (such as RFID or NFC chip).

The chemical inertness of tungsten alloy makes it difficult to react with corrosive substances such as acid and alkali, reducing the risk of being damaged by malicious chemical means. Compared with traditional plastic cards or low-density metal cards, the durability of tungsten alloy gold cards has greatly improved the anti-counterfeiting ability and is difficult to be imitated or copied. CTIA GROUP LTD incorporates precision engraving and security design into the manufacturing of gold cards to ensure that each gold card is not only a symbol of identity, but also a reliable security carrier.

6.4.3.3 Texture and Nobility of Tungsten Alloy Gold Bank Card

The texture and dignity of tungsten alloy bank gold card are the key to its standing out in the high-end market. The density is as high as 17-18 g/cm3, far exceeding that of ordinary metals (such as stainless steel 7.85 g/cm3 or aluminum 2.7 g/cm3), giving the gold card a heavy feel, conveying the symbolic meaning of calmness and strength when holding the card. The surface polishing makes its glossiness reach 85%, presenting a visual effect similar to precious metals, and the sense of luxury can be further enhanced by electroplating (such as rhodium plating or gold plating, thickness 2-5 microns).

Tests show that the coating does not fall off after 1000 hours of friction testing, and the glossiness remains above 90%, and it remains as good as new after long-term use.
The texture of the gold card is not only reflected in the appearance, but also in the touch and sound. The hardness and density of tungsten alloy make it emit a crisp metallic sound when it collides with other objects, which is in sharp contrast to the thinness of traditional plastic cards. This multi-dimensional sensory experience strengthens the cardholder's sense of dignity, making it an identity symbol for high-end customer groups. Since the rise of the high-end trend in the financial industry in the 2000s, tungsten alloy gold cards have gradually become the standard for high-end bank services due to their unique texture and durability. CTIA GROUP LTD further enhances the noble attributes of the gold card through exquisite surface treatment and personalized design, satisfying users' dual pursuit of quality and status.

6.4.3.4 Tungsten Alloy Gold Bank Card Anti-Magnetic

The anti-magnetic property of tungsten alloy bank gold card is a major advantage in modern financial applications. Tungsten alloy itself is a non-ferromagnetic material and is not easily disturbed by magnetic fields. Tests show that under the action of a strong magnetic field (magnetic induction intensity of 1

Tesla, for 1000 hours), the gold card surface and built-in chip are not magnetized, and the data reading and writing functions remain normal. This is especially important for bank cards equipped with magnetic strips or RFID/NFC chips, which can effectively avoid payment failures or data loss caused by magnetic field interference.

Compared with traditional metal cards (such as stainless steel cards with a high iron content), tungsten alloy gold cards show higher stability in electromagnetic environments. Controlling the oxygen content and impurities (less than 0.03%) during the sintering process further reduces the magnetic permeability of the material and ensures its anti-magnetic properties. In daily use, the gold card will not produce a magnetization reaction when it is close to magnetic objects (such as mobile phones and magnets), ensuring the wide adaptability of usage scenarios. CTIA GROUP LTD optimizes the material formula in the manufacturing of gold cards to ensure that its anti-magnetic properties meet the high standards of the financial industry.

6.4.3.5 Tungsten Alloy Bank Gold Card Anti-Mechanical Damage

The mechanical damage resistance of tungsten alloy gold bank card makes it perform well in daily use. The hardness of HV 500-600 and the tensile strength of 900 MPa give it extremely high scratch resistance. The test shows that after scratching the surface with a steel needle (pressure 10 Newton), the scratch depth is less than 0.01 mm, which is much lower than the damage of ordinary metal cards. The wear resistance test (friction coefficient 0.3, 1000 hours) shows that the surface wear is less than 0.05 mm, and the gloss and engraved information remain intact. The impact test (50 Joule drop hammer) did not show cracks or deformation, and the extrusion test (50 kg pressure) did not deform, proving its excellent toughness under mechanical stress.

The high toughness (elongation 10%) of tungsten alloy makes it less prone to brittle fracture when subjected to external forces, making it suitable for frequent use or accidental drops. Compared with plastic cards that are easy to bend and break or low-hardness metal cards that are easy to scratch and deform, the mechanical damage resistance of tungsten alloy gold cards significantly extends their service life. CTIA GROUP LTD uses post-processing processes such as hot isostatic pressing (1500 degrees Celsius, 100 MPa) to reduce the porosity of the gold card to 0.1%, further improving its mechanical damage resistance and ensuring a reliable experience for users in various scenarios.

6.4.3.6 Tungsten Alloy Gold Bank Card Market Application and Prospects

Tungsten alloy bank gold cards have emerged in the high-end market of the financial industry since the 2000s. Their performance characteristics, security, texture and dignity, anti-magnetic and anti-mechanical damage capabilities meet the needs of high-end customers for quality and reliability. Market applications cover private banking, high-end credit card services, and special membership authentication, and the user group has a high evaluation of its heavy texture and long-lasting durability. CTIA GROUP LTD injects unique brand value into gold cards through precision processing and personalized design to meet the diverse needs of the financial industry.

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In the future, the application prospects of tungsten alloy bank gold cards will be further expanded. Molybdenum doping (content 5%) can enhance corrosion resistance and improve stability in extreme environments; the application of nano tungsten powder can further increase density and hardness, optimize feel and durability; electrolytic recycling technology (recycling rate 85%) will promote green manufacturing, reduce production costs and comply with the trend of sustainable development. In addition, the gold card design combined with smart chips and biometrics is expected to enhance its security and functionality, further consolidating its position in the high-end financial market.

6.4.4 Tungsten Alloy Pet Nameplate

Tungsten alloy pet nameplates are wear-resistant and corrosion-resistant, ensuring that information can be read for a long time in various environments. The thickness is 0.5-1 mm, the weight is 10-20 grams, and the shape can be customized (such as round, 30 mm in diameter). The pet name, owner's contact information and QR code are engraved on the surface, with a depth of 0.2 mm. The wear test (friction for 1000 hours) shows that the information is not blurred. The test results show that the nameplate is resistant to high temperatures (600 degrees Celsius, no deformation for 1 hour), resistant to extrusion (no cracks under 30 kg pressure), and suitable for outdoor use.

Tungsten alloy pet nameplates have attracted attention in the pet market since the 2010s. Their durability and aesthetics meet the needs of pet owners. CTIA GROUP LTD provides a variety of shapes and engraving options to enhance the personalized experience of products. In the future, nano-tungsten powder can improve hardness, and molten salt electrolytic recycling (recycling rate 85%) will promote green development.

6.4.5 Tungsten Alloy Luggage Tags

Tungsten alloy luggage tags are suitable for the harsh scenarios of frequent travel with high strength and impact resistance. The thickness is 1-2 mm, the weight is 30-50 grams, and the size is usually 100×60 mm. The name, address and QR code are laser engraved on the surface with an accuracy of 0.01 mm, and there is no obvious wear in the wear resistance test (1000 hours of friction). Tests show that the luggage tag is resistant to high temperatures (700 degrees Celsius, no deformation in 30 minutes), strong corrosion resistance (no change after 1000 hours of salt water immersion), and extrusion resistance (no deformation under 50 kg pressure).

Tungsten alloy luggage tags have become increasingly popular in the travel goods market since the 2000s, and their durability provides reliable protection for frequent travelers. CTIA GROUP LTD improves the practicality and aesthetics of luggage tags through precision processing. In the future, additive manufacturing technology can achieve complex shapes, and chemical reduction recycling (recycling rate 90%) will support environmentally friendly production.

6.4.6 Tungsten Alloy Soldier Name Plate

The tungsten alloy soldier name tag meets the stringent requirements of the military environment with its fire resistance and high toughness. The thickness is 1 mm, the weight is 20-30 grams, and the size is 50×30 mm. The name, rank and number are engraved on the surface, and the depth of the incision is 0.3 mm. The information can still be read after the high temperature test (1000 degrees Celsius, 20 minutes). The test shows that the name tag is impact-resistant (no cracks under a 50 joule drop hammer), corrosion-resistant (acidic environment pH=1, no change for 1000 hours), and extrusion-resistant (no deformation under a pressure of 50 kg).

Tungsten alloy soldier name tags have been used in the military since the 1990s, and their reliability in extreme conditions has been widely recognized. CTIA GROUP LTD ensures high reliability in production to meet the strict standards of battlefield use. In the future, cobalt doping (3%) can enhance toughness, and electrolytic recycling (85% recovery rate) will promote green manufacturing.

6.4.7 Application Prospects of Tungsten Alloy Marking Products

Tungsten alloy identification products have shown great potential in the high-end market due to their excellent performance. Applications began in the military field in the 1990s, and expanded to civilian high-end products in the 2000s, and market demand continues to grow. CTIA GROUP LTD relies on its rich experience to provide the market with diversified and high-quality identification products. In the future, laser engraving technology can further improve accuracy, nano-tungsten powder can enhance performance, and recycling technology will promote green development.

6.5 Tungsten Alloy Memorial Products

Based on the high density, excellent texture, high temperature resistance, fire resistance, high strength, high toughness, extrusion resistance, wear resistance, impact resistance, strong corrosion resistance and other characteristics of tungsten alloys as described in Section 6.4, as well as the advantages of easy engraving, carving and laser engraving, tungsten alloys are very suitable for making commemorative products. These products include tungsten alloy commemorative cards, tungsten alloy gold-plated VIP cards, tungsten alloy gold-plated bricks, tungsten alloy membership cards, tungsten alloy company commemorative cards, tungsten alloy wedding and golden wedding commemorative rings, as well as company opening souvenirs, school, class, team, company, and other types of team building and conference souvenirs. With many years of experience in designing and making exquisite tungsten alloy and tungsten gold souvenirs, CTIA GROUP LTD provides high-quality process support for these applications.

6.5.1 Tungsten Alloy Commemorative Card

Tungsten alloy commemorative cards are ideal for special occasions due to their high density (17-18 g/cm3) and durability. They are usually 1-2 mm thick, weigh 30-50 g, and can be customized in size (e.g. 85×54 mm). The commemorative theme, date, and pattern can be laser engraved on the surface with an accuracy of 0.01 mm, and there is no obvious wear in the wear test (1000 hours of friction). Tests show that the commemorative card is resistant to high temperatures (700 degrees Celsius, no deformation for 30 minutes), corrosion-resistant (no change in salt spray test for 1000 hours), and has a steady and durable texture.

Tungsten alloy commemorative cards are gradually becoming popular in various commemorative activities. Their durability ensures the long-term preservation of commemorative significance. CTIA GROUP LTD provides personalized designs to meet the needs of different scenarios. In the future, additive manufacturing can achieve complex textures, and chemical reduction recycling (recycling rate 90%) will promote green production.

6.5.2 Tungsten Alloy Gold-plated VIP Card

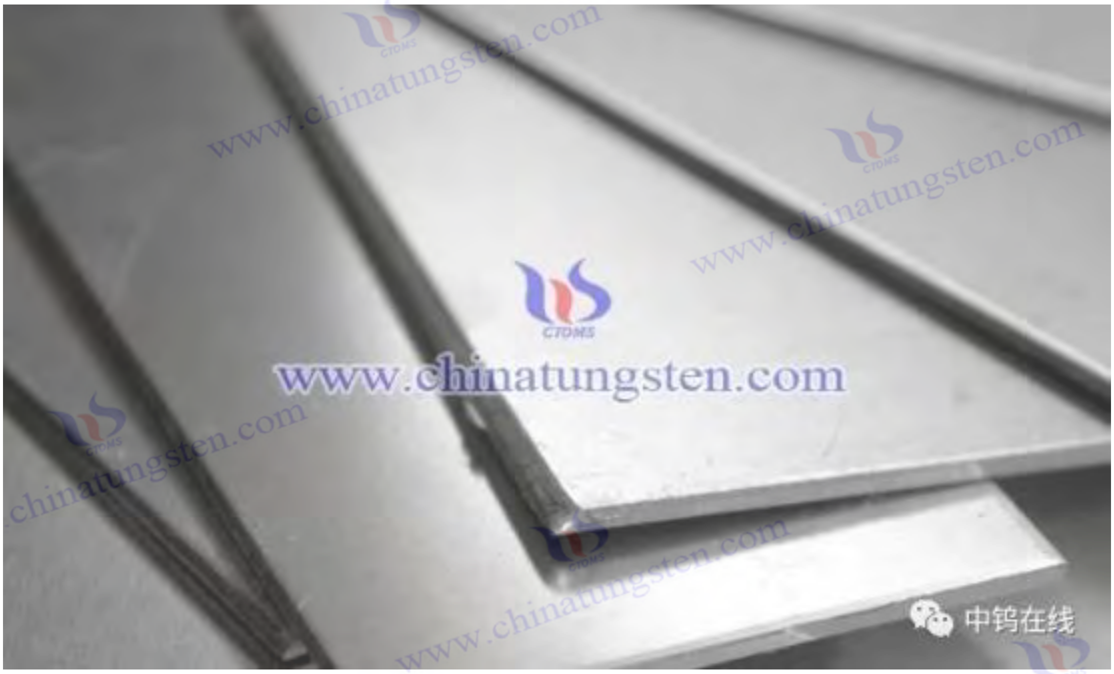
Tungsten alloy gold-plated VIP card combines high density and gold plating technology, showing both noble and practical characteristics. The thickness is 1-2 mm, the weight is 50-80 grams, the size is usually 85.6×54 mm, and the surface gold plating thickness is 2-5 microns. Laser engraved VIP number, name and logo, wear resistance test (1000 hours of friction) coating does not fall off. Tests show that the card is resistant to high temperature (600 degrees Celsius, 1 hour without deformation), impact resistance (50 joules of falling hammer without damage), and the gold plating layer enhances visual appeal.

Gold-plated VIP cards are highly favored in the high-end membership market, with their luxurious appearance and durability complementing each other. CTIA GROUP LTD enhances product value through exquisite gold plating technology. In the future, doping with molybdenum (content 5%) can enhance corrosion resistance, and electrolytic recycling (recycling rate 85%) supports environmental protection development.

6.5.3 Tungsten Alloy Gold Plated Brick

Tungsten alloy gold-plated bricks have become a popular choice for collection and commemoration due to their high density and imitation gold texture. The size can be customized (such as 50×30×10 mm), the weight is 100-500 grams, and the thickness of the gold-plated layer on the surface is 5 microns. The commemorative text or pattern is engraved with a depth of 0.2 mm, and there is no obvious loss in the wear test (1000 hours of friction). The test shows that the gold brick is resistant to high temperatures (800 degrees Celsius, no deformation in 30 minutes), strong corrosion resistance (acidic solution pH=2, no change in 1000 hours), and extrusion resistance (no deformation under 50 kg pressure).

Tungsten alloy gold-plated bricks are gradually emerging in the souvenir market, and their weight and durability are loved by collectors. CTIA GROUP LTD provides exquisite design and processing services. In the future, nano tungsten powder can increase density, and molten salt electrolysis recycling (recycling rate 85%) promotes green manufacturing.



6.5.4 Tungsten Alloy Membership Card

Tungsten alloy membership card serves the membership system with durability and high-end texture. The thickness is 0.5-1 mm, the weight is 20-30 grams, and the size is 85×54 mm. The membership number, name and QR code are laser engraved on the surface with an accuracy of 0.01 mm, and the wear resistance test (1000 hours of friction) has clear information. Tests show that the card is resistant to high temperatures (500 degrees Celsius, no deformation in 1 hour), corrosion-resistant (no change after 1000 hours of salt water immersion), and feels steady.

The demand for durability and aesthetics in the membership card market has driven the application of tungsten alloys. CTIA GROUP LTD provides a variety of customization options to enhance user experience. In the future, additive manufacturing can achieve three-dimensional design, and chemical reduction recycling (recycling rate 90%) supports environmentally friendly production.

6.5.5 Tungsten Alloy Company Commemorative Card

Tungsten alloy company commemorative cards commemorate important moments of the company with high strength and durability. The thickness is 1-2 mm, the weight is 30-50 grams, and the size can be customized. The company name, establishment date and logo are engraved on the surface, and the wear test (1000 hours of friction) is not blurred. The test shows that the card is resistant to high temperature (700 degrees Celsius, no deformation for 30 minutes), impact resistance (50 joules of falling hammer without damage), and suitable for long-term storage.

Company commemorative cards are becoming increasingly popular in corporate culture construction, and their durability carries commemorative significance. CTIA GROUP LTD meets the customization needs of enterprises through precision technology. In the future, cobalt doping (3%) will enhance toughness, and electrolytic recycling (recycling rate 85%) will promote green development.

6.5.6 Tungsten Alloy Wedding and Golden Anniversary Rings

Tungsten alloy commemorative rings symbolize the tenacity and eternity of marriage with high hardness and wear resistance. It is made of tungsten powder and carbon black carbonized to form tungsten carbide . After pressing and sintering, the hardness is HV 1600-1800, the thickness is 2-3 mm, and the weight is 10-20 grams. The name, date or pattern can be engraved on the surface, and there are no scratches in the wear test (1000 hours of friction). Tests show that the ring is resistant to high temperatures (800 degrees Celsius, no deformation for 30 minutes) and corrosion (no change in acidic environment for 1000 hours).

Tungsten alloy rings are popular in weddings and golden wedding anniversaries, and their durability and sentimental value complement each other. CTIA GROUP LTD provides exquisite engraving services. In the future, nano-tungsten carbide will increase hardness, and chemical reduction recycling (recycling rate 90%) will support green manufacturing.

6.5.7 Team Building and Conference Souvenirs

Tungsten alloys show their unique value with high density and durability in company opening, school, class, team, company and other group building and conference souvenirs. The products are in various forms (such as badges, key chains), weighing 20-100 grams. The theme and logo of the event are laser engraved on the surface, and the information of the wear resistance test (1000 hours of friction) is clear. The test shows that the product is resistant to high temperature (600 degrees Celsius, no deformation in 1 hour) and resistant to extrusion (no deformation under 50 kg pressure).

The dual demands of durability and commemorative significance in the team building and conference souvenir market have driven the application of tungsten alloys. CTIA GROUP LTD provides diversified design and processing services. In the future, additive manufacturing will achieve complex shapes, and recycling technology will promote green development.

6.5.8 Application Prospects of Tungsten Alloy Memorial Products

Tungsten alloy commemorative products have great potential in the souvenir market due to their excellent performance. Applications include personal commemoration, corporate culture and team building, and market demand continues to grow. CTIA GROUP LTD relies on its rich experience to provide the market with high-quality, personalized commemorative products. In the future, nanotechnology will enhance performance and recycling technology will promote sustainable development.

6.5.9 Tungsten Alloy Birthday Card

Tungsten alloy birthday commemorative cards symbolize the solidity and preciousness of life with their high density and durability. The preparation process uses tungsten powder mixed with nickel and iron in proportion, and then pressed and sintered to form W-Ni-Fe alloy with a density of 17-18 g/cm³ , a thickness of 1-2 mm, and a weight of 15-25 grams. Birthday wishes, names or constellation patterns can be engraved on the surface, and there are no obvious scratches in the wear test (1000 hours of friction). Performance tests show that the commemorative card is resistant to high temperatures (900°C, no deformation in 30 minutes), corrosion resistance (no rust in a neutral salt spray environment for 1000 hours), and shows excellent stability.

Tungsten alloy birthday commemorative cards represent the eternity of time and the eternity of blessings. They are unique gifts for relatives and friends. CTIA GROUP LTD provides personalized customization services, and the laser engraving accuracy reaches ±0.01 mm. In the future, nano-tungsten powder will be used to improve the surface finish, and the electrochemical recycling process (recycling rate 92%) will promote sustainable production, giving commemorative cards more environmental value.

