Encyclopedia of Spherical 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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Preface

Writing background and significance

As an advanced metal material with high melting point, high density, high thermal conductivity and good fluidity, spherical tungsten powder has shown more and more extensive application potential in high-end technology fields such as additive manufacturing (3D printing), powder metallurgy, aerospace, microelectronics, energy materials, etc. in recent years. Compared with traditional irregular tungsten powder, spherical tungsten powder has higher forming uniformity, better stacking density and better process adaptability, and has become one of the important raw materials for manufacturing high-performance complex components and realizing intelligent manufacturing.

At present, with the development of high-end manufacturing technology and the strict requirements of downstream application fields on powder quality, the basic research, industrial preparation technology, standard testing methods, application expansion and green sustainable development of spherical tungsten powder at home and abroad are increasingly concerned. However, the systematic data on spherical tungsten powder is still relatively scattered, lacking a comprehensive, in-depth and authoritative professional reference book. Therefore, the compilation of the "Encyclopedia of Spherical Tungsten Powder" aims to fill this gap, build a knowledge system and technical platform in the field of spherical tungsten powder , and serve scientific research, engineering and industrial practice.

Strategic Value of Spherical Tungsten Powder

Tungsten is one of my country's important strategic resources and is widely used in the manufacture of high-temperature structural parts, armor-piercing warheads, nuclear shielding materials, electronic electrodes and other key fields. In the context of increasingly fierce global competition for high-performance powder materials, spherical tungsten powder, as a high-value-added, high-tech barrier frontier material, has become an important indicator of a country's advanced manufacturing capabilities.

Spherical tungsten powder can not only significantly improve the material utilization rate and forming quality of additive manufacturing , but also meet the urgent needs of the new generation of microelectronic packaging, energy conversion devices and complex structural parts for high-precision and high-density materials. In the future, spherical tungsten powder will play a more important role in key "neck" technology fields such as military industry, aviation, energy, medical care, and nuclear industry. Therefore, promoting the development of systematic technologies such as the preparation, testing, and application of spherical tungsten powder is of great strategic significance for improving the country's material security capabilities and the core competitiveness of the manufacturing industry.

How this book is structured

This book is divided into ten chapters and an appendix, and the contents are arranged as follows:

- Chapter 1 to Chapter 2: Introduce the definition, development history, and raw material basis of spherical tungsten powder;
- Chapter 3 to Chapter 4: Detailed discussion of the