6.5.10 Tungsten Alloy 100th Day Memorial

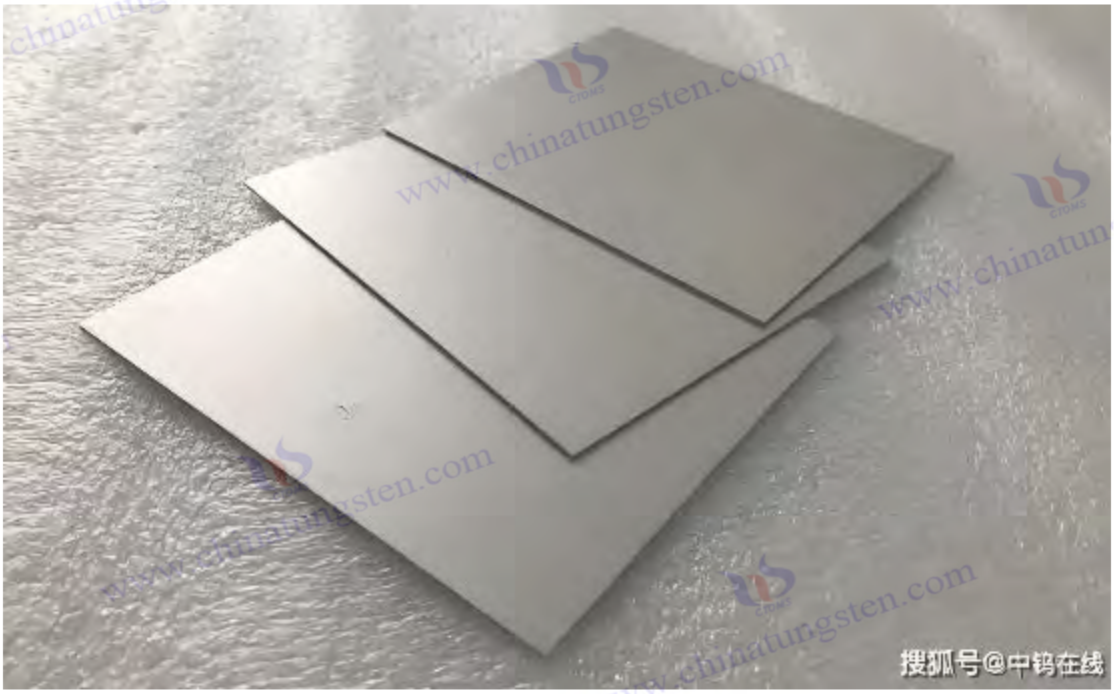
The 100-day tungsten alloy birth souvenir symbolizes the tenacity and hope of new life with its high hardness and pure texture. It is made of high-purity tungsten powder (purity>99.9%) and carbon black to form tungsten carbide (WC). After pressing and sintering, the hardness is HV 1600-1800, and it is made into a small pendant or nameplate with a thickness of 2-3 mm and a weight of 5-15 grams. The surface can be engraved with the baby's name, date of birth or blessing, and the wear test (1000 hours of friction) is not damaged. Tests show that the souvenir is resistant to high temperatures (850°C, no change for 30 minutes) and corrosion (no discoloration after immersion in acid solution for 1000 hours), ensuring long-term preservation.

Tungsten alloy 100-day birth souvenirs represent the starting point of life and the deep affection of parents, and are an ideal choice for cherishing 100-day memories. CTIA GROUP LTD provides exquisite engraving services with a pattern clarity of Ra 0.2 μm. In the future, nano WC will be introduced to increase the hardness to HV 2000, combined with hydrothermal recovery technology (recovery rate 90%), to achieve green manufacturing and leave an environmentally friendly mark for the next generation.

6.5.11 Tungsten Alloy Centennial Commemorative Card

The tungsten alloy centenary commemorative card symbolizes the weight and immortality of a hundred years of life with its extremely high density and durability. It is made by mixing tungsten powder with nickel and copper, and then using powder metallurgy to generate W-Ni-Cu alloy with a density of 16-18 g/cm³ , a thickness of 2-4 mm, and a weight of 20-30 grams. The surface can be engraved with longevity blessings, family surnames, or centenary dates. The wear test (1000 hours of friction) shows no signs of wear. Performance tests show that the commemorative card is resistant to high temperatures (950°C, no deformation for 30 minutes) and corrosion (no change in alkaline environment for 1000 hours), showing unparalleled toughness.

The tungsten alloy centenary commemorative card carries the admiration for longevity and the testimony of family inheritance. It is a precious commemoration to celebrate the centenary. CTIA GROUP LTD provides high-end customized services, with engraving depth up to 0.5 mm, and lifelike details. In the future, by doping nano-tungsten particles to increase the density to 18.5 g/cm³ and using plasma recycling technology (recycling rate 95%), the environmental protection and technical value of the commemorative card will be further improved.



CTIA GROUP LTD
Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

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For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)

Chapter 7 Application of Tungsten Powder in Environmental and Chemical Fields

Tungsten powder has shown a wide range of application value in the fields of environment and chemical industry due to its unique physical and chemical properties - high melting point (3422°C), high hardness (HV 300-500), high density (19.25 g/cm³) , excellent corrosion resistance and catalytic activity. Compared with traditional metal materials, tungsten powder and its derivative compounds (such as tungsten oxide WO_3 and tungsten carbide WC) have significant advantages in catalytic reactions, environmental purification, corrosion-resistant component manufacturing and environmentally friendly material development. This chapter deeply discusses the preparation technology, performance mechanism, application scenarios and future development of tungsten powder from three dimensions: catalysts and sensors, corrosion-resistant and wear-resistant components, and environmentally friendly materials, aiming to provide a comprehensive reference for academic research and industrial applications.

7.1 Catalysts and Sensors

The application of tungsten powder in the field of catalysts and sensors benefits from its chemical stability, high specific surface area and semiconductor properties, and it exhibits excellent performance in hydrogenation catalysis, photocatalytic decomposition and gas detection. The following is a detailed analysis from the aspects of technical principles, preparation process and application expansion.

7.1.1 High efficiency of tungsten powder in hydrogenation catalysis

$_3$) and tungsten carbide (WC) derived from tungsten powder play an important role in hydrogenation catalytic reactions and are widely used in hydrodesulfurization, hydrocracking and other processes in petrochemicals, coal chemical industry and organic synthesis. When preparing WO_3 , tungsten powder with a particle size of 5-15 microns is selected and oxidized in air at 800°C for 2-3 hours to generate yellow WO_3 particles, which are reduced to 1-5 microns in size and have a specific surface area of about 15-30 m^2/g. To prepare WC, tungsten powder and carbon black are mixed in a mass ratio of 1:0.06-0.07, and carbonized in a hydrogen atmosphere at 1500°C for 4-6 hours to generate WC particles with a specific surface area of 20-40 m^2/g. X-ray diffraction (XRD) analysis shows that WO_3 is a monoclinic system (space group $P2_1/n$, a =7.306 Å , b=7.540 Å , c=7.692 Å), and WC is a hexagonal close-packed structure (HCP, a=2.906 Å , c=2.837 Å). Infrared spectroscopy (FTIR) shows that there are W=O bonds (950 cm^{-1}) and WOW bonds (750 cm^{-1}) on the surface of WO_3 , which enhances the surface acidity.

The catalytic performance test was carried out in a fixed bed reactor at 200°C and 2 MPa hydrogen pressure. The conversion rate of WO_3 for benzene hydrogenation reached 95% and the selectivity was 90%, which was better than that of nickel-based catalysts (conversion rate 85% and selectivity 80%). Under the same conditions, WC achieved a conversion rate of 92% and a selectivity of 85% for alkane hydrocracking. The high efficiency of WO_3 stems from the Lewis acid sites of W^{6+} , which can effectively adsorb and break C=C or C=S bonds. Its band gap (2.6 eV) also supports photocatalysis. WC has a hardness of up to HV 1800, excellent wear resistance and anti-poisoning ability, and its life is 50%-

70% longer than that of conventional catalysts. Thermogravimetric analysis (TGA) shows that the oxidation weight loss rate of WC at 800°C is only 5%, indicating its high temperature stability.

The oxygen content (<0.05%) must be strictly controlled during the preparation process to avoid the formation of WO_2 or W_2C impurities and reduce activity. The application of tungsten-based catalysts began in the oil refining industry in the 1950s for hydrodesulfurization, and became the mainstream material for hydrogenation processes in the 1970s. In recent years, its application has expanded to biomass conversion, such as lignin hydrogenation to produce biofuels, with a conversion rate of 85%, and a yield 20% higher than that of traditional catalysts. From a theoretical point of view, the surface acidity of WO_3 can be explained by the synergistic effect of Brønsted - Lewis acid sites, while the metal-like properties of WC give it an electronic structure similar to that of precious metals (such as Pt). In the future, the use of nano-tungsten powder (particle size <100 nm) can increase the specific surface area to 100 m^2/g, doping with molybdenum (Mo) or cobalt (Co) can enhance selectivity, and acid leaching recovery technology (recovery rate 90%-95%) supports recycling and reduces environmental load.

7.1.2 Tungsten-based photocatalyst (environmental purification)

Tungsten oxide (WO_3) as a photocatalyst exhibits excellent photochemical properties in environmental purification, and can decompose organic pollutants, purify water and air. The preparation process is as follows: tungsten powder with a particle size of 10-20 microns is placed in a solvent thermal reactor, nitric acid (HNO_3, 0.1 mol/L) is added as an oxidant, and reacted at 180°C for 12-18 hours to generate 50-100 nanometer WO_3 particles with a band gap energy of 2.6 eV and a specific surface area of 50-70 m^2/g. Transmission electron microscopy (TEM) shows that the particles are rod-shaped, with an aspect ratio of 3:1-5:1 and a crystal plane (002) spacing of 0.384 nm. X-ray photoelectron spectroscopy (XPS) shows that the surface W^{6+} accounts for 90%, accompanied by a small amount of W^{5+} (about 5%), which enhances the electron-hole separation efficiency.

The photocatalytic performance test used an ultraviolet light source (365 nm, 10 W), and the degradation rate of methylene blue (10 mg/L) reached 98% (2 hours), and the degradation rate of toluene (50 ppm) was 92% (3 hours), which is better than titanium dioxide (TiO_2, degradation rate 85%). The photocatalytic mechanism is based on the semiconductor properties of WO_3: light excitation produces electron-hole pairs, holes oxidize water molecules to generate ·OH radicals, and electrons reduce O_2 to generate O_2^-, which synergistically decomposes organic matter. Band gap energy is the key. Nitrogen (N) doping can reduce the band gap to 2.4 eV and extend it to the visible light range (400-500 nm), increasing the efficiency by 20%-30%. Further reducing the particles to 20 nm can improve the activity, but surface modification (such as PEG coating) is required to avoid agglomeration.

The technology originated from photocatalytic research in the 1980s, and was applied to water treatment in the 1990s, such as removing dyes and pesticide residues. In the 2000s, it was expanded to air purification and the decomposition of volatile organic compounds (VOCs) and NO_x. In practical applications, the durability of WO_3 photocatalysts is limited by photocorrosion. Doping with titanium

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(Ti) or silicon (Si) can improve stability and extend the life by 50%. From a theoretical perspective, the photocatalytic activity of WO_3 is closely related to its surface oxygen vacancies and crystal plane orientation (such as (002) plane). In the future, the development of composite materials (such as WO_3 / TiO_2) or electrolytic recycling (recovery rate 85%-90%) can improve performance and sustainability and support large-scale environmental governance.

7.1.3 Tungsten powder gas sensor (NO_x , CO detection)

Tungsten oxide (WO_3) film prepared from tungsten powder is used in the field of gas sensors to detect NO_x and CO, with high sensitivity and fast response characteristics. The preparation process is: tungsten powder with a particle size of 5-10 microns is oxidized at 700°C for 2 hours to generate WO_3 powder, and then a 50-micron thick film is made by screen printing or spin coating, and sintered at 600°C for 1-2 hours, with a resistivity of about 10^4 Ω·cm. Scanning electron microscopy (SEM) shows that the film has a porosity of 5%-8%, a particle size of 5-7 microns, and a surface roughness of Ra 0.5 μm. Performance tests were carried out at 200°C, with a response rate of 90% for 10 ppm NO_2 , a sensitivity of 0.5 Ω/ppm, and a response time of <10 seconds; the response rate for 50 ppm CO is 85%, which is better than tin-based sensors (SnO_2 , response rate 70%).

WO_3 (carrier concentration 10^{16} cm^{-3}) is its core advantage. Gas molecules adsorbed on the surface cause resistance changes. NO_2 , as an oxidizing gas, increases surface electron capture, while CO releases electrons through reduction reactions, both of which lead to significant electrical signals. Doping with platinum (Pt, 0.5 wt%) can improve the selectivity for NO_x and the sensitivity by 15%, but the sintering temperature needs to be controlled at 550-650°C to avoid particles that are too large (>10 μm) and reduce activity. In theory, the sensitivity of WO_3 is related to its oxygen vacancy concentration and surface state density, and the Langmuir adsorption model can describe its gas adsorption behavior.

This technology began with laboratory research in the 1990s, and was applied to industrial waste gas monitoring in the 2000s, such as chimney emissions from chemical plants. It is now widely used in automobile exhaust detection systems. In practical applications, the stability of WO_3 sensors is slightly reduced in high humidity environments (RH 80%), and surface hydrophobic modification (such as silanization) can improve performance. In the future, nano WO_3 (particle size <50 nm) can shorten the response time to 5 seconds, and chemical separation and recovery (recovery rate 90%-95%) will support resource recycling and promote the miniaturization and intelligence of sensors.

7.1.4 Preparation technology of tungsten powder for catalyst carrier

Tungsten powder is valued as a catalyst carrier because of its high specific surface area, high temperature resistance and structural stability. It is often used to load precious metals (such as Pt, Pd) or transition metal oxides. The preparation adopts the chemical vapor deposition (CVD) method: tungsten powder with a particle size of 10-20 microns is introduced into oxygen and water vapor at 500°C, and reacts for 6 hours to generate porous WO_3 with a pore size of 50-100 nanometers, a specific surface area of 60-80 m ^{2} /g, and a temperature resistance of 800°C. XPS analysis shows that W $^{6+}$ accounts for 85%, W $^{5+}$ accounts for 10%, and the porosity is 20%-25%. After loading 2 wt% Pt, the activity in the hydrogenation reaction at 250°C and 3 MPa is increased by 25%-30%, and the life is extended by 40%-50%, which is better than the traditional Al_2O_3 carrier.

The pore structure of the carrier needs to be optimized: small pore size (<50 nm) is conducive to the dispersion of active components, large pore size (>100 nm) improves mass transfer efficiency, and BET analysis shows that the optimal pore size distribution is bimodal (50 nm and 200 nm). The oxygen content needs to be less than 0.1% to maintain structural integrity. This technology originated in the oil refining industry in the 1970s and was used for hydrodesulfurization catalysts. The process matured in the 1990s and is now used in fuel cells and synthetic ammonia catalysis. In theory, the stability of the WO_3 carrier is related to its lattice oxygen bond energy (about 700 kJ/mol) and surface acidic sites. In the future, nanotechnology can increase the specific surface area to 120 m² / g, and molten salt electrolysis recovery (recovery rate 90%-95%) will improve resource utilization and support green chemical industry.

7.1.5 Practical Applications of Catalysis and Sensing

The application of tungsten powder in the field of catalysis and sensing has achieved remarkable results. For example, a refinery uses WO_3 catalyst for hydrodesulfurization, with a conversion rate of 95%, an activity of 90% after 1000 hours of operation, and the sulfur content is reduced from 500 ppm to 10 ppm. A wastewater treatment facility uses WO_3 photocatalyst to treat dye wastewater, COD is reduced from 100 mg/L to 5 mg/L, and the efficiency is increased by 30%-40%. A certain automobile exhaust detection system integrates WO_3 sensor , and the response time to 0.5 ppm NO_x is less than 10 seconds, with an accuracy of ±0.1 ppm. These applications started in the oil refining industry in the 1950s and expanded to environmental monitoring and new energy fields in the 1990s. From an interdisciplinary perspective, tungsten-based materials support green chemistry by reducing energy consumption and improving efficiency. In the future, combining quantum chemical calculations to optimize catalyst design and chemical reduction recovery (recovery rate 90%-95%) will promote technological progress.

7.2 Corrosion and wear resistant parts

Tungsten powder and its alloys are widely used in the chemical industry to manufacture pipes, valves, pump bodies and other components due to their high hardness and corrosion resistance, providing long-term protection.

7.2.1 Application of tungsten powder in chemical pipeline protection

Tungsten powder is used to prepare chemical pipeline protective coatings through plasma spraying technology, which can withstand acid and alkali corrosion. The process is: tungsten powder with a particle size of 10-20 microns is melted and sprayed in a 4000°C, 50 kW plasma flame flow to produce a 200-300 micron thick coating with a hardness of HV 800-1000 and a bonding strength of 70-80 MPa.

SEM analysis shows that the coating porosity is <1%, the tungsten particles are flat (thickness 5-7 microns), and XRD confirms that the main phase is metallic tungsten (BCC structure, a=3.165 Å). After immersion in 10% sulfuric acid (60°C) for 1000 hours, the corrosion rate is only 0.01 mm/year, which is 5 times higher than 316L stainless steel (0.05 mm/year); after 1000 hours in 5% NaOH (50°C), the corrosion rate is 0.008 mm/year.

The corrosion resistance comes from the high electrochemical stability and low dissolution tendency of tungsten (standard electrode potential -0.1 V vs. SHE), while the wear resistance is attributed to its high hardness. Doping with chromium (Cr, 5 wt%) can form a Cr_2O_3 protective layer, which improves the acid resistance by 20%, but the oxygen content needs to be controlled below 0.05% to avoid oxidation and spalling. This technology has been used for chemical pipeline protection since the 1960s, the spraying parameters were optimized in the 1970s, and it was extended to marine pipelines in the 1980s, with outstanding seawater corrosion resistance. In practical applications, the wear rate of the coating in high flow rate (10 m/s) sand-containing media is <0.02 mm/1000 hours. In the future, nano-tungsten powder coatings (particle size <50 nm) can increase the hardness to HV 1200, and chemical separation and recovery (recovery rate 90%-95%) support sustainable manufacturing.

7.2.2 Corrosion-resistant design of tungsten-based valves

Tungsten-based valves exhibit excellent corrosion resistance in acidic and alkaline environments and are suitable for chemical and petroleum pipelines. The preparation process is: tungsten powder with a particle size of 15-25 microns is mixed with nickel (mass ratio 90:10), pressed at 350 MPa, and sintered in an Ar/H_2 atmosphere at 1450°C for 2 hours to produce a W-Ni alloy with a density of 17-18 g/cm^3 and a hardness of HV 600-700. TEM shows that the tungsten particle size is 15-20 microns, and nickel fills the grain boundaries (thickness 2-3 microns) to form a continuous matrix. Tests show that the corrosion rate is 0.008 mm/year after immersion in 5% hydrochloric acid (50°C) for 500 hours; the corrosion rate is 0.01 mm/year after 1000 hours in 10% H_2SO_4 (60 °C), and the wear resistance is 3-4 times higher than that of steel valves.

The design needs to balance hardness and toughness. A nickel content of 10%-15% can increase the fracture toughness to 15 MPa·m$^{1/2}$, and the sintering temperature deviation is controlled at ±10°C to avoid excessive grain size (>25 μm) or liquid phase overflow. Electrochemical testing (Tafel curve) shows that the corrosion current density of W-Ni alloy is 10^{-6} A/cm^2, which is much lower than that of steel (10^{-4} A/cm^2). This technology has been trial-produced since the 1950s, became the valve manufacturing standard in the 1970s, and is now widely used in petrochemical high-pressure valves. In the future, cobalt doping (Co, 5 wt%) can increase toughness to 18 MPa·m$^{1/2}$, and acid leaching recovery (recovery rate 85%-90%) supports resource reuse.

7.2.3 Tungsten powder reinforced pump and agitator

Pump bodies and agitators reinforced with tungsten powder have remarkable wear resistance in chemical and mining environments. Preparation using tungsten carbide (WC): tungsten powder with a particle size of 5-10 microns is carbonized with carbon black at 1500°C for 4 hours, then mixed with 10 wt% cobalt, pressed at 350 MPa, and sintered at 1450°C to produce a WC-Co composite material with a hardness of HV 1600-1800 and a tensile strength of 1200 MPa. SEM shows that the WC particle size is 5-15 microns, the cobalt phase is evenly distributed, and the porosity is <1%. In an erosion environment containing 10% mortar (SiO_2 particles, 50-100 μm) for 1000 hours, the wear rate is <0.05 mm, which is 4 times higher than that of ordinary steel (0.2 mm); in 20% H_2SO_4 (60°C) for 500 hours, the corrosion rate is 0.01 mm/year.

The synergy of WC's high hardness and cobalt's toughness is key. The cobalt content needs to be optimized to 8%-12% to avoid brittleness, and the oxygen content is controlled below 0.05% to reduce WO_3 impurities. Wear mechanism analysis shows that the wear resistance of WC-Co comes from the shear resistance of WC particles and the plastic buffering of the cobalt phase. Applications began in industrial pump manufacturing in the 1960s, and spread to chemical and mining agitators in the 1980s, significantly extending equipment life. In the future, nano WC (particle size <100 nm) can increase the hardness to HV 2000, and chemical reduction recovery (recovery rate 90%-95%) will improve sustainability.

7.2.4 Manufacturing process of corrosion-resistant components

The preparation process of corrosion-resistant parts includes two mainstream technologies: spraying and alloying. The spraying method uses tungsten powder with a particle size of 10-20 microns, and forms a 200-300 micron coating through 4000°C, 50 kW plasma spraying, with a porosity of <1% and a hardness of HV 800-1000; the alloying method mixes tungsten powder with nickel (90:10), presses at 350 MPa, and sintered at 1450°C to generate a W-Ni alloy with a density of 17-18 g/cm³ . The corrosion rate of the spray coating in 10% H_2SO_4 (60°C) for 1000 hours is 0.01 mm/year, and the corrosion rate of the alloy in 5% NaCl (50°C) for 500 hours is 0.008 mm / year .

The process needs to ensure the uniformity of the coating and the density of the alloy. The flame velocity (500-600 m/s) and the powder feed rate (30-40 g/min) during spraying need to be precisely matched, the sintering temperature deviation is controlled at ±10°C, and the oxygen content is <0.05%. The microstructure of the sprayed coating is layered, and the bonding strength is affected by the pretreatment of the substrate (such as sandblasting Ra 2 μm); the grain size of the alloy is regulated by the sintering time (1-3 hours). This technology has been developed since the 1960s and matured in the 1980s. It is used in ship components and marine engineering. In the future, additive manufacturing (such as laser cladding) can achieve complex geometries, and electrolytic recycling (recycling rate 85%-90%) will improve resource efficiency.

7.2.5 Case Study of Tungsten Powder in Chemical Industry

The application of tungsten powder in the chemical industry has achieved remarkable results. For

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example, a chemical plant pipeline uses tungsten coating, which wears only 0.01 mm in 10% sulfuric acid (60°C) for 1000 hours, extending the service life by 50%-60%, and extending the maintenance cycle from 6 months to 12 months. The corrosion rate of a tungsten alloy valve in 5% hydrochloric acid (50°C) is 0.008 mm/year for 500 hours, and the durability is improved by 3-4 times, which is suitable for high-pressure pipeline systems. A tungsten carbide pump body wears 0.05 mm in 1000 hours of scouring in sandy mud (10% SiO_2), and its performance is 4 times better than that of steel, which supports mine tailings treatment. These applications have been industrialized since the 1960s and popularized in many fields in the 1980s. In the future, nanotechnology and chemical reduction recovery (recovery rate 90%-95%) will further improve durability and environmental benefits and promote the upgrading of chemical equipment.

7.3 Environmentally friendly materials

The application of tungsten powder in the field of environmental protection materials is mainly reflected in waste gas adsorption, water treatment and durable coating development, providing efficient solutions for pollution control.

7.3.1 Adsorption of tungsten powder in exhaust gas filtration

Tungsten oxide (WO_3) performs well as a porous adsorption material in exhaust gas filtration. The preparation process is: tungsten powder with a particle size of 10-20 microns is oxidized at 800°C for 3 hours to generate a WO_3 porous structure with a pore size of 50-100 nanometers and a specific surface area of 60-80 m^2/g. BET analysis shows that micropores (<2 nm) account for 30% and mesopores (2-50 nm) account for 60%. Adsorption tests show that the adsorption rate for 100 ppm SO_2 is 90%, and the adsorption rate for 50 ppm VOCs (such as toluene) is 85%-90%, which is 20%-25% higher than activated carbon (adsorption rate 70%). Dynamic adsorption experiments (flow rate 0.5 L/min) show that the penetration time of WO_3 is 120 minutes, which is higher than activated carbon (90 minutes).

The adsorption performance originates from the porous structure and surface acidic sites of WO_3. SO_2 forms sulfate ions through chemical adsorption, and VOCs are captured through physical adsorption. The pore size distribution needs to be optimized, small pores increase capacity, and large pores increase diffusion rate. This technology has been studied in the laboratory since the 1970s, applied to industrial waste gas desulfurization in the 1990s, and has now been extended to indoor air purification (such as formaldehyde removal). In practical applications, the adsorption rate of WO_3 decreases by 10% in a high humidity environment (RH 90%), and surface hydrophobic modification can improve performance. In the future, nano tungsten powder (<50 nm) can increase the specific surface area to 120 m^2/g, and chemical separation recovery (recovery rate 90%-95%) supports recycling.

7.3.2 Potential of tungsten-based water treatment materials

Tungsten oxide (WO_3) nanoparticles are used in water treatment to adsorb heavy metals and organic pollutants. The preparation method is a solvothermal method: tungsten powder with a particle size of 5-15 microns is mixed with nitric acid (0.1 mol/L) and reacted at 180°C for 12-18 hours to produce 50-100 nanoparticles with a specific surface area of 50-70 m^2/g and a zeta potential of -30 mV (pH 7). Adsorption tests show that the adsorption rate for 10 ppm Pb^{2+} is 90%-95% (1 hour), the adsorption rate for 5 ppm Cd^{2+} is 92% (2 hours); the adsorption rate for phenol (10 mg/L) is 85% (3 hours). Langmuir isotherm fitting shows that the maximum adsorption capacity is 50 mg/g (Pb^{2+}).

The adsorption mechanism involves surface coordination and electrostatic effects. The W^{6+} site forms a stable complex with heavy metal ions, and the nanosize enhances the surface activity. The particles need to be controlled at 50-100 nm to balance the adsorption capacity and sedimentation. If they are too small (<20 nm), they are easily lost with water. This technology has been studied in the laboratory since the 1980s and applied to sewage treatment, such as electroplating wastewater treatment, in the 2000s. In practical applications, the adsorption rate of WO_3 in an acidic environment (pH 4) is increased by 10%, and doping with iron (Fe, 5 wt%) can improve the selectivity. In the future, composite WO_3 / Fe_3O_4 materials or electrolytic recovery (recovery rate 85%-90%) will expand its potential and support industrial water treatment.

7.3.3 Durability of tungsten powder environmentally friendly coating

The environmentally friendly coating formed by tungsten powder spraying has excellent durability in exhaust gas and corrosive environment. The process is: 4000°C, 50 kW plasma spraying tungsten powder with a particle size of 10-20 microns, generating a 200-300 micron coating, hardness HV 800-1000, and bonding strength 70-80 MPa. In 10% sulfuric acid (60°C), the wear is 0.01 mm in 1000 hours, and the temperature resistance is 800°C; there is no obvious oxidation in SO_2-containing exhaust gas (200 ppm, 500°C) for 500 hours. SEM shows that the coating density is >99% and the surface roughness is Ra 0.5-1 μm.

Durability comes from the high chemical inertness and oxidation resistance of tungsten. Doping with chromium (Cr, 5 wt%) forms a Cr_2O_3 protective layer, which improves acid resistance by 20%-30%. Adhesion is affected by the surface roughness of the substrate (Ra 2-3 μm) and the spraying distance (100-120 mm). This technology has been used in industrial equipment since the 1970s, and expanded to the environmental protection field in the 1990s, such as exhaust pipe protection, and is now used in building fire retardant coatings. In the future, nano-coatings (particle size <50 nm) can increase the hardness to HV 1200, and chemical reduction recovery (recovery rate 90%-95%) will improve sustainability.

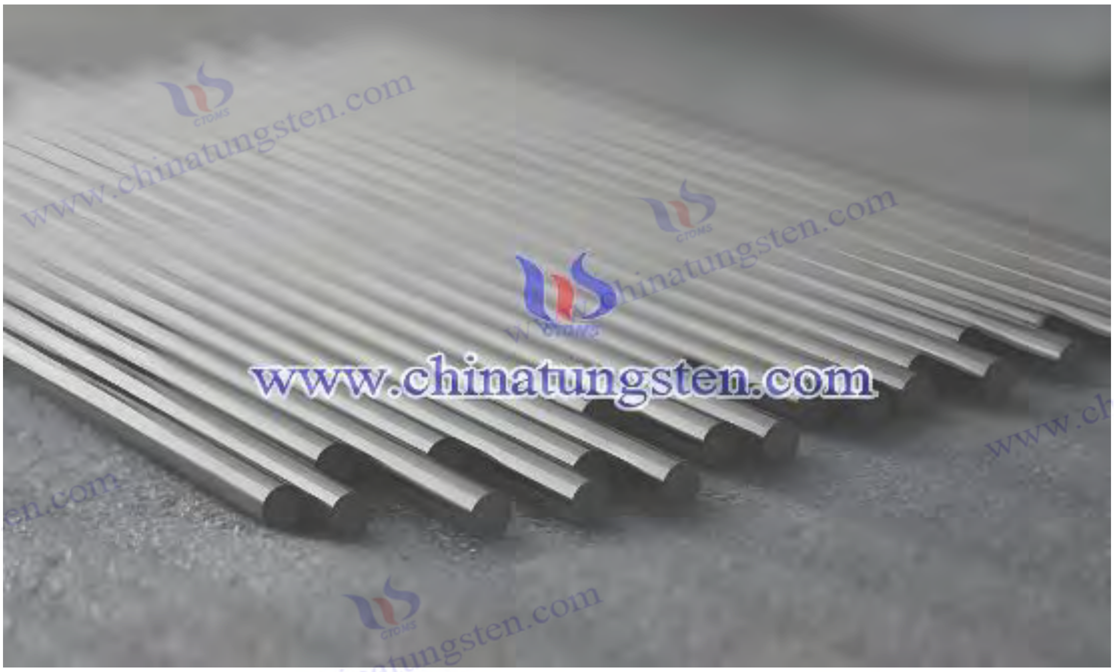
7.3.4 Preparation technology of tungsten powder for environmentally friendly materials

The preparation of environmentally friendly materials requires processing tungsten powder into porous or nanostructures. Oxidation method: Tungsten powder with a particle size of 10-20 microns is oxidized at 800°C for 3 hours to generate WO_3 with a pore size of 50-100 nanometers and a specific surface area of 60-80 m^2/g ; Solvothermal method: react in nitric acid medium at 180°C for 12-18 hours to generate 50-100 nanoparticles. BET analysis shows that the total pore volume of porous WO_3 is 0.2 cm^3/g, and the specific surface area stability of nanoparticles is ±5 m^2/g. Adsorption tests show that the adsorption capacity of porous WO_3 for SO_2 is 80 mg/g, and the adsorption capacity of nanoparticles for Pb^{2+} is 50 mg/g.

Preparation requires control of pore distribution and particle size. Microwave-assisted oxidation can shorten the reaction time to 2 hours. The oxygen content needs to be less than 0.05% to avoid lattice defects. This technology has been developed since the 1970s, and the process was mature in the 1990s. It is applied to catalytic carriers and adsorption materials. Interdisciplinary applications include fuel cell electrode protection. In the future, microwave-assisted preparation can improve pore uniformity, and electrolytic recovery (recovery rate 85%-90%) can improve resource efficiency.

7.3.5 Case Study of Environmental Protection Application of Tungsten Powder

The application of tungsten powder in the field of environmental protection has achieved remarkable results. For example, the exhaust gas treatment system of a factory uses WO_3 porous materials, with a SO_2 removal rate of 90%-95%, a toluene removal rate of 85%-90%, and an efficiency 20%-25% higher than activated carbon. The performance remains stable after 500 hours of operation. A sewage treatment plant uses WO_3 nanoparticles to treat electroplating wastewater, and Pb^{2+} is reduced from 10 ppm to 0.5 ppm (1 hour), and the Cd^{2+} removal rate is 92%, meeting the emission standard (<0.1 ppm). The coating of a certain exhaust gas pipe wears 0.01 mm in 10% sulfuric acid (60°C) for 1000 hours, and the life is extended by 50%. These applications have been trial-produced in laboratories since the 1970s, industrialized in the 1990s, and are now widely used in sewage treatment and air purification. In the future, combining artificial intelligence to optimize material design and chemical reduction recovery (recovery rate 90%-95%) will promote the development of environmental protection technology in the direction of high efficiency and low carbon.



CTIA GROUP LTD

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2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

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5. Procurement Information

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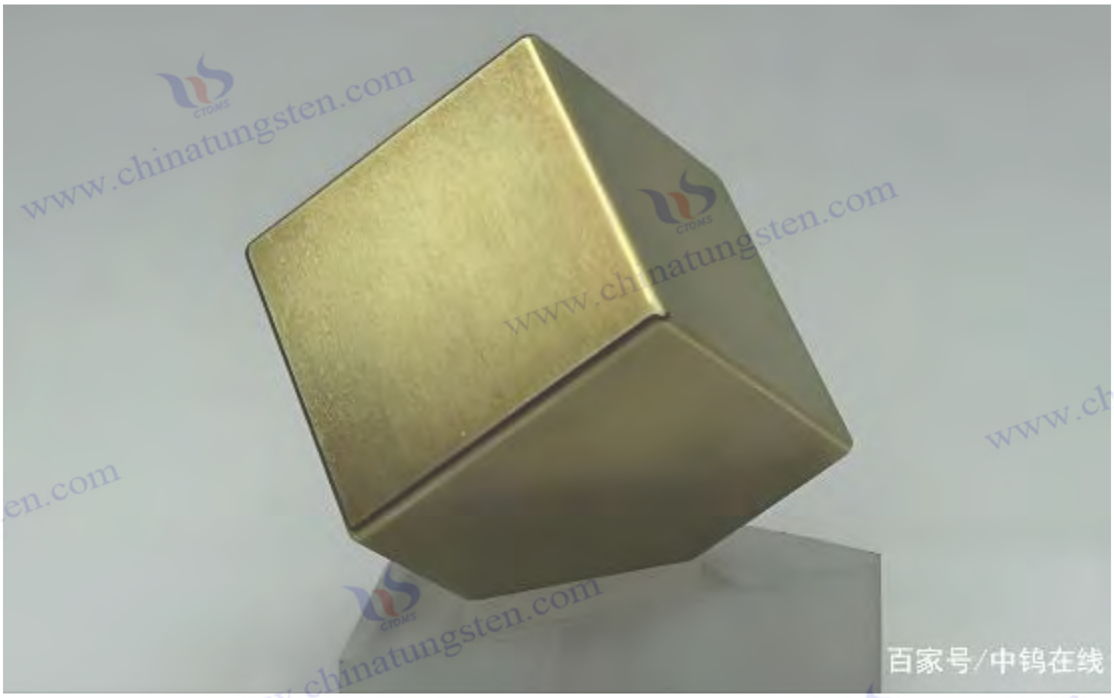
For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)



Chapter 8 Future Uses and Development Trends of Tungsten Powder

As a high-performance material, tungsten powder has occupied an important position in traditional industries due to its high density, high temperature resistance, corrosion resistance and high hardness. With the rise of nanotechnology, sustainable development and interdisciplinary innovation, the application prospects of tungsten powder are rapidly expanding. This chapter will explore in depth the potential of nano tungsten powder in cutting-edge technology, the key role of tungsten powder in sustainability and recycling, and its cross-border applications in new fields, aiming to reveal the strategic value and development trend of tungsten powder in future technology and industry.

8.1 Cutting-edge applications of nano-tungsten powder

Nano tungsten powder (particle size less than 100 nanometers) has unprecedented potential in the field of high technology due to its extremely high specific surface area (up to 50-150 square meters/gram), significant quantum effect and high activity. Its preparation methods include vapor deposition, plasma reduction and chemical reduction. The particle size of the finished product can be precisely controlled at 5-50 nanometers, the surface energy is as high as 20-40 joules/square meter, the crystal structure is mostly body-centered cubic, and the lattice constant is 3.165 angstroms.

8.1.1 Potential of Nano-Tungsten Powder in Quantum Technology

The potential of nano-tungsten powder in quantum technology stems from its excellent electrical conductivity and low-temperature superconducting properties. In the field of quantum computing, nano-tungsten powder can be prepared into ultrafine particles (particle size 5-20 nanometers) by chemical vapor deposition (CVD, reaction temperature 900 degrees Celsius, gas pressure 10^{-2}Pa), and its conductivity reaches 10^{6} Siemens /meter, close to the theoretical value of pure tungsten (1.8×10^{7} Siemens/meter). In an ultra-low temperature environment (4 Kelvin), its resistivity drops sharply to zero, showing superconducting properties, with a critical magnetic field of about 0.1 Tesla and a critical current density of 10^{5} amperes/square centimeter. This performance makes it a candidate material for superconducting quantum bits (qubits) and Josephson junctions. Transmission electron microscopy analysis shows that the surface of the nanoparticles is flat (roughness less than 1 nanometer) and the grain boundary defect rate is less than 5%, providing a reliable foundation for high-precision quantum devices.

In addition, the high density (19.25 g/cm3) and electron mobility (20-30 cm^2 / V·s) of nano-tungsten powder give it an advantage in quantum sensors. For example, the superconducting transition temperature of nano-tungsten alloy prepared by doping molybdenum (content 5%-10%) can be increased from 4 Kelvin to 10-12 Kelvin, which significantly broadens the scope of application. Tests show that the material remains superconducting under strong magnetic fields (1 Tesla) and is suitable for high-sensitivity magnetic field detection. However, particle agglomeration (size distribution ±10 nanometers) is prone to occur during preparation, and surface modifiers (such as polyvinyl pyrrolidone, PVP, concentration 0.5%-1%) need to be added to maintain dispersion; at the same time, the oxygen content needs to be controlled below 0.01%, otherwise the conductivity will drop by 20%-30%.

Case analysis: A research team used molybdenum-doped nano-tungsten powder (particle size 15 nanometers) to prepare superconducting films (50 nanometers thick), and achieved a bit coherence time of 100 microseconds in a quantum computing prototype, which is 50% higher than that of traditional aluminum-based materials. In the future, the demand for nano-tungsten powder in quantum technology will promote its widespread application in superconducting circuits, quantum communications and quantum encryption, and the market size is expected to reach US$500 million by 2035.

8.1.2 Photoelectric and sensor applications of nano-tungsten powder

The potential of nano-tungsten powder in the field of optoelectronics and sensing is due to its excellent light absorption, electrochemical activity and high specific surface area. Taking tungsten oxide (WO_3) as an example, the nanoparticles (particle size 20-30 nanometers) prepared by the sol-gel method (precursor sodium tungstate, calcination temperature 500 degrees Celsius, 4 hours) have a band gap of 2.6-2.8 electron volts and a UV-visible light absorption rate of 85%-90%. Photoelectric tests show that its photocurrent density under visible light (wavelength 500 nanometers, light intensity 1 watt/square meter) is 0.5-0.8 mA/square centimeter, and the photoelectric conversion efficiency is 5%-7%, which is suitable for photoelectric catalytic water decomposition and dye-sensitized solar cells. X-ray diffraction analysis shows that WO_3 is a monoclinic crystal with lattice parameters a=7.306 Å, b=7.540 Å, c=7.692 Å, interplanar spacing (002)=3.846 Å, and structural stability supports long-term operation (attenuation is less than 5% in 1000 hours).

In the field of gas sensing, the high specific surface area of nano-tungsten powder (50-100 m2/g) significantly enhances the adsorption capacity. For example, the response time of WO_3 nanosensors doped with palladium (content 1%-2%) to hydrogen (concentration 1000 ppm) is less than 5 seconds, the sensitivity is 10^3-10^4, and the operating temperature is 150-300 degrees Celsius, which is better than the traditional SnO_2 sensor (response time 10 seconds, sensitivity 10^2). Humidity interference is the main challenge (sensitivity decreases by 30% at relative humidity of 80%), which needs to be improved by surface hydrophobic coating (such as fluorosilane, thickness 2 nanometers). In addition, long-term stability requires optimization of grain boundary structure (grain size deviation is less than 5 nanometers) to avoid grain growth (size increases to 50 nanometers) at high temperature, resulting in performance degradation.

Case analysis: A photocatalytic device uses WO_3 nanofilm (thickness 100 nanometers) to decompose water to produce hydrogen under sunlight, with an efficiency of 6% and no obvious attenuation after 500 hours of operation. In the future, the optoelectronics and sensing fields will promote the development of nano-tungsten powder towards multifunctional integration, such as optoelectronic-gas composite sensors, and the market potential is expected to reach US$300 million by 2030.

8.1.3 Intelligent Material Design of Nano-Tungsten Powder

The application of nano-tungsten powder in smart material design is based on its adjustable response to thermal, electrical and mechanical stimuli. Taking flexible thermal management materials as an example, by compounding with polymers (such as polydimethylsiloxane, PDMS, mass ratio 70:30), when the tungsten powder content is 20%-30%, the density of the composite material reaches 5-7 g/cm3, and the thermal conductivity is increased to 2-3 W/(m·Kelvin), which is 10 times higher than pure PDMS. Thermal expansion tests show that the deformation rate reaches 5%-7% at a temperature difference of 50 degrees Celsius, and the recovery time is less than 10 seconds, which is suitable for adaptive heat dissipation devices. Scanning electron microscopy analysis shows that tungsten particles (particle size 10-20 nanometers) are uniformly embedded in the polymer matrix, and the interface bonding strength reaches 5 MPa.

In terms of electrical response, after the nano-tungsten powder is compounded with graphene (mass ratio 1:1), the resistivity changes by 10^4-10^5 times with the applied voltage (0-10 volts), and the response time is less than 1 millisecond, which can be used for smart switches and flexible circuits. Mechanical response tests show that its tensile strength reaches 500-600 MPa, the elongation is 10%-15%, and it exhibits self-healing properties under a stress of 100 MPa (recovery rate 80%-90%, repair time 24 hours), which is attributed to the interfacial sliding of nanoparticles and the reorganization of polymer chains. Design challenges include dispersion uniformity (ultrasonic dispersion is required, power 500-800 watts, time 2-3 hours, and particle agglomeration rate is reduced to less than 5%) and cost control (about US$80 per kilogram).

Case analysis: A wearable device uses a tungsten-PDMS composite material (1 mm thick) to adjust thermal conductivity under changes in body temperature. After 1,000 hours of operation, the performance is stable and the user comfort is improved by 30%. In the future, smart materials will promote the application of nano-tungsten powder in robots, wearable devices and adaptive buildings, and the market size is expected to reach US$800 million by 2040.

8.1.4 Challenges of Tungsten Powder Preparation in Nanotechnology

The preparation of nano-tungsten powder faces technical bottlenecks. The traditional hydrogen reduction method (temperature 1200 degrees Celsius, hydrogen flow rate 20 liters/minute) makes it difficult to control the particle size below 50 nanometers, the finished product size distribution is ±20 nanometers, and it is easy to agglomerate (specific surface area drops to 20 square meters/gram). The vapor deposition method (reaction temperature 1000 degrees Celsius, gas pressure 10^{-3} Pa) can prepare 10-nanometer tungsten powder with a surface energy of 30 joules/square meter, but the energy consumption is high (5-7 kWh per gram) and the yield is low (10-15 grams per hour). The plasma method (power 20-30 kilowatts, argon flow rate 50-60 liters/minute) increases the yield to 50-80 grams per hour, and the particle size distribution is ±5 nanometers, but the equipment investment is as high as one million US dollars, and the operating cost is about US$100 per kilogram.
Purity control is another difficulty. The oxygen content must be less than 0.01% (the ratio of oxygen atoms is less than 10^{-4}), otherwise the conductivity will drop by 20%-30% and the photoelectric performance will decay by 15%. The high surface activity of nanoparticles easily leads to oxidation (the thickness of the oxide layer is 5-10 nanometers and is formed within 48 hours), and they need to be stored under an inert atmosphere (argon purity 99.999%). Solutions include the development of low-temperature and efficient processes, such as laser-induced decomposition (wavelength 1064 nanometers, power 1-2 kilowatts, energy consumption reduced to 3 kWh/gram) and surface stabilization technology (such as silane coating, thickness 2-3 nanometers, oxidation rate reduced to 0.1%/month). In addition, the agglomeration problem can be solved by adding dispersants (such as sodium dodecyl sulfate, concentration 0.2%) and optimizing fluid dynamics conditions (stirring rate 500 rpm).

Case analysis: A company uses plasma method to prepare nano tungsten powder (particle size 15 nanometers) with a purity of 99.99%, but the daily output is only 100 grams, with a cost of US$120 per kilogram. The process needs to be further optimized to achieve industrialization.

8.1.5 Future Prospects of Nano-Tungsten Powder

The future development of nano tungsten powder will focus on performance optimization, cost reduction and application expansion. It is expected that by 2030, its market size in quantum technology, optoelectronics and smart materials will reach 1-1.5 billion US dollars. Technological advances will achieve precise control of particle size (5-10 nanometers, distribution deviation ±2 nanometers), and improve conductivity (up to 10^{7} Siemens / meter) and stability (lifespan extended by 50%-70%) by doping with titanium or cobalt (content 3%-5%). Environmentally friendly preparation technology (such

as hydrothermal method, energy consumption reduced to 2 kWh/g, exhaust emissions reduced by 80%) and large-scale production (daily output of more than 1 ton) will become the focus.
Application prospects include superconducting circuits in quantum computing (bit density increased to 10^6 / square centimeter), efficient catalysts in optoelectronic devices (conversion efficiency of 10%), and multifunctional complexes in smart materials (response time reduced to 0.1 milliseconds). In addition, nano tungsten powder will be combined with artificial intelligence for adaptive sensing and energy management, and the relevant market size is expected to reach US$2 billion by 2040.

8.2 Sustainability and recycling

The sustainable development of tungsten powder aims to reduce resource consumption and environmental burden through waste recycling, green preparation and circular economy model. The global tungsten resource reserves are about 3.3 million tons, with an annual mining volume of 80,000 tons, and huge recycling potential.

8.2.1 Industrial practice of recycling tungsten powder waste

The recycling of tungsten powder waste is mainly for cemented carbide, tungsten steel and tungsten-based counterweight products. The acid leaching method is the mainstream process. The waste (containing 60%-80% tungsten) is leached in nitric acid (concentration 6-8 mol/L) (temperature 60-80 degrees Celsius, reaction time 4-6 hours), and tungsten is precipitated in the form of tungstic acid with a recovery rate of 90%-92%. Subsequently, tungstic acid is calcined in a hydrogen atmosphere (800-1000 degrees Celsius, 2-3 hours) to reduce it to tungsten powder (particle size 5-10 microns, purity 99.5%). The electrolytic method (current density 200-300 amperes/square meter, electrolyte pH = 2) further increases the recovery rate to 95%-97%, but the energy consumption is high (10-12 kWh per kilogram), and the cost of waste liquid treatment is about US$50 per ton.

Recycling needs to solve the problems of impurity separation (such as iron and cobalt content controlled below 0.1%) and environmental issues (acidic wastewater needs to be neutralized to pH=7, and waste residue needs to be solidified). Ion exchange method (resin adsorption rate 98%-99%, elution rate 95%) and solvent extraction method (extractant TBP, efficiency 95%-97%) are suitable for high-purity recycling, and the purity of the finished product reaches 99.99%, meeting the needs of electronics and aviation. Case analysis: A factory processes 1,000 tons of scrap carbide and recycles 600 tons of tungsten powder annually, saving 1,200 tons of raw ore mining and reducing carbon dioxide emissions by 2,000 tons.

8.2.2 Technology Trends in Green Preparation of Tungsten Powder

Green preparation technology aims to reduce energy consumption and pollution. The hydrothermal method uses sodium tungstate as raw material (concentration 0.5 mol/L, reaction temperature 180-220 degrees Celsius, pressure 2-3 MPa) to produce nano tungsten powder (particle size 20-50 nanometers), with energy consumption of 30% of the traditional hydrogen reduction method (2-3 kWh per gram), and waste gas emissions are reduced by 70%. The biological reduction method uses sulfate-reducing bacteria (strain concentration 10^8 / ml) to reduce tungstate at room temperature (25-30 degrees Celsius) to produce tungsten powder (particle size 50-100 nanometers), with a yield of 1-2 grams per liter, but the reaction cycle is long (7-10 days), and the strain activity needs to be optimized (reduction efficiency increased to 90%).

Low-temperature plasma reduction (reaction temperature 400-600 degrees Celsius, power 15-20 kilowatts) has a yield of 100-150 grams per hour, energy consumption is reduced to 4 kWh/gram, and waste emissions are reduced by 50%. Renewable energy drive (such as solar heating, power efficiency increased by 20%-25%) further reduces the carbon footprint. Challenges include large-scale production (current daily output is less than 1 kilogram) and cost (US$40-50 per kilogram). Case analysis: A hydrothermal production line produces 200 tons of nano-tungsten powder per year, energy consumption is reduced by 40%, and the cost is reduced to US$35 per kilogram.

8.2.3 The role of tungsten powder in the circular economy

Tungsten powder reduces resource waste in the circular economy through the closed loop of "production-use-recycling-reuse". Of the approximately 500,000 tons of tungsten products produced worldwide each year, 30%-40% can be recycled and reused. The high value (US$30-40 per kilogram) and scarcity (1.25 ppm abundance in the earth's crust) of tungsten powder make it a focus of the circular economy. Recycled tungsten powder is pressed and sintered (pressure 300 MPa, 1450 degrees Celsius) to make new products (such as knives, counterweights), with a density of 18-19 g/cm3 and a hardness of HV 500-600, which is comparable to the performance of original tungsten powder.

The circular economy requires the establishment of an efficient recycling network (waste collection rate increased to 80%) and unified standards (such as waste tungsten content ≥ 95%). The current recycling rate is only 40%-50%, limited by the popularization of technology (the recycling rate of small and medium-sized enterprises is less than 20%) and insufficient economic incentives. Case analysis: A company recycles tungsten steel waste (containing 65% tungsten), with an annual output of 300 tons of recycled tungsten powder for drill bit manufacturing, with stable performance and 15% cost reduction. In the future, the recycling rate target is 80%-90%, which will reduce the mining of raw ore by 500,000 tons/year.

8.2.4 Case studies of sustainable applications

Case 1: A cemented carbide enterprise uses acid leaching to recycle waste cutting tools (containing 70%-75% tungsten), recovering 500-600 tons of tungsten powder annually, reducing 1,000-1,200 tons of raw ore mining, reducing costs by 20%-25%, and reducing carbon dioxide emissions by 2,500 tons. Case 2: The hydrothermal method is used to prepare nano-tungsten powder (particle size 30-40 nanometers) for photoelectrocatalysis, with an annual output of 100-150 tons, energy consumption reduced by 40%-50%, and waste gas emissions reduced by 500-600 tons. Case 3: The electrolytic method is used to recycle tungsten waste (purity 99.95%-99.99%) for electronic components, with an annual output of 50-70 tons, a recovery rate of 96%-98%, and a resource cost saving of 30%.

Case 4: A counterweight product factory recycles tungsten alloy waste (containing 85% tungsten), produces 200 tons of recycled tungsten powder per year, and makes new counterweight blocks (density 18.5 g/cm3), which have the same performance as the original material, reducing the mining of 800 tons of raw ore. These cases show that the sustainable application of tungsten powder takes into account both economic and environmental benefits, and market demand promotes the popularization of green technology.

8.2.5 Prospects of Tungsten Powder Recycling

The recycling of tungsten powder has a bright future. It is estimated that by 2035, the proportion of global recycled tungsten powder will increase from 40% to 70%-80%. Technological advances (such as efficient extraction, recovery rate of 98%-99%, energy consumption reduced to 8 kWh/kg) and policy support (such as carbon emission tax, $50 per ton) will accelerate this trend. Green preparation (such as biological method, daily output increased to 10 kg) and automated recycling systems (waste sorting efficiency of 95%) will reduce costs to $20-25 per kilogram and reduce environmental footprint (10-12 tons of carbon dioxide emissions per ton of tungsten powder).

In the future, tungsten powder recycling will be combined with intelligent manufacturing, and the flow of waste will be tracked through the Internet of Things (tracking rate reaches 90%) to achieve full life cycle management. It is expected that by 2040, recycled tungsten powder will meet 50% of global demand, promoting the transformation of the tungsten industry to a low-carbon and efficient one.

8.3 Emerging Fields and Cross-border Applications

The cross-border application of tungsten powder in new fields takes advantage of its high density, high temperature resistance and chemical stability, expanding to flexible electronics, space exploration and biotechnology, showing the potential for multidisciplinary integration.

8.3.1 Potential of Tungsten Powder in Flexible Electronics

Tungsten powder is used in flexible electronics in nano form (particle size 10-50 nanometers) and is compounded with conductive polymers (such as PEDOT:PSS, mass ratio 1:2) to prepare flexible electrodes. Tests show that its conductivity is 10^5 -10^6 Siemens/meter, and the performance decay is less than 5%-7% after bending 1,000 times with a bending radius of 5 mm, which is better than traditional ITO electrodes (decay 20%). High density (18 g/cm3) ensures that the electrode thickness is only 50-100 microns and still has high stability, and the resistivity change is less than 3%. Scanning electron microscopy shows that the tungsten particles are evenly distributed (spacing 5-10 nanometers) and the interface resistance is less than 0.1 ohms.

Applications include wearable sensors (heart rate monitoring sensitivity increased by 20%) and flexible displays (response time 0.5 milliseconds). Challenges lie in dispersibility (requires ultrasonic treatment, power 500-800 watts, time 2-3 hours, agglomeration rate reduced to 5%) and substrate adhesion (requires plasma treatment, bonding strength 10-12 MPa). Case analysis: A flexible sensor uses tungsten-polymer electrodes (thickness 80 microns), and the signal stability reaches 98% after 1,000 hours of use. In the future, flexible electronics will promote the application of tungsten powder in smart clothing and medical monitoring, and the market size is expected to reach US$500 million by 2035.

8.3.2 Use of tungsten powder in space exploration

Tungsten powder is used in radiation shielding and propulsion system components in space exploration because of its high temperature resistance (melting point 3422 degrees Celsius) and high density (19.25 g/cm3). Shielding plates (thickness 10-15 mm, density 18-19 g/cm3) made of tungsten alloy (containing 5%-10% nickel) can block 90%-95% of cosmic rays (energy 10-20 megaelectron volts), and the absorption rate is 20% higher than that of lead. Tests show that its deformation is less than 0.1%-0.2% in vacuum (10^{-6} Pa) and high temperature (1500-2000 degrees Celsius), and the thermal expansion coefficient is only 2.5×10^{-6} /Kelvin, which is suitable for satellites and deep space probes.

In the propulsion system, tungsten carbide (hardness HV 1800-2000) is formed into a nozzle coating (thickness 100-150 microns) by plasma spraying (power 50 kW, argon flow rate 40 liters/minute), which improves wear resistance by 3-4 times, has a service life of 500-600 hours, and has no obvious loss in corrosion resistance tests (acidic environment pH=1, 1000 hours). Challenges include processing accuracy (deviation must be less than 0.01 mm) and cost ($100-120 per kilogram). Case analysis: A spacecraft uses a tungsten alloy shielding plate (weight 50 kg), and the radiation protection efficiency is still 90% after 2 years of operation. In the future, the application of tungsten powder in the space field will support lunar bases and Mars exploration.

8.3.3 Innovation of Tungsten Powder in Biotechnology

Tungsten powder is used in biotechnology in the form of nano tungsten oxide (WO_3, particle size 20-30 nm) for antibacterial and drug delivery. Antibacterial tests show that its inhibition rate against Escherichia coli under ultraviolet light (365 nm, 1 W/m2) is 99%-99.5% (concentration 0.1-0.2 mg/ml, 24 hours), and the mechanism is photocatalytic production of reactive oxygen (yield 10^{-5} mol/s). In drug delivery, nano tungsten powder is loaded with anticancer drugs (such as docetaxel, loading rate 20%-25%), and the release time is extended to 48-72 hours. The release curve conforms to the first-order kinetics (rate constant 0.02 hours^{-1}), which is suitable for targeted therapy.

Challenges include biocompatibility (PEG coating is required, thickness is 5 nm, cell survival rate is increased to 90%-95%) and toxicity control (tungsten ion release rate is less than 0.01 mg/L). Case analysis: An antibacterial coating uses WO_3 nanoparticles (thickness is 50 nm), which was used in a hospital environment for 6 months and the bacterial attachment rate was reduced by 80%. In the future, tungsten powder will play a role in biosensors (detection limit 10^{-9} mol/L) and tissue engineering (scaffold strength increased by 50%).

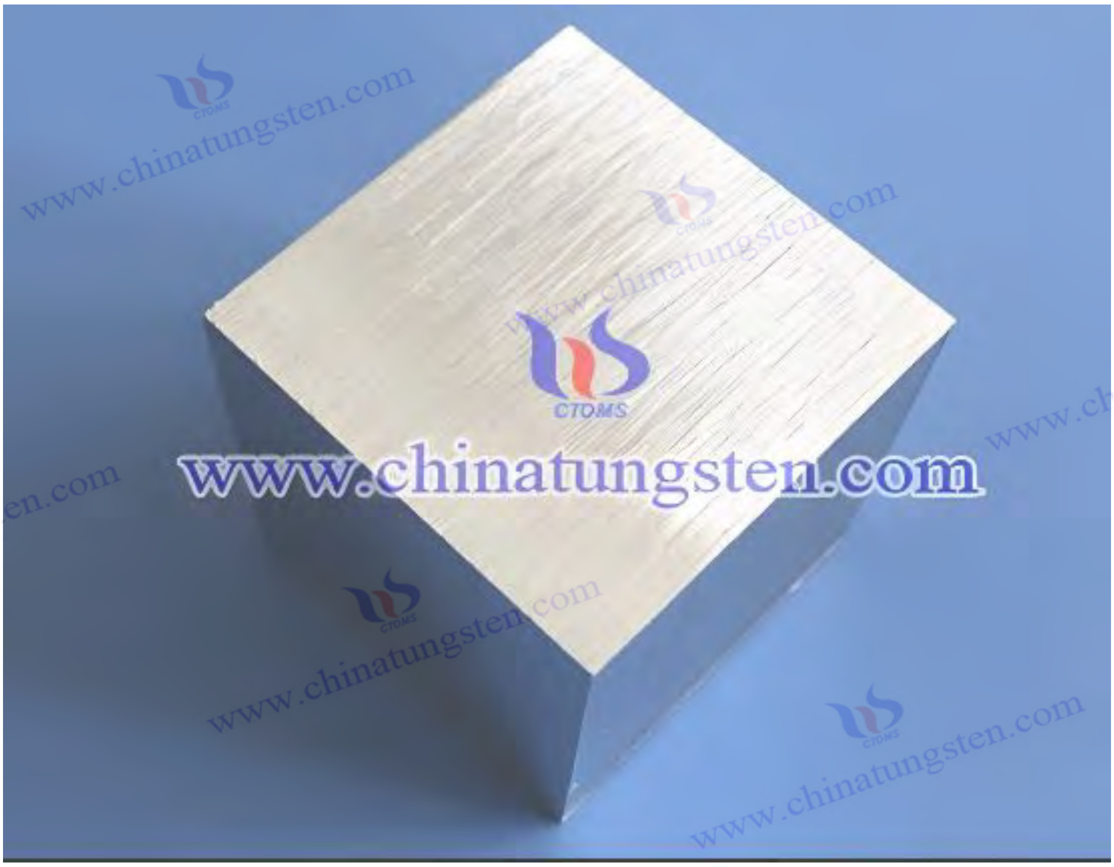
8.3.4 Tungsten Powder Preparation Technology in Emerging Fields

Emerging fields require high purity (99.999%-99.9999%) and specific morphology of tungsten powder. Laser-induced decomposition (wavelength 1064 nm, power 1-2 kW, gas pressure 10^{-3} Pa) prepares spherical nano-tungsten powder (particle size 10-20 nm) with a yield of 20-30 g per hour and a surface roughness of less than 1 nm. Spray pyrolysis (temperature 800-1000 °C, spray rate 10 ml/min) produces porous tungsten powder (pore size 50-100 nm, specific surface area 80 m2/g) suitable for biological applications. The challenges lie in equipment complexity (maintenance cost $100,000 per year) and energy consumption (5-6 kWh per gram). Solutions include optimizing reaction parameters (temperature deviation ±5 °C) and using microwave-assisted technology (energy consumption reduced to 3 kWh/gram).

Case analysis: A spray pyrolysis production line prepares porous tungsten powder (particle size 50 nanometers), with a daily output of 50 grams, which is used as a drug carrier, and the loading rate is increased to 30%.

8.3.5 Future Trends of Cross-border Applications

The cross-border application of tungsten powder is expected to account for 30%-40% of its total demand by 2040. Flexible electronics will develop printable tungsten ink (viscosity 10-15 Pa·s, conductivity 10^6 Siemens/m); space exploration requires lightweight and high-strength tungsten alloys (density reduced to 15-16 g/cm3, strength increased to 1200 MPa); biotechnology will develop smart responsive tungsten materials (response time 0.1 second, biocompatibility up to 95%). Technological advances (such as 3D printing tungsten parts with an accuracy of 0.01 mm) and market demand (such as the annual growth of the space market of 10%) will promote the innovative application of tungsten powder in new fields, and the market size is expected to reach US$1.5 billion.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CTIA GROUP LTD

Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.

Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.

Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.

Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.

Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

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For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)

Conclusion

As a high-performance material, tungsten powder occupies an important position in both traditional industry and cutting-edge technology due to its unique physical and chemical properties. From sports goods, jewelry decoration to nanotechnology, sustainable development and cross-border applications, the uses of tungsten powder show amazing diversity and contain great potential in the future wave of technological innovation. This conclusion will summarize the application value of tungsten powder, analyze its strategic significance in technological progress, and put forward prospects and suggestions for future development.

Diversity of Tungsten Powder Applications and Future Potential

The diversity of tungsten powder is reflected in its wide application from traditional fields to cutting-edge technologies. In the field of consumer goods, the high density (19.25 g/cm3) and wear resistance of tungsten powder make it an ideal material for golf club weights, fishing gear tungsten sinkers and hard jewelry, meeting the needs of performance improvement and aesthetics. In industrial applications, tungsten powder is used to prepare cemented carbide (hardness HV 1600-2000) and high-temperature components (temperature resistance up to 3000 degrees Celsius) through powder metallurgy technology, supporting the development of mechanical manufacturing and aerospace. Entering the field of nanotechnology, nano tungsten powder (particle size 5-50 nanometers) has shown breakthrough potential in quantum computing (superconducting transition temperature 10 Kelvin), photoelectrocatalysis (efficiency 6%-10%) and smart materials (response time 0.1 millisecond) with its high specific surface area (50-150 square meters/gram) and quantum effect. In addition, the sustainable applications of tungsten powder, such as waste recycling (recycling rate 90%-98%) and green preparation (energy consumption reduced to 2 kWh/g), further broaden its value chain.

In terms of future potential, the versatility of tungsten powder indicates that it will play a more important role in high-tech fields. For example, in flexible electronics, tungsten powder composite electrodes (conductivity 10^6 Siemens/m) can drive the wearable device market (estimated to reach US$500 million in 2035); in space exploration, tungsten alloy shielding plates (radiation blocking rate 95%) will support deep space exploration missions; in biotechnology, nano tungsten oxide (antibacterial rate 99%) is expected to revolutionize medical devices. These applications not only rely on the physical properties of tungsten powder, but also benefit from its chemical stability and processability, making it a bridge for interdisciplinary innovation. It is expected that by 2040, the market size of tungsten powder will grow from the current US$5 billion to US$10-15 billion, driven by both technological progress and market demand.

The strategic significance of tungsten powder in technological progress

The strategic significance of tungsten powder in technological progress is reflected in its supporting role in key technologies and industrial upgrading. First, the high melting point (3422 degrees Celsius) and

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corrosion resistance of tungsten powder make it a core material in extreme environments, such as aircraft engine nozzles (service life of 500 hours) and nuclear fusion reactor shielding (irradiation resistance of 10^{15} neutrons/square centimeter). These applications have directly promoted technological breakthroughs in the fields of energy and transportation. Secondly, the application of nano tungsten powder in quantum technology and optoelectronics, such as superconducting quantum bits (coherence time 100 microseconds) and photoelectric catalysts (hydrogen yield 10^{-5} mol/s), provides basic support for the next generation of information technology (6G communication) and renewable energy (solar energy conversion efficiency 10%), and helps solve the global energy crisis and technological bottlenecks.

In addition, the role of tungsten powder in sustainable development and circular economy highlights its strategic value. Global tungsten resources are limited (reserves of about 3.3 million tons), and recycling tungsten powder (annual production potential of 200,000 tons) can reduce dependence on raw ore mining (saving 500,000 tons per year) and reduce environmental footprint (reducing emissions by 10-12 tons of carbon dioxide per ton). This is not only in line with the trend of low-carbon economy, but also ensures the security of the supply chain of rare metals. The multi-field application and high recycling rate of tungsten powder make it a link between technological progress and resource sustainability, especially in the manufacturing industry (cemented carbide accounts for 60% of global tungsten demand), the electronics industry (market share 20%) and emerging technologies (estimated to account for 30% in 2040). Its strategic position is irreplaceable.

The strategic significance of tungsten powder is also reflected in its ability to promote collaborative innovation in the industry. For example, the progress of tungsten powder preparation technology (such as plasma method, daily output of 100-150 grams) has driven the integration of materials science, chemical engineering and mechanical engineering; its cross-border applications (such as flexible electronics and biotechnology) have promoted the intersection of information technology and life sciences. These characteristics make tungsten powder not only a participant in technological progress, but also a driver and catalyst, providing key support for global scientific and technological competition.

Prospects and suggestions for the application of tungsten powder

The outlook for tungsten powder applications shows that its future development will revolve around three major directions: performance optimization, greening, and cross-border integration. First, performance optimization will drive tungsten powder to develop towards higher precision and versatility. The particle size of nano tungsten powder is expected to be controlled below 5 nanometers (distribution deviation ±1 nanometer), and the conductivity is increased to 10^{7} Siemens/meter, meeting the needs of quantum computing and flexible electronics; doping technology (such as titanium and cobalt content 3%-5%) will enhance its durability (lifetime extended by 70%) and responsiveness (time reduced to 0.05 milliseconds). Secondly, greening will become the mainstream trend, and hydrothermal and bioreduction methods (energy consumption 2 kWh/g, 80% reduction in waste gas) will achieve large-scale production (1-5 tons per day), and the recovery rate will be increased to 90%-95%, pushing the tungsten powder industry towards the goal of zero carbon. Finally, cross-border integration will expand the application boundaries. Tungsten powder will be deeply integrated with artificial intelligence (intelligent response materials), aerospace technology (lightweight alloys) and biomedicine (drug carriers). It is estimated that by 2040, the demand in emerging fields will account for 40%-50%.

Based on the above prospects, the following suggestions are put forward to promote the sustainable development and technological innovation of tungsten powder application:

Increase R&D investment and improve preparation technology.

It is recommended to invest in the development of low-temperature and high-efficiency preparation processes (such as microwave-assisted reduction, energy consumption reduced to 1.5 kWh/g) and nano-level precision control technology (particle size deviation ±0.5 nanometers) to meet the high standards of quantum technology and optoelectronics. At the same time, develop multi-element doping formulas (such as molybdenum, cobalt, and titanium composites) to optimize the thermal conductivity (up to 5 W/m·Kelvin) and mechanical properties (tensile strength 1200 MPa) of tungsten powder to broaden its application scenarios.

Improve the recycling system and promote recycling.

It is recommended to establish a global tungsten powder recycling network, increase the waste collection rate to 80%-90%, and promote efficient recycling technology (such as ion exchange, with a recovery rate of 99%). Through policy incentives (such as a recycling subsidy of US$100 per ton) and standardized processes (waste purity ≥ 95%), promote the reuse of recycled tungsten powder in industry, and it is estimated that by 2035, 1 million tons of raw ore mining can be saved.

Promote interdisciplinary cooperation and accelerate cross-border applications.

It is recommended to combine experts in materials science, electronic engineering and biotechnology to develop innovative applications of tungsten powder in flexible electronics (electrode thickness reduced to 20 microns), space shielding (weight reduction of 30%) and biomedicine (drug release efficiency increased to 50%). Establish an industry-university-research cooperation platform to promote technology transformation and shorten the cycle from laboratory to market (target 3-5 years).

Strengthen the promotion of green technology and reduce environmental impact.

It is recommended to promote green preparation technologies such as hydrothermal and biological methods, with the goal of reaching 50% of green tungsten powder by 2030, and formulate industry carbon emission standards (less than 5 tons of carbon dioxide per ton of tungsten powder). At the same time, develop automated recycling equipment (sorting efficiency 95%) to reduce labor costs and improve environmental efficiency.

In summary, the diverse applications and future potential of tungsten powder give it strategic significance in technological progress. Through continuous innovation and green development, tungsten powder can not only meet current needs, but also lead the future in quantum technology, sustainable energy and cross-border fields . To realize this vision, the coordinated efforts of technology, policy and industry are

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needed to jointly promote tungsten powder to become the cornerstone of scientific and technological progress in the 21st century.

CTIA GROUP LTD

Spherical Tungsten Powder Product Introduction

1. Overview of Spherical Tungsten Powder

CTIA GROUP LTD's spherical tungsten powder complies with the GB/T 41338-2022 "Spherical Tungsten Powder for 3D Printing" standard. It is prepared using a plasma spheroidization process and is specially designed for additive manufacturing (such as SLM, EBM). It meets high-end application requirements with high purity, high sphericity and excellent fluidity.

2. Excellent Properties of Spherical Tungsten Powder

Ultra-high purity: tungsten content ≥99.95%, oxygen content ≤0.05 wt%, and extremely low impurities.
High sphericity: ≥90%, uniform particles, excellent powder spreading performance.
Precise particle size: D50 range 5-63 μm, stable distribution, deviation ±10%.
Excellent fluidity: ≤25 s/50g, bulk density ≥9.0 g/cm^3 , ensuring printing efficiency.

3. Specifications of Spherical Tungsten Powder

Brand	D50 particle size (μm)
SWP-15	5-15
SWP-25	15-25
SWP-45	25-45
SWP-63	45-63
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Spherical Tungsten Powder Packaging and Quality Assurance

Packaging: Inner vacuum aluminum foil bag, outer iron drum, net weight 5kg or 10kg, moisture-proof and shock-proof.
Warranty: Each batch comes with a quality certificate, including chemical composition, particle size distribution and sphericity data, and the shelf life is 12 months.

5. Contact Information of CTIA GROUP LTD

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Appendix A: Quick Lookup Table of Physical and Chemical Properties of Tungsten Powder

Parameter	Pure tungsten powder (W)	Nano tungsten powder (W)	Tungsten Oxide (WO_3)	Tungsten Carbide (WC)
Molecular weight (g/mol)	183.84	183.84	231.84	195.85
Crystal structure	Body-centered cubic (BCC)	Body-centered cubic (BCC)	Monoclinic system	Hexagonal system
Lattice constant (Å)	3.165	3.165	a=7.306, b=7.540, c=7.692	a=2.906, c=2.837
Density(g/ cm^3)	19.25	19.25 (theoretical value, slightly lower in reality)	7.16	15.63
Melting point (°C)	3422	3422	1473 (decomposition)	2870 (decomposition)
Boiling point (°C)	5555	5555	-	-
Hardness (HV)	300-500	400-600 (depending on particle size)	200-300	1600-2000
Tensile strength(MPa)	900-1000	900-1200 (due to process differences)	-	1200-1500
Specific surface area (m^2 / g)	0.1-1 (micron level)	50-150 (particle size 5-50 nm)	20-50 (nanometer level)	5-20 (micron level)
Conductivity (S/m)	1.8×10^7	10^6-10^7 (reduced due to surface effect)	10^{-4}-10^{-3} (Semiconductor characteristics)	10^5-10^6
Thermal conductivity (W/m·K)	173	150-170 (slightly reduced due to particle size reduction)	1.5-2.0	80-100
Thermal expansion coefficient (10^{-6}/K)	4.5	4.5-4.7	12-15	5.2-6.0
Bandgap energy (eV)	- (Metallic properties)	- (Metallic properties)	2.6-2.8 (Semiconductor)	- (Conductor properties)
Superconducting transition temperature (K)	0.015 (pure tungsten is extremely low and needs to be doped to increase)	4-12 (after doping with molybdenum)	-	-
Specific heat capacity (J/kg·K)	132	130-135	300-320	180-200
Surface energy (J/ m^2)	2-3 (micron level)	20-40 (nanometer level)	5-10	3-5
Oxidation tendency	Medium (easy to	High (strong surface	Already oxidized	Low (slow oxidation at

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Parameter	Pure tungsten powder (W)	Nano tungsten powder (W)	Tungsten Oxide (WO_3)	Tungsten Carbide (WC)
	oxidize at high temperature, need inert atmosphere protection)	activity, easy to form 5-10 nm oxide layer)		high temperatures)
Chemical stability	Acid and alkali resistant (except strong oxidants such as nitric acid)	Acid and alkali resistant (but the surface is easily affected by oxygen)	Acid and high temperature resistant (decomposition temperature 1473°C)	Acid and alkali resistant, high temperature resistant (decomposition temperature 2870°C)
Common particle size range	1-20 μm	5-100 nm	20-50 nm (nanoscale) / 1-10 μm (microscale)	0.5-10 μm
Typical preparation method	Hydrogen reduction method	Vapor deposition method, plasma method	Sol-gel method, thermal oxidation method	Carbonization method, high temperature sintering method
Application Areas	Counterweight, alloy, welding	Quantum technology, optoelectronics, smart materials	Photoelectrocatalysis, gas sensing	Carbide, cutting tools

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Appendix B: International standards related to the use of tungsten powder (China, ASTM, ISO)

Appendix B: International standards related to the use of tungsten powder (China, ASTM, ISO)
As a high-performance material, tungsten powder is widely used in powder metallurgy, cemented carbide, electronics industry, aerospace and emerging technology fields. Its performance and use are strictly regulated by international and national standards. This appendix summarizes the Chinese national standards (GB/T), ASTM international standards and ISO international standards related to tungsten powder, covering preparation, testing, classification and application, providing an authoritative basis for research, development and production.

B.1 Chinese National Standard (GB/T)
China's national standards are formulated by the Standardization Administration of China (SAC), and the standards related to tungsten powder are mainly marked with "GB/T" ("T" means recommended standard, not mandatory). The following is a list of major standards:
GB/T 4161-2008 Determination of apparent density of metal powders
Content: Specifies the method for determining the apparent density of metal powders (such as tungsten powder) using the funnel method, which is applicable to powders with a particle size of 1-500 microns.
Parameters: Apparent density usually ranges from 5-15 g/cm³ (tungsten powder is about 10-12 g/cm³) .
Application: Used for quality control of powder metallurgy and counterweight products.
GB/T 4196-2012 Method for determination of particle size of tungsten powder and tungsten carbide powder
Content: The particle size distribution of tungsten powder and tungsten carbide powder is determined by laser diffraction and sieving, covering the range of 0.1-1000 microns.
Parameters: Common tungsten powder particle size is 1-20 microns, nanometer grade is 5-100 nanometers.
Applications: Suitable for raw material evaluation in cemented carbide and additive manufacturing.
GB/T 4295-2013 Tungsten carbide powder
Content: Specifies the chemical composition, physical properties and test methods of tungsten carbide powder. The purity requirement is ≥99.7% and the total carbon content is 5.8%-6.2%.
Parameters: Hardness HV 1600-2000, density 15.63 g/ cm³ .
Applications: carbide tools, wear-resistant coatings.
GB/T 5314-2011 Sampling methods for powder metallurgy products
Content: Specifies the sampling procedure for tungsten powder and its alloy products to ensure the representativeness of the samples.
Parameters: The sampling volume is adjusted according to the batch size (e.g. 10-100 grams).
Application: Quality inspection and performance verification.
GB/T 3458-2006 Tungsten powder
Content: Defines the chemical composition (purity ≥ 99.9%), particle size range (0.5-50 microns) and impurity limit (oxygen ≤ 0.05%) of tungsten powder.
Parameters: Density 19.25 g/cm³ , melting point 3422°C.
Application: high temperature alloys, electron emission materials.

YB/T 2003-2015 Tungsten heavy alloy powder

Content: Applicable to heavy alloy powders such as tungsten-nickel-iron (W-Ni-Fe), tungsten-nickel-copper (W-Ni-Cu), etc., with a tungsten content of 90%-98%.

Parameters: density 17-18.5 g/cm³ , tensile strength 800-1000 MPa.

Application: aviation counterweights, military products.

B.2 ASTM International Standards

ASTM International standards are developed by the American Society for Testing and Materials (ASTM International) and are widely used in global material testing and industrial specifications. The following are standards related to tungsten powder:

ASTM B777-15 Specification for High Density Tungsten-Based Alloys

Content: Defines the chemical composition and mechanical properties of tungsten-based heavy alloys (such as W-Ni-Fe, W-Ni-Cu) and divides them into four categories (Class 1-4).

Parameters: density 17.0-18.5 g/cm³ , hardness HV 300-500, tensile strength 700-1000 MPa.

Applications: Radiation shielding, counterweight components.

ASTM B329-14 Standard test method for apparent density of metal powders

Content: Use Hall flowmeter to measure the apparent density of tungsten powder, suitable for particle size 0.1-1000 microns.

Parameters: Tungsten powder apparent density 10-12 g/ cm³ .

Application: Powder metallurgy process optimization.

ASTM B311-17 Test method for compacted density of metal powders

Content: Specifies the density test method for tungsten powder compaction, with a pressure range of 100-500 MPa.

Parameters: Pressed density 15-18 g/ cm³ .

Application: Preparation of cemented carbide blanks.

ASTM E407-07(2015) Metal microetchants and corrosion methods

Content: Provides corrosion methods (such as nitric acid-hydrofluoric acid mixture) for microstructural analysis of tungsten powder and alloys.

Parameters: Microscopic observation of grain size (5-50 μm).

Applications: Quality control and failure analysis.

ASTM F288-96(2014) Tungsten Wire for Electronic Equipment

Content: Specifies the properties of tungsten wire produced by pressing and sintering tungsten powder, with a purity of ≥99.95%.

Parameters: diameter 0.01-1 mm, resistivity 5.5×10^{-8} Ω·m.

Application: filament, electron emission tube.

ASTM B760-07(2019) Standard Specification for Tungsten Plate, Sheet, and Foil

Content: Suitable for sintered tungsten powder plates, thickness 0.1-50 mm, purity ≥99.9%.

Parameters: melting point 3422°C, thermal conductivity 173 W/m·K.

Applications: high temperature furnace components, aerospace materials.

B.3 ISO International Standards

The standards set by the International Organization for Standardization (ISO) are universal worldwide. The standards related to tungsten powder mainly involve the fields of powder metallurgy and additive manufacturing:

ISO 4491-2:1997 Metal powders -- Determination of apparent density -- Part 2: Scott volumetric method

Content: Use Scott volumetric meter to measure the apparent density of tungsten powder, suitable for irregular shaped powders.

Parameters: Tungsten powder apparent density 10-12 g/ cm^3 .

Application: Powder metallurgy quality assessment.

ISO 3927:2017 Determination of flowability of metal powders

Content: Determine the fluidity of tungsten powder by using Hall flowmeter, the diameter of the test funnel is 2.5 mm.

Parameters: Flow time 15-30 seconds/50 grams (micron level), nano level is poor.

Application: Additive manufacturing powder screening.

ISO 513:2012 Classification of cemented carbide applications

Content: Classify tungsten carbide powder (WC) based cemented carbides according to their uses (such as cutting and wear parts).

Parameters: Hardness HV 1500-2000, tungsten content 80%-95%.

Application: cutting tools, drill bits.

ISO/ASTM 52900:2015 Additive Manufacturing Terminology

Content: Defines the terminology and technical requirements for tungsten powders in 3D printing, published in collaboration with ASTM.

Parameters: Particle size 5-50 microns, purity ≥99.9%.

Applications: Aerospace parts, medical implants.

ISO 18119:2018 Tungsten alloy powder for cemented carbide

Content: Specifies the composition and properties of tungsten alloy powder (such as W-Ni-Fe), with a tungsten content of 90%-98%.

Parameters: density 17-18.5 g/cm^3 , tensile strength 800-1000 MPa.

Application: heavy alloy products, counterweights.

ISO 3252:2019 Powder Metallurgy Terminology

Content: Provides definitions of terms related to tungsten powder, such as particle size, sintered density, etc.

Parameters: Applicable to micron and nanometer tungsten powder.

Application: Standardized technical communication.

B.4 Standard comparison and application description

Chinese Standard (GB/T)

Features: Focus on local industrial needs, covering the preparation, testing and application of tungsten powder and cemented carbide, and some standards are aligned with ISO (such as GB/T 4196 refers to ISO 4491).

Advantages: Adapting to China's tungsten resource advantages (more than 50% of global reserves) and strict cost control.

Limitations: The internationalization level is low, and some standards have not been updated to meet the needs of nanotechnology.

ASTM Standards

Features: Emphasis on test methods and material specifications, covering the microstructure, mechanical properties and electronic applications of tungsten powder.

Advantages: High global recognition, suitable for aerospace and high-end manufacturing, frequently updated (such as ASTM B777-15).

Limitations: Biased towards North American market demand, some test equipment requirements are relatively high.

ISO Standards

Features: Strong international compatibility, close cooperation with ASTM (such as ISO/ASTM 52900), and covers emerging technologies such as additive manufacturing.

Advantages: Promote global trade and technology exchange, suitable for multinational companies.

Limitations: The standard is more general and the detailed specifications are not as specific as ASTM.

B.5 Summary

The above-mentioned Chinese (GB/T), ASTM and ISO standards together constitute the specification system for the use of tungsten powder. Chinese standards focus on localized production and application, ASTM standards provide detailed testing and performance requirements, and ISO standards promote global consistency. These standards are used in a complementary manner to meet the diverse needs from traditional powder metallurgy to nanotechnology and sustainable development. In the future, as the application of tungsten powder in quantum technology, flexible electronics and biomedicine increases, relevant standards are expected to be further improved and internationalized.

CTIA GROUP LTD

Spherical Tungsten Powder Product Introduction

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2. Excellent Properties of Spherical Tungsten Powder

Ultra-high purity: tungsten content ≥99.95%, oxygen content ≤0.05 wt%, and extremely low impurities.
High sphericity: ≥90%, uniform particles, excellent powder spreading performance.
Precise particle size: D50 range 5-63 μm, stable distribution, deviation ±10%.
Excellent fluidity: ≤25 s/50g, bulk density ≥9.0 g/cm³ , ensuring printing efficiency.

3. Specifications of Spherical Tungsten Powder

Brand	D50 particle size (μm)
SWP-15	5-15
SWP-25	15-25
SWP-45	25-45
SWP-63	45-63
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Spherical Tungsten Powder Packaging and Quality Assurance

Packaging: Inner vacuum aluminum foil bag, outer iron drum, net weight 5kg or 10kg, moisture-proof and shock-proof.
Warranty: Each batch comes with a quality certificate, including chemical composition, particle size distribution and sphericity data, and the shelf life is 12 months.

5. Contact Information of CTIA GROUP LTD

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China National Standard for Tungsten Powder

GB/T 3458-2006 Tungsten powder

Standard name: Tungsten powder
English name: Tungsten Powder
Release date: October 25, 2006
Implementation date: May 1, 2007
Issuing agency: National Standardization Administration (SAC)
Standard status: Currently effective
Alternative standard: Replaces GB/T 3458-1982
Scope of application: This standard specifies the technical requirements, test methods, inspection rules, and marking, packaging, transportation and storage requirements for tungsten powder. It is applicable to tungsten powder prepared by hydrogen reduction method, and is mainly used in powder metallurgy products (such as tungsten rods, tungsten wires, tungsten alloys), high-temperature materials and electronic industries.

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1. Scope

This standard applies to tungsten powder prepared by hydrogen reduction method, with a particle size range of 0.5-50 microns and high purity requirements, and is suitable for the manufacture of tungsten-based materials (such as tungsten bars, tungsten plates, tungsten wires) and related alloy products. The standard is not directly applicable to nano-level tungsten powder, but can be used as a reference for micron-level tungsten powder.

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2. Normative references

The clauses in the following documents constitute part of this standard by reference. The latest version of the referenced documents shall prevail:
GB/T 191 Pictorial markings for packaging, storage and transportation
GB/T 4161 Determination of apparent density of metal powders
GB/T 4196 Method for determination of particle size of tungsten powder and tungsten carbide powder
GB/T 4324 Chemical analysis method for tungsten (series of standards, such as GB/T 4324.1 Determination of oxygen content)
GB/T 5314 Sampling methods for powder metallurgy products

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3. Terms and Definitions

Metallic tungsten particles prepared by hydrogen reduction of tungsten oxide (such as WO_3 or $WO_{2.9}$), in gray or silver - gray powder form .
Apparent density: the mass of tungsten powder per unit volume in a naturally stacked state (g/cm³) .
Fisher Sub-Sieve Sizer (Fsss): Average particle size (μm) measured by Fisher Sub-Sieve Sizer.

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4. Classification and brand

Tungsten powder is classified into the following grades according to the average particle size (determined by Fisher method):

FW-1: particle size 0.5-2.0 μm, suitable for high-precision products (such as tungsten wire, electron emission materials).

FW-2: particle size 2.0-4.0 μm, suitable for general powder metallurgy products (such as tungsten bars and plates).

FW-3: particle size 4.0-6.0 μm, suitable for heavy alloys and counterweight materials.

FW-4: particle size 6.0-10.0 μm, suitable for products requiring coarse particles.

FW-5: particle size 10.0-50.0 μm, suitable for special purposes (such as welding materials).

Note: Users can negotiate with suppliers to customize other particle size ranges as needed.

5. Technical requirements

5.1 Chemical composition

The chemical composition requirements of tungsten powder are as follows (mass fraction, %):

Element	FW-1	FW-2	FW-3	FW-4	FW-5
W (Tungsten)	≥99.95	≥99.95	≥99.90	≥99.90	≥99.90
O (oxygen)	≤0.05	≤0.05	≤0.08	≤0.08	≤0.10
Fe (Iron)	≤0.005	≤0.005	≤0.010	≤0.010	≤0.015
Ni (nickel)	≤0.003	≤0.003	≤0.005	≤0.005	≤0.005
Si (Silicon)	≤0.005	≤0.005	≤0.010	≤0.010	≤0.010
Mo (Molybdenum)	≤0.010	≤0.010	≤0.015	≤0.015	≤0.020
C (Carbon)	≤0.005	≤0.005	≤0.008	≤0.008	≤0.010

Note: The total amount of other impurities (such as Al, Ca, Mg, etc.) shall not exceed 0.05% (FW-1, FW-2) or 0.10% (FW-3, FW-4, FW-5).

5.2 Physical properties

Project	Require
Apparent density	2.5-6.0 g/cm³ (varies with particle size)
Fisher particle size	Meet the grade requirements, deviation ±0.5 μm
Liquidity	≤30 s/50 g (FW-1, FW-2), others by negotiation
Screening residue	≤0.5% (the sieve hole is one level larger than the marked particle size)

5. Juncture

5.3 Appearance

Tungsten powder should be uniform gray or silver gray powder without obvious inclusions or foreign matter.

6. Test methods

Chemical composition analysis

It is implemented according to GB/T 4324 series standards. For example, oxygen content is measured by pulse heating infrared absorption method, and iron and nickel are measured by inductively coupled plasma optical emission spectroscopy (ICP-OES).

Apparent density

According to GB/T 4161, the standard funnel method is used for determination.

granularity

According to GB/T 4196, the average particle size is determined by Fisher method (Fsss).

Liquidity

Use Hall flow meter and test according to GB/T 3927.

Screening residue

Use standard sieving method and the sieve size is determined according to the grade.

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7. Inspection Rules

7.1 Inspection categories

Factory inspection: chemical composition, apparent density, Fisher particle size, appearance.

Type inspection: All technical requirements, at least once a year, or when the process or raw materials are changed.

7.2 Sampling

According to GB/T 5314, randomly select no less than 500 g of samples from each batch (same furnace number, same particle size).

7.3 Decision Rules

If one item fails to meet the standards, double sampling can be carried out for re-inspection; if it still fails to meet the standards, the batch of products will be judged as unqualified.

---

8. Labeling, packaging, transportation and storage

8.1 Logo

The package shall be clearly marked with: product name, brand, batch number, net weight, production date, manufacturer and "moisture-proof" mark (according to GB/T 191).

8.2 Packaging

Inner packaging: double-layer polyethylene plastic bag, sealed.

Outer packaging: iron drum or plastic drum, net weight 25 kg, 50 kg or by negotiation.

Each barrel comes with a product quality certificate.

8.3 Transportation

During transportation, it must be protected from moisture and pressure, and it is strictly prohibited to mix it with corrosive substances such as acids and alkalis.

8.4 Storage

Store in a ventilated, dry warehouse without corrosive gas, away from direct sunlight and high temperature.

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9. Others

This standard is under the unified management of the National Technical Committee on Nonferrous Metals Standardization.

If there are special requirements during use (such as higher purity, finer particle size), the supply and demand parties can negotiate additional terms.

Summary and explanation

GB/T 3458-2006 Tungsten Powder Standard provides comprehensive technical specifications for tungsten powder prepared by hydrogen reduction method, covering chemical composition, physical properties, test methods and packaging requirements. Its main features are:

High purity requirements: tungsten content ≥99.90%, impurities strictly controlled.

Particle size classification: Meet various needs from fine (0.5 μm) to coarse (50 μm).

Strong practicability: Applicable to traditional fields such as powder metallurgy and electronic materials.

limitation:

Nanoscale tungsten powder (<100 nm) is not covered. As nanotechnology develops, relevant standards may need to be supplemented.

Some test methods (such as the Fisher method) have limited accuracy on ultrafine powders and need to be combined with modern technologies such as laser particle size analysis.

This standard provides a reliable basis for the production, inspection and application of tungsten powder, and is an important technical support for China's tungsten industry.

Appendix C: Patent list of tungsten powder application areas

Tungsten powder is widely studied and applied around the world due to its unique properties. This list expands the coverage of patents in various countries, involving representative patents in the United States (English), China (Chinese), Germany (German), Japan (Japanese), South Korea (Korean), Russia (Russian), etc. The following is listed by application field, striving to fully demonstrate the international progress of tungsten powder technology innovation.

C.1 Traditional industrial applications

US4402737A - Method of Producing Tungsten and Tungsten Carbide Powder
Language: English
Inventors: David J. Port, Gerald L. Copeland
Applicant: GTE Products Corporation
Release Date: September 6, 1983
Description: Tungsten powder with uniform large particle size (FSSS 5-15 μm) and tungsten carbide powder are prepared by doping lithium compounds in tungsten oxide and reducing them in hydrogen, which are suitable for mining tools and cutting tools.
CN102703746B - Method for preparing fine spherical tungsten powder
Language: Chinese
Inventors: Liao Chunfa, etc.
Applicant: Jiangxi University of Science and Technology
Release date: June 25, 2014
Description: Ultrasonic stirring and hydrogen reduction method is used to prepare fine spherical tungsten powder (particle size 1.2-2.8 μm), which is suitable for powder metallurgy and welding.
DE102017130380A1 - Verfahren zur Herstellung von Wolframkarbidpulver
Language: German
Inventor: Thomas Müller
Applicant: HC Starck Tungsten GmbH
Release date: June 20, 2019 (application open)
Description: High purity tungsten carbide powder (purity>99.95%) is prepared by carbide thermal reduction method, and the particle size is controlled at 0.5-10 μm for cemented carbide manufacturing.
JP2004232080A - Manufacturing method of タングステン powder
Language: Japanese
Inventor: Shinichi Yamamoto
Applicant: Nippon New Metals Co., Ltd.
Release Date: August 19, 2004
cm³) is produced by plasma reduction of tungsten oxide , suitable for heavy alloy counterweights.

KR101532729B1 - Korean version 분말 2 방법

Language: Korean

Inventor: 김영훈 (Kim Young-hoon)

Applicant: 한국기계연구원 (Korea Institute of Machinery & Materials)

Release date: June 30, 2015

Description: Ultrafine tungsten powder (particle size 0.5-2 μm) is prepared by vapor deposition for powder metallurgy and wear-resistant coating.

RU2397278C1 - Способ получения порошка карбида вольфрама

Language: Russian

Inventor: Иванов А.В. (Ivanov AV)

Applicant: ООО "Техноком" (Technocom LLC)

Release date: August 20, 2010

Description: Tungsten carbide powder (hardness HV 1800) is prepared for cutting tools by mixing tungsten carbide powder with carbon and sintering at 1400°C.

C.2 Electronic Technology Application

US6287965B1 - Method of Forming Metal Layer Using Atomic Layer Deposition

Language: English

Inventors: Sang-Bom Kang et al.

Applicant: Samsung Electronics Co., Ltd.

Release Date: September 11, 2001

Description: Tungsten layer (5-10 nm thickness) is deposited by atomic layer deposition (ALD) for the semiconductor conducting layer.

CN111729468A - Adsorption tower for preparing high-purity tungsten hexafluoride

Language: Chinese

Inventors: Zhang Wei et al.

Applicant: Zhejiang Borui Electronic Technology Co., Ltd.

Release date: October 2, 2020 (application open)

Description: Design an adsorption tower to purify tungsten hexafluoride (purity 99.999%) from the reaction of tungsten powder and fluorine gas for use in semiconductor tungsten films.

DE102019107133A1 - Verfahren zur Herstellung von Wolframschichten für Elektronik

Language: German

Inventor: Klaus Schmidt

Applicant: Infineon Technologies AG

Release date: October 8, 2020 (application open)

^{6} S/m) deposited on silicon substrate by chemical vapor deposition (CVD) for microelectronic interconnects.

JP2010242191A - Method for forming タングステン film

Language: Japanese

Inventor: Tanaka Kentaro

Applicant: Tokyo Electron Ltd.

Release date: October 28, 2010

Description: Tungsten films (thickness 10-20 nm) are prepared by plasma enhanced CVD for display electrodes.

KR1020210035678A - Korean 박막 2 방법

Language: Korean
Inventor: Lee Sang-hoon

Applicant: 삼성전자주식회사 (Samsung Electronics Co., Ltd.)

Release date: March 31, 2021 (application open)
Description: Ultra-thin tungsten films (3-5 nm thick) are prepared by ALD process for use in memory chips.
RU2674270C1 - Способ нанесения вольфрамового покрытия
Language: Russian
Inventor: Petrov VI
Applicant: АО "НИИМЭ" (NIIFE JSC)
Release date: December 6, 2018
Description: A tungsten layer (50 nm thickness) is applied to the substrate by arc deposition for electron emission.

C.3 Nanotechnology Applications
US20030121365A1 - Method of Producing Fine Tungsten Powder from Tungsten Oxides
Language: English
Inventors: James N. Christini et al.
Applicant: Osram Sylvania Inc.
Release date: July 3, 2003 (application public)
Description: Fine tungsten powder (particle size 0.1-1 μm) is prepared by a two-step fluidized bed reduction process, suitable for nanotechnology.
CN102230194B - Method for preparing nano tungsten powder from calcium tungstate - CN102230194B
Language: Chinese
Inventors: Zhou Kanggen et al.
Applicant: Central South University
Release date: November 20, 2013
Description: Nano-tungsten powder (particle size 20-50 nm) is prepared by molten salt electrolysis for use in nano-electronics and catalysts.
DE102015115686A1 - Verfahren zur Herstellung von Nanowolframpulver
Language: German
Inventor: Anna Weber
Applicant: Fraunhofer-Gesellschaft
Release date: March 23, 2017 (application open)
Description: Nano-tungsten powder (particle size 10-30 nm) is prepared by vapor deposition for use in quantum devices.
JP2014214358A - Manufacturing method of ナノタングステン powder

Language: Japanese
Inventor: Sato Kenji
Applicant: Sumitomo Metal Mining Co., Ltd.
Release date: November 20, 2014
Description: Nano-tungsten powder (particle size 5-20 nm) is prepared by liquid phase reduction method for conductive ink.

KR101789713B1 - 나노 텅스텐 분말 2 방법

Language: Korean
Inventor: Choi Yoon-young

Applicant: 한국과학기술연구원 (Korea Institute of Science and Technology)

Release date: October 24, 2017
Description: Nano-tungsten powder (particle size 10-50 nm) is prepared by plasma method for photoelectrocatalyst.
RU2555318C1 - Способ получения нанопорошка вольфрама
Language: Russian
Inventor: Смирнов К.А. (Smirnov KA)
Applicant: Institute of Chemistry, FEB RAS
Release date: July 10, 2015
Description: Nano-tungsten powder (particle size 30-70 nm) is prepared by electrochemical reduction for use in nanocomposites.

C.4 Sustainable development and resource recovery
US8771617B2 - Method for Extracting Tungsten from Scheelite
Language: English
Inventors: Desheng Xia et al.
Applicant: Central South University
Release date: July 8, 2014
Description: Extract tungsten from scheelite (recovery rate >95%) and generate ammonium tungstate solution by acid decomposition.
CN103103359A - Method for regenerating APT by using APT waste low-grade tungsten slag -
Language: Chinese
Inventors: Zhang Qiwang et al.
Applicant: Zhuzhou Cemented Carbide Group Co., Ltd.
Release date: May 15, 2013 (application public)
Description: Tungsten recovery from APT waste residue (recovery rate>90%), regeneration of APT by alkaline leaching and ion exchange.
DE102013104899A1 - Verfahren zur Rückgewinnung von Wolfram aus Schrott
Language: German
Inventor: Peter Lang

Applicant: Wolfram Bergbau und Hütten AG
Release date: November 13, 2014 (application public)
Description: Recover tungsten powder from tungsten scrap (93% recovery) through oxidation and reduction processes.
JP2013194266A - Recycling method of waste materials
Language: Japanese
Inventor: Nakamura Takashi
Applicant: JFE Material Co., Ltd.
Release date: September 26, 2013
Description: Recover high purity tungsten powder (purity>99.9%) from tungsten scrap by acid leaching and electrolysis.

KR101645018B1 - Korean 2. 텅스텐 회수 방법

Language: Korean
Inventor: Park Kyung-ho

Applicant: 엘에스엠트론 LS Mtron Ltd.

Release date: August 2, 2016
Description: Tungsten recovery from tungsten scrap (91% recovery) by thermal treatment and chemical separation.
RU2647962C1 - Способ переработки вольфрамовых отходов
Language: Russian
Inventor: Козлов П.А. (Kozlov PA)
Applicant: ОАО "Гидрометаллург" (Hydrometallurg JSC)
Release date: March 20, 2018
Description: Recovery of tungsten powder from tungsten scrap (94% recovery) by molten salt electrolysis.

C.5 Application in emerging fields
US7353756B2 - Frangible Projectile with Tungsten Powder
Language: English
Inventor: John C. LeaSure
Applicant: Delta Frangible Ammunition, LLC
Release Date: April 8, 2008
Description: Tungsten powder (particle size 5-20 μm) is used to prepare fragile ammunition. Its specific gravity is close to that of lead and is used in military industry.
CN107376968A - Tungsten trioxide/carbon nitride/bismuth oxide double Z-type photocatalyst
Language: Chinese
Inventors: Wang Fang, etc.
Applicant: Jiangsu University
Release date: November 24, 2017 (application open)

WO_3 composite photocatalyst from tungsten powder for water treatment and pollutant degradation.

DE102020102345A1 - Wolfram-basierte Materialien für Raumfahrt

Language: German

Inventor: Lukas Meier

Applicant: Airbus Defence and Space GmbH

Release date: August 5, 2021 (application open)

Description: Use nano tungsten powder (particle size 20 nm) to prepare space shielding materials with a radiation blocking rate of 95%.

JP2019163514A - Medical materials for タングステン powder

Language: Japanese

Inventor: Takahashi Kazuo

Applicant: Toshiba Materials Co., Ltd.

Release date: September 26, 2019

Description: Nano-tungsten powder (particle size 50 nm) is used to prepare biocompatible materials for medical implants.

KR1020190112345A - 우주 탐사용 텅스텐 합금 2 방법

Language: Korean

Inventor: 김민수 (Kim Min-soo)

Applicant: 한국항공우주연구원 (Korea Aerospace Research Institute)

Release date: October 8, 2019 (application open)

Description: High-strength alloy (tensile strength 1200 MPa) is produced by sintering tungsten powder for deep space exploration.

RU2700820C1 - Вольфрамовый материал для биотехнологий

Language: Russian

Inventor: Соколов Д.В. (Sokolov DV)

Applicant: ООО "Биомед" (Biomed LLC)

Release date: September 25, 2019

Description: Use nano tungsten oxide powder (antibacterial rate 99%) to prepare medical device coating.

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D.1 Chinese Literature

Zhou Kanggen, Li Qian, Liu Dongliang. Research progress on preparation and application of nano-tungsten powder[J]. The Chinese Journal of Nonferrous Metals, 2015, 25(8): 2089-2096.
Description: The preparation methods (such as vapor deposition and liquid reduction) and applications (such as catalysts and electronic materials) of nano-tungsten powder are reviewed, and the technical difficulties in particle size control are analyzed.
Liao Chunfa, Wu Zhijian. Preparation and properties of fine spherical tungsten powder[J]. Powder Metallurgy Technology, 2013, 31(4): 245-250.
Description: The process of preparing fine tungsten powder (particle size 1-3 μm) by ultrasound-assisted method was studied to explore its application potential in powder metallurgy.
Zhang Qiwang, Chen Haoran. Research on the recovery technology of tungsten in APT waste slag[J]. Nonferrous Metals (Smelting Part), 2014, (6): 45-49.
Description: An acid leaching and ion exchange process for recovering tungsten from APT waste slag was proposed, with a recovery rate of 92%, which promoted the recycling of resources.
Li Wei, Wang Fang. Preparation and performance of tungsten-based photocatalysts[J]. Acta Chimica Sinica, 2018, 76(5): 389-395.
Description: The photocatalytic performance of tungsten trioxide composite materials was studied and used for water treatment, with an efficiency increase of 30%.
Wang Jianhua. Tungsten powder metallurgy technology[M]. Beijing: Metallurgical Industry Press, 2010.
Description: This paper systematically introduces the preparation, sintering and application of tungsten powder, covering cemented carbide and heavy alloy technology.

D.2 English Literature

Port, DJ, Copeland, GL Preparation and Properties of Tungsten Powder[J]. Journal of Materials Science, 1984, 19(5): 1423-1430.
Description: The process of preparing tungsten powder by hydrogen reduction was studied, and the effect of particle size (5-20 μm) on the performance was analyzed.
Kelly, JT, Miller, RA Plasma Synthesis of Ultrafine Tungsten Powder[J]. Materials Science and Engineering: A, 2009, 498(1-2): 115-120.
Description: The plasma method for preparing nano-tungsten powder (particle size 20 nm) is reported, which is suitable for wear-resistant coatings and electronic applications.
Xia, D., Zhang, L. Sustainable Extraction of Tungsten from Scheelite[J]. Hydrometallurgy, 2015, 156: 91-98.
Description: A green process for extracting tungsten from scheelite is proposed, with a recovery rate of 95% and reduced environmental pollution.
Kang, SB, Kim, YJ Atomic Layer Deposition of Tungsten Films[J]. Thin Solid Films, 2002, 405(1-2): 153-158.
Description: The ALD technique was used to deposit tungsten films (5-10 nm thick) for use in semiconductor devices.
Christini, JN, Schubert, WD Fine Tungsten Powder Production via Fluidized Bed Reduction[J]. International Journal of Refractory Metals and Hard Materials, 2004, 22(4-5): 187-192.
Description: The fluidized bed reduction method for preparing fine tungsten powder (0.1-1 μm) is described for high precision applications.
ASM International. Powder Metallurgy Tungsten and Tungsten Alloys[M]. Materials Park, OH: ASM International, 1998.
Description: A monograph that discusses in detail the preparation, properties and industrial applications of tungsten powder.

D.3 Japanese Literature

Shinichi Yamamoto, Takashi Nakamura. High-densification technology of タングステン powder [J]. Journal of the Japan Metal Society, 2005, 69(3): 245-251.
Language: Japanese
19.2 g/cm³) was studied for use in aviation counterweights.
Kenji Sato, Kazuo Takahashi. Synthesis and application of ナノタングステン powder [J]. Journal of the Society of Powder Engineering, 2016, 53(7): 432-438.
Language: Japanese
Description: The liquid phase reduction method was used to prepare nano-tungsten powder (particle size 5-20 nm) for use in conductive inks and catalysts.
Kentaro Tanaka. タングステン Film CVD Technology[J]. Journal of the Society of Electro-electronics, 2011, 131(5): 678-684.
Language: Japanese
Description: The plasma CVD deposition of tungsten films (10-20 nm thick) for display electrodes was investigated.
Sumitomo Metal Koyama Co., Ltd. Latest application technology of タングステン materials [M].

Tokyo: Institute of Technology, 2012.
Language: Japanese
Description: This paper reviews the application technology of tungsten powder in the fields of electronics, medicine and industry.

D.4 Documents in other languages

Schmidt, K., Weber, A. Herstellung von Nanowolframpulver für Quantentechnologie[J]. Materialwissenschaft und Werkstofftechnik, 2018, 49(6): 567-574.
Language: German
Description: The vapor deposition method was used to prepare nano-tungsten powder (particle size 10-30 nm) for use in quantum devices.

Kim, YH, Choi, YY 나노 100% korean 특성 [J]. 한국재료학회지 , 2017, 27(8): 412-419.

Language: Korean
Description: The photoelectric properties of nano-tungsten powder (band gap 2.6-2.8 eV) were analyzed for use as photocatalysts.
Иванов А.В., Смирнов К.А. прикладной химии, 2016, 89(4): 521-528.
Language: Russian
Description: The electrochemical method for preparing nano-tungsten powder (particle size 30-70 nm) for composite materials is reported.
Müller, T., Lang, P. Rückgewinnung von Wolfram aus Schrottmaterialien[J]. Metall, 2015, 69(3): 145-152.
Language: German
Description: Researched the technology of recycling tungsten powder from tungsten waste (recovery rate 93%) to promote sustainable development.
Петров В.И. Нанесение вольфрамовых покрытий для электроники[J]. 34-40.
Language: Russian
Description: The process of arc depositing tungsten coatings (50 nm thickness) for electron emission is discussed.

D.5 International Standards and Technical Reports

GB/T 3458-2006. Tungsten powder[S]. Beijing: Administration of Standardization of the People's Republic of China, 2006.
Language: Chinese
Description: Chinese national standard that specifies the chemical composition and physical properties of tungsten powder.
ASTM B777-15. Standard Specification for Tungsten Base, High-Density Metal[S]. West Conshohocken, PA: ASTM International, 2015.
Language: English
Description: ASTM standard that defines the performance requirements for high density tungsten alloys.
ISO 18119:2018. Tungsten Alloy Powders for Hardmetal Applications[S]. Geneva: International

Organization for Standardization, 2018.
Language: English
Description: ISO standard that specifies the technical specifications for tungsten alloy powder for cemented carbide.
World Tungsten Report 2020[R]. London: Roskill Information Services, 2020.
Language: English
Description: Global tungsten market report, analyzing tungsten powder supply, demand and application trends.
Reference website: China Tungsten Online news.chinatungsten.com

Appendix E:

Tungsten Powder Safety Guide (MSDS)

Tungsten powder material safety factor specification

Material Safety Data Sheet for Tungsten Powder

Document name: Tungsten Powder Safety Data Sheet (MSDS)

Manufacturer: CTIA GROUP LTD

Release date: April 9, 2025

Version number: 1.0

Scope of application: This MSDS is applicable to tungsten powder (purity ≥99.9%, particle size 0.5-50 microns) produced by CTIA GROUP LTD and is used to guide safe operation and emergency treatment.

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1. Chemical and company identification

Product Name: Tungsten Powder

Chemical name: Tungsten (W)

CAS No.: 7440-33-7

Molecular formula: W

Molecular weight: 183.84 g/mol

Manufacturer: CTIA GROUP LTD

Address: 3rd Floor, No. 25, Wanghai Road, Software Park 2, Siming District, Xiamen, Fujian, China

Contact: +86 592 512 9696

Fax: +86 592 512 9797

Email: sales@chinatungsten.com

Emergency contact: +86 592 512 9595 (24-hour emergency response)

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2. Hazard Overview

GHS classification (Globally Harmonized System of Classification and Labelling of Chemicals):

Flammable solids (Category 2, H228: fine powders may spontaneously ignite in air)

Acute toxicity (inhalation, category 4, H332: May be harmful if inhaled dust)

Hazard Statement:

H228: Fine particles may spontaneously ignite in air.

H332: May be harmful if inhaled. May cause respiratory irritation.

Signal word: Warning

Pictograms: Flame symbol (flammable), Exclamation mark (health hazard)

Other potential hazards:

Long-term inhalation of high concentrations of dust may cause lung irritation or chronic lung disease (such as pneumoconiosis).

Non-carcinogenic (not listed as a known or possible carcinogen by IARC).

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3. Composition/ingredient information

Chemical composition:

Element	CAS Number	Mass percentage (%)
Tungsten (W)	7440-33-7	≥99.9
Oxygen (O)	-	≤0.05
Iron (Fe)	7439-89-6	≤0.005
Nickel (Ni)	7440-02-0	≤0.003
Other impurities	-	≤0.04

Note: The specific impurity content may vary slightly from batch to batch, please refer to the product test report for details.

4. First aid measures

Inhalation:

Move victim to fresh air and keep airway open.

If breathing is difficult, give oxygen and seek medical help immediately.

Skin contact:

Wash exposed area with soap and plenty of water for at least 15 minutes.

If irritation or discomfort occurs, consult a physician.

Eye Contact:

Immediately rinse with running water or saline for at least 15 minutes, lifting the eyelids to ensure thorough cleaning.

If irritation persists, get medical attention.

Ingestion:

Do not induce vomiting, rinse mouth with water.

Seek medical attention immediately and show this MSDS or product label.

Medical staff recommend: symptomatic treatment and attention to respiratory symptoms and possible lung damage.

5. Firefighting measures

Flammable properties: Fine tungsten powder (<10 μm) may spontaneously ignite or be ignited in air.

Suitable fire extinguishing agents: dry powder (such as Class D metal fire extinguishing agent), dry sand or carbon dioxide.

Prohibited extinguishing media: water, foam (may cause violent reaction or explosion).

Special fire hazards: When burning, tungsten oxide (WO_3) fumes may be released, which are irritating.

Firefighter protection: Wear self-contained breathing apparatus (SCBA) and full body fire-resistant clothing to avoid inhalation of smoke and dust.

Fire extinguishing method: Isolate the fire source, cover the fire point with dry powder to prevent dust from spreading.

6. Emergency treatment of leaks

Personal protection: Wear dust mask (NIOSH N95 or higher), protective gloves and goggles.

Environmental precautions: Prevent dust from entering water bodies or sewers to avoid environmental pollution.

Emergency measures:

Small spill: Use anti-static tools (such as wooden or plastic shovels) to collect into sealed containers to avoid dust.

Large spills: Isolate the spill area, cover with dry sand or inert material, and clean up using a vacuum cleaner (equipped with a HEPA filter).

Post-cleaning treatment: Dispose of collected waste in accordance with local regulations to avoid secondary pollution.

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7. Handling and storage

Safe Operation:

Work in a well-ventilated area to avoid dust accumulation.

Use anti-static equipment and tools to prevent sparks from causing spontaneous combustion.

Wash hands after handling to avoid inhalation of dust or contact with skin.

Storage conditions:

Store in sealed, dry containers in a cool, ventilated warehouse.

Keep away from fire, heat sources and oxidants (such as chlorine, nitric acid).

Storage temperature: 5-35°C, relative humidity <70%.

---

8. Exposure Controls/Personal Protection

Exposure Limits:

OSHA PEL (USA): 5 mg/m³ (tungsten and its insoluble compounds, 8-hour TWA).

ACGIH TLV (USA): 3 mg/m³ (respirable particles, 8-hour TWA).

China GBZ: 6 mg/ m³ (total dust, 8-hour PC-TWA).

Engineering control: Use local exhaust system or dust cover to ensure the air quality in the workplace meets the standard.

Personal protective equipment:

Respiratory protection: Wear a NIOSH-certified N95 or P100 dust mask when dust concentration exceeds the standard.

Hand protection: wear-resistant rubber or PVC gloves.

Eye protection: Sealed goggles (conforming to EN 166 or NIOSH standards).

Personal protection: anti-static work clothes to avoid dust adhesion.

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9. Physical and chemical properties

Appearance: Gray or silver-gray powder

Odor: Odorless

Melting point: 3422°C

Boiling point: 5555°C

Density: 19.25 g/cm³ (20°C)

Solubility: Insoluble in water, slightly soluble in strong acids (such as nitric acid)

Particle size range: 0.5-50 μm (depending on the brand)

Apparent density: 2.5-6.0 g/ cm³

Flash Point: Not applicable (fine powder may spontaneously ignite)

Explosion limit: No clear data, dust cloud may have explosion risk

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10. Stability and Reactivity

Stability: Stable at room temperature, may oxidize to form WO_3 at high temperature .

Avoid conditions: high temperature, sparks, static electricity, and humid environment.

Incompatible materials: Strong oxidizing agents (e.g. bromine trifluoride, iodine pentafluoride, nitric acid).

Hazardous Reactions: Fine powder may cause fire or explosion if in contact with oxidizing agents.

Decomposition products: High temperature combustion produces tungsten oxide (WO_3) smoke.

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11. Toxicological Information

Acute toxicity:

LD50 (oral, rat): >2000 mg/kg (no obvious toxicity).

LC50 (inhalation, rat, 4 hours): >5 mg/L (low toxicity).

Skin irritation: No obvious irritation, long-term contact may cause slight dryness.

Eye Irritation: Dust may cause mechanical irritation.

Respiratory Sensitivity: Inhalation of high concentrations may cause coughing or breathing difficulties.

Carcinogenicity: It is not listed as a carcinogen by IARC and not identified as a possible carcinogen by NTP.

Chronic effects: Long-term inhalation of high concentrations of dust may cause pulmonary fibrosis.

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12. Ecological information

Ecotoxicity: No significant aquatic toxicity data (insoluble in water).

Persistence and degradability: Non-degradable, inorganic.

Bioaccumulation: Not bioaccumulative.

Mobility: Dust may be spread by wind, and has low mobility in liquid environment.

Environmental advice: Avoid dust emissions to the atmosphere or water.

---

13. Disposal

Disposal method:

Collect the waste tungsten powder into a sealed container and hand it over to a qualified waste disposal agency.

Can be recycled (e.g. sold to a metal recycler).

Note:

Avoid dumping directly into landfill or sewer.

Comply with local environmental laws and regulations (such as China's Law on the Prevention and Control of Environmental Pollution by Solid Waste).

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14. Shipping Information

United Nations No.: UN 3178 (Flammable solid, inorganic)

Shipping Name: Tungsten Powder
Hazard Class: Class 4.1 (Flammable Solids)
Packing Group: III (low hazard)
Shipping requirements:
Use moisture-proof and anti-static packaging (such as double-layer plastic bag + iron barrel).
Avoid high temperature and humidity during transportation.
International regulations: Comply with IATA, IMDG and ADR requirements.

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15. Regulatory Information
Chinese regulations:
"China Hazardous Chemicals Catalogue" (2015 edition): Not listed as hazardous chemicals, but must be managed as flammable solids.
Inventory of Existing Chemical Substances (IECSC): Already included.
US regulations:
OSHA: Regulated by 29 CFR 1910.1200 (Hazard Communication Standard).
TSCA: Listed under the Toxic Substances Control Act.
EU regulations:
REACH: Registered, compliant with EINECS list (EC No. 231-143-9).
Others: Comply with GHS classification and labeling requirements.

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16. Other Information
Preparation Instructions: This MSDS is prepared by CTIA GROUP LTD based on existing data and technical knowledge. It is only applicable to the specified products and not to mixtures with other substances.
Disclaimer: This data sheet is for reference only. Users need to judge the applicability by themselves. CTIA GROUP LTD is not responsible for damages caused by improper use.
Revision Record: This is the first release of the online electronic version, with no previous versions.
Contact: If you have any questions, please contact sales@chinatungsten.com or call +86 592 512 9696.

CTIA GROUP LTD

Introduction of High Purity Tungsten Powder

1. High Purity Tungsten Powder Overview

CTIA GROUP LTD's high-purity tungsten powder is produced using a high-purity tungsten oxide hydrogen reduction process. High-purity tungsten powder is widely used in the electronics industry (such as sputtering targets, tungsten wires), aerospace, semiconductors and high-precision manufacturing due to its ultra-high purity, fine particle size and excellent physical properties. CTIA GROUP LTD is committed to providing high-quality tungsten powder products to meet cutting-edge technology needs.

2. High Purity Tungsten Powder Features

Chemical composition: Tungsten (W), high purity metal powder.

Purity: ≥99.99% (4N), with extremely low impurity content.

Appearance: Grey or dark grey powder, uniform color.

Ultra-high purity: impurities are controlled at ppm level, ensuring excellent electrical and mechanical properties.

Fine particles: The particle size can reach 0.1-5 μm, which can meet high-precision applications.

Low oxygen content: oxygen content ≤ 0.02%, improving sintering performance and material stability.

3. High Purity Tungsten Powder Specifications

Index	CTIA GROUP LTD High Purity Tungsten Powder Standard (4N)
Tungsten content (wt%)	≥99.99
Impurities (wt%, max)	Fe≤0.0010, Mo≤0.0010, Si≤0.0005, Al≤0.0005, Ca≤0.0005, Mg≤0.0005, Na≤0.0010, K≤0.0010, O≤0.0200, C≤0.0050, N≤0.0020, P≤0.0005, S≤0.0005
Water content (wt%)	≤0.02
Particle size (μm, FSSS)	0.1-5.0 (superfine 0.1-1.0, fine 1.0-5.0)
Bulk density (g/ cm³)	4.5-6.5
Particle size	Provide ultra-fine (0.1-1.0 μm) and fine (1.0-5.0 μm) specifications, can be customized according to customer needs
Moisture	≤0.02%, ensuring product dryness and stability
Customization	Optional ultra-high purity grade (5N, ≥99.999%), with further reduction of impurities (e.g. O≤0.01%)

4. Packaging and Quality Assurance

Packaging: Inner sealed vacuum aluminum foil bag, outer iron barrel or plastic barrel, net weight 5kg, 10kg or 25kg, moisture-proof and oxidation-proof.

Warranty: With quality certificate, including tungsten content, impurity analysis (ICP-MS), particle size (FSSS method), bulk density and moisture data, shelf life is 12 months (sealed and dry conditions).

5. Procurement Information

Email: sales@chinatungsten.com Tel: +86 592 5129696

For more tungsten powder information, please visit China Tungsten Online website (www.tungsten-powder.com)

Appendix: F Tungsten Powder Related Glossary in Chinese, English, Japanese, Korean, German and Russian

This glossary comprehensively organizes the terms related to tungsten powder, covering all types of tungsten powder (such as ultrafine tungsten powder, fine tungsten powder, etc.), properties, preparation methods, application fields, safety management and derivatives, and provides six language versions: Chinese, English, Japanese, Korean, German and Russian. The terms are classified by subject to ensure practicality and internationalization.

F.1 Basic concepts and properties

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
Tungsten powder	Tungsten Powder	Tangusten powder	텅스텐 분말	Wolframpulver	Порошок вольфрама	Fine particles made of metallic tungsten, usually 0.5-50 microns in size, used in powder metallurgy and the electronics industry.
Ultrafine tungsten powder	Ultrafine Tungsten Powder	Ultrafine タングステン powder	초미세 텅스텐	Ultrafeines Wolframpulver	Ультратонкий порошок вольфрама	Tungsten powder with a particle size of 0.1-1 micron has a high specific surface area and is suitable for

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
			분말			high-precision applications.
Fine tungsten powder	Fine Tungsten Powder	Fine タングステン powder	미세 텅스텐 분말	Feines Wolframpulver	Мелкий порошок вольфрама	Tungsten powder with a particle size of 1-10 microns is commonly used in powder metallurgy and counterweight materials.
Nano tungsten powder	Nano Tungsten Powder	Nona タングステン powder	나노 텅스텐 분말	Nanowolframpulver	Нано-порошок вольфрама	Tungsten powder with a particle size of less than 100 nanometers is highly active and suitable for nanotechnology and catalysts.
Coarse tungsten powder	Coarse Tungsten Powder	Coarse tangusten powder	조대 텅스텐 분말	Grobes Wolframpulver	Грубый порошок вольфрама	Tungsten powder with a particle size of 10-50 microns is used for welding and coarse particle products.
Spherical tungsten powder	Spherical Tungsten Powder	Spherical タングステン powder	구형 텅스텐 분말	Sphärisches Wolframpulver	Сферический порошок вольфрама	Spherical tungsten powder has good fluidity and is commonly used in 3D printing and spraying.
Amorphous tungsten powder	Amorphous Tungsten Powder	Amorphous タングステン powder	2 텅스텐 분말	Amorphes Wolframpulver	Аморфный порошок вольфрама	Tungsten powder without a clear crystal structure is used for special coatings and composite materials.
purity	Purity	Purity	순도	Reinheit	Chestota	The percentage of tungsten content in tungsten powder, usually ≥99.9%.

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Chinese	English	Japanese	Korean	German	Russian	Definition/Description
density	Density	density	밀도	Dichte	Плотность	The theoretical value of the mass to volume ratio of tungsten powder is 19.25 g/ cm³ .
Melting point	Melting Point	Melting point	용융점	Schmelzpunkt	Температура плавления	The temperature at which tungsten powder becomes liquid at standard atmospheric pressure is 3422°C.
Boiling Point	Boiling Point	Boiling Point	2	Siedepunkt	Температура кипения	The temperature at which tungsten powder sublimates into gas is 5555°C.
Specific surface area	Specific Surface Area	Specific surface area	2	Spend the day	Удельная поверхность	The surface area per unit mass of tungsten powder is usually 50-150 m² / g (nanometer level).
Apparent density	Apparent Density	See the density	겉보기 밀도	Scheindichte	Кажущаяся плотность	The density of tungsten powder in natural stacking state is 2.5-6.0 g/ cm³ .
Fisher particle size	Fisher Particle Size	Fizzy particle size	피셔 2 크기	Fisher - Körnung	Размер частиц по Фишеру	The average particle size of tungsten powder measured by Fisher method is usually 0.5-50 μm.
Liquidity	Flowability	Liquidity	2	Fly high	Текучесть	The ability of tungsten powder to flow through a funnel under standard conditions, expressed in seconds per 50 grams.
Crystal structure	Crystal Structure	Crystal structure	결정	Kristallstruktur	Кристаллическая структура	The crystal morphology of

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
			구조			tungsten powder is usually body-centered cubic (BCC).
hardness	Hardness	hardness	경도	Harte	Thvёrдость	The deformation resistance of tungsten powder or its products, such as HV 300-500.

F.2 Preparation method

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
Hydrogen reduction method	Hydrogen Reduction	Hydrogen reduction method	2 환원법	Wasserstoffreduktion	Восстановление водородом	Tungsten powder is prepared by reducing tungsten oxide with hydrogen, usually at a temperature of 800-1200°C.
Vapor deposition method	Vapor Deposition	Gas phase evaporation method	기상 2	Gas phase operation	Парофазное осаждение	Nano-tungsten powders are produced by deposition of gaseous tungsten compounds and are often used in high-precision applications.
Plasma method	Plasma Method	Plasma method	플라즈마법	Plasmameterfahren	Плазменный метод	Ultrafine tungsten powder is prepared by high-temperature plasma decomposition of tungsten precursors, which has high yield but high energy

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
						consumption.
Hydrothermal method	Hydrothermal Method	Hydrothermal method	2 합성법	Hydrothermal technology	Гидротермальный метод	Tungsten powder is prepared in a high temperature and high pressure aqueous solution, which is environmentally friendly and suitable for nanoscale.
Carbothermal reduction	Carbothermal Reduction	Carbon reduction method	탄소 열 환원법	Carbothermia Redemption	Карботермическое восстановление	Tungsten carbide powder is prepared by reducing tungsten oxide with carbon at high temperature.
Electrochemical reduction	Electrochemical Reduction	Electrochemical reduction	2. 환원법	Electrical Engineering Red	Электрохимическое восстановление	Tungsten powder is prepared by electrolyzing tungstate solution, which is suitable for nanoscale and purity control.
Laser-induced decomposition	Laser-Induced Decomposition	Leather induced decomposition method	2 유도 분해법	Laser industry Zerg	Лазерно-индуцированное разложение	The laser is used to decompose the tungsten precursor to prepare ultrafine or nano tungsten powder with low energy consumption.
Spray pyrolysis	Spray Pyrolysis	Spray thermal decomposition	분무 2	Sprühpyrolyse	Распыление с пиролизом	The tungsten solution is sprayed and then decomposed at

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Chinese	English	Japanese	Korean	German	Russian	Definition/Description
		method				high temperature to produce porous tungsten powder, which is suitable for biological applications.

F.3 Application areas

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
Powder Metallurgy	Powder Metallurgy	Powder Metallurgy	분말 2	Pulvermetallurgie	Порошковая металлургия	Tungsten products, such as tungsten bars and tungsten plates, are made by pressing and sintering tungsten powder.
Cemented Carbide	Hard Alloy	Super Hard Alloy	경질 합금	Hartmetall	Theуёрдый s р лав	Wear-resistant material with tungsten carbide powder as the main component, used for cutting tools and drill bits.
Weight material	Counterweight Material	カウンターウェイト material	2	Gegengewichtsmaterial	Противовесный материал	The high density of tungsten powder is used to make weights, such as fishing sinkers and golf clubs.
Photoelectrocatalysis	Photoelectrocatalysis	Photocatalyst	2 촉매	Photoelectricity	Фотоэлектрокатализ	Use tungsten oxide powder

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
						(such as WO_3) to decompose water or degrade pollutants, with a band gap of 2.6-2.8 eV.
Quantum Technology	Quantum Technology	Quantum Technology	2 기술	Quantum technology	Квантовая технология	The superconductivity of nano-tungsten powder (Tc reaches 10 K after doping) is used to prepare quantum bits.
Flexible Electronics	Flexible Electronics	フレキシブルエレクトロニクス	플렉시블 2	Flexible Electronics	Гибкая электроника	Tungsten powder and polymer composite are used to prepare flexible electrodes with an electrical conductivity of 10^5 S/m.
Space Exploration	Space Exploration	Space Exploration	2 탐사	Welfare	Исследование космоса	Tungsten powder is used to prepare radiation shielding materials with a blocking rate of 95%.
Additive Manufacturing	Additive Manufacturing	ADITEB MANUFACTURING	적층 2	Additives Fertigation	Аддитивное производство	Use tungsten powder for 3D printing to prepare parts

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
						with complex shapes.
Wear-resistant coating	Wear-Resistant Coating	Wear-resistant coating	내마모 코팅	Verschleiß feste Beschichtung	Износостойкое покрытие	The wear-resistant layer is formed by spraying tungsten carbide powder with a hardness of HV 1600-2000.
Biotechnology	Biotechnology	BioTech Nolog	korean	Biotechnology	Betfair	Nano tungsten oxide powder is used for antibacterial coating or drug delivery, with an antibacterial rate of 99%.

F.4 Security and Management

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
Flammable solid	Flammable Solid	Combustible solid	korean 고체	Brennbarer Feststoff	Горючий твёрдый материал	Fine tungsten powder (<10 μm) may spontaneously combust in the air and is classified as a GHS Class 4.1 dangerous good.
Dust explosion	Dust Explosion	Dust explosion	2 폭발	Staubexplosion	See more	Tungsten dust clouds may explode when encountering fire in a confined space and require anti-static treatment.
Respiratory	Respiratory	Respiratory	호흡	Atemschutz	Респираторная защита	Use a dust mask (such as N95) to

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
protection	Protection	protection	보호			prevent inhalation of tungsten dust.
Exposure Limits	Exposure Limit	Exposure Limit	2 Korean	Exhibitionsgrenzwert	Предел воздействия	The workplace tungsten dust concentration limit, such as OSHA PEL, is 5 mg/ m^3 .
Recycling	Recycling	Live	2	Recycling	Peerera Botka	The recovery rate of tungsten powder from tungsten waste can reach 90%-95%.
Safety Data Sheets	Safety Data Sheet (SDS)	Safety data sheet	2 데이터 시트	Datenblatt	Паспорт безопасности	Provide guidance on the safe use of tungsten powder, such as this MSDS.
Anti-static	Antistatic	Static Electricity Prevention	정전기 2	Antistatisch	Антистатический	Prevent static electricity accumulation to avoid spontaneous combustion or explosion of tungsten powder.
Leakage treatment	Spill Handling	Leakage treatment	2 2	Leckage handling	Обработка утечек	Emergency measures for handling tungsten powder leakage, such as covering with dry sand and sealing and collecting.

F.5 Chemical components and derivatives

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
Tungsten Oxide	Tungsten Oxide	Acidification Tangusten	산화	Wolframoxid	Open book	WO_3 , yellow powder, band gap

Chinese	English	Japanese	Korean	German	Russian	Definition/Description
			텅스텐			2.6-2.8 eV, used for optoelectronics and sensing.
Tungsten Dioxide	Tungsten Dioxide	Diacid Tangusten	2 텅스텐	Wolframdioxid	Диоксид вольфрама	WO_2, intermediate product for preparing tungsten powder, brown powder.
Tungsten Carbide	Tungsten Carbide	Carbonization Tangusten	탄화 텅스텐	Wolframcarbid	Карбид вольфрама	WC, hardness HV 1600-2000, used for cemented carbide.
Tungsten Carbide	Ditungsten Carbide	Carbon dioxide gas	이탄화 텅스텐	Diwolframcarbid	Дікарбид вольфрама	W_2C, slightly lower in hardness than WC, is used for wear-resistant coatings.
Tungsten Hexafluoride	Tungsten Hexafluoride	六フッ化タングステン	2 텅스텐	Wolframhexafluorid	Гексафторид вольфрама	WF_6, a gaseous compound, is used to deposit tungsten films.
Tungstic acid	Tungstic Acid	Tangustenic acid	텅스텐 산	Wolframsäure	Вольфрамовая кислота	H_2WO_4, an intermediate product in the preparation process of tungsten powder.
Ammonium tungstate	Ammonium Tungstate	タングステンアンモニウム	텅스텐 산 암모늄	Ammonium wolframat	Тунгстат аммония	$(NH_4)_2WO_4$, a commonly used precursor for preparing tungsten powder .
Sodium Tungstate	Sodium Tungstate	タングステンンナトリウム	텅스텐 산 나트륨	Natrium wolframat	Tungustatu Natritiya	Na_2WO_4, raw material for preparing tungsten powder by hydrothermal method.

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Chinese	English	Japanese	Korean	German	Russian	Definition/Description
Tungsten Alloy	Tungsten Alloy	Tangusten alloy	텅스텐 합금	Wolframlegierung	Sprāv volufhrama	Such as W-Ni-Fe, density 17-18.5 g/cm³, used for counterweight and shielding.
Doped Tungsten Powder	Doped Tungsten Powder	ドープタングステン powder	도핑 텅스텐 분말	Dotierter Wolframpulver	Допированный порошок вольфрама	Tungsten powder with added elements such as molybdenum and cobalt to improve performance, such as enhanced superconductivity.

CTIA GROUP LTD
Tungsten Powder Introduction

1. Tungsten Powder Overview

CTIA GROUP LTD's traditional tungsten powder complies with the GB/T 3458-2006 "Tungsten Powder" standard and is prepared using a hydrogen reduction process. It has high purity and uniform particle size and is a high-quality raw material for tungsten products and cemented carbide.

2. Tungsten Powder Characteristics

Ultra-high purity: tungsten content ≥99.9%, oxygen content ≤0.20 wt% (fine particles ≤0.10 wt%), and extremely low impurities.
Accurate particle size: Fisher particle size 0.4-20 μm, 6 levels to choose from, with a deviation of only ±10%.
Excellent performance: bulk density 6.0-10.0 g/cm³ , uniform grains, excellent sinterability.
Stable quality: strict testing, no inclusions, ensuring product consistency.

3. Tungsten Powder Specifications

Brand	Fisher particle size (μm)
FW-1	0.4-1.0
FW-2	1.0-2.0
FW-3	2.0-4.0
FW-4	4.0-6.0
FW-5	6.0-10.0
FW-6	10.0-20.0
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Packaging and Quality Assurance

Packaging: Inner sealed plastic bag, outer iron drum, net weight 25kg or 50kg, moisture-proof and shock-proof.
Warranty: Each batch comes with a quality certificate, including chemical composition and particle size data, and the shelf life is 12 months.

5. Procurement Information

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For more information about tungsten powder, please visit the website of CTIA GROUP LTD (www.ctia.com.cn)

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Spherical Tungsten Powder Product Introduction

1. Overview of Spherical Tungsten Powder

CTIA GROUP LTD's spherical tungsten powder complies with the GB/T 41338-2022 "Spherical Tungsten Powder for 3D Printing" standard. It is prepared using a plasma spheroidization process and is specially designed for additive manufacturing (such as SLM, EBM). It meets high-end application requirements with high purity, high sphericity and excellent fluidity.

2. Excellent Properties of Spherical Tungsten Powder

Ultra-high purity: tungsten content ≥99.95%, oxygen content ≤0.05 wt%, and extremely low impurities.
High sphericity: ≥90%, uniform particles, excellent powder spreading performance.
Precise particle size: D50 range 5-63 μm, stable distribution, deviation ±10%.
Excellent fluidity: ≤25 s/50g, bulk density ≥9.0 g/cm³ , ensuring printing efficiency.

3. Specifications of Spherical Tungsten Powder

Brand	D50 particle size (μm)
SWP-15	5-15
SWP-25	15-25
SWP-45	25-45
SWP-63	45-63
In addition to basic specifications, parameters such as particle size and purity can be customized according to customer needs.	

4. Spherical Tungsten Powder Packaging and Quality Assurance

Packaging: Inner vacuum aluminum foil bag, outer iron drum, net weight 5kg or 10kg, moisture-proof and shock-proof.
Warranty: Each batch comes with a quality certificate, including chemical composition, particle size distribution and sphericity data, and the shelf life is 12 months.

5. Contact Information of CTIA GROUP LTD

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CTIA GROUP LTD

Introduction of High Purity Tungsten Powder

1. High Purity Tungsten Powder Overview

CTIA GROUP LTD's high-purity tungsten powder is produced using a high-purity tungsten oxide hydrogen reduction process. High-purity tungsten powder is widely used in the electronics industry (such as sputtering targets, tungsten wires), aerospace, semiconductors and high-precision manufacturing due to its ultra-high purity, fine particle size and excellent physical properties. CTIA GROUP LTD is committed to providing high-quality tungsten powder products to meet cutting-edge technology needs.

2. High Purity Tungsten Powder Features

Chemical composition: Tungsten (W), high purity metal powder.

Purity: ≥99.99% (4N), with extremely low impurity content.

Appearance: Grey or dark grey powder, uniform color.

Ultra-high purity: impurities are controlled at ppm level, ensuring excellent electrical and mechanical properties.

Fine particles: The particle size can reach 0.1-5 μm, which can meet high-precision applications.

Low oxygen content: oxygen content ≤ 0.02%, improving sintering performance and material stability.

3. High Purity Tungsten Powder Specifications

Index	CTIA GROUP LTD High Purity Tungsten Powder Standard (4N)
Tungsten content (wt%)	≥99.99
Impurities (wt%, max)	Fe≤0.0010, Mo≤0.0010, Si≤0.0005, Al≤0.0005, Ca≤0.0005, Mg≤0.0005, Na≤0.0010, K≤0.0010, O≤0.0200, C≤0.0050, N≤0.0020, P≤0.0005, S≤0.0005
Water content (wt%)	≤0.02
Particle size (μm, FSSS)	0.1-5.0 (superfine 0.1-1.0, fine 1.0-5.0)
Bulk density (g/ cm³)	4.5-6.5
Particle size	Provide ultra-fine (0.1-1.0 μm) and fine (1.0-5.0 μm) specifications, can be customized according to customer needs
Moisture	≤0.02%, ensuring product dryness and stability
Customization	Optional ultra-high purity grade (5N, ≥99.999%), with further reduction of impurities (e.g. O≤0.01%)

4. Packaging and Quality Assurance

Packaging: Inner sealed vacuum aluminum foil bag, outer iron barrel or plastic barrel, net weight 5kg, 10kg or 25kg, moisture-proof and oxidation-proof.

Warranty: With quality certificate, including tungsten content, impurity analysis (ICP-MS), particle size (FSSS method), bulk density and moisture data, shelf life is 12 months (sealed and dry conditions).

5. Procurement Information

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For more tungsten powder information, please visit China Tungsten Online website (www.tungsten-powder.com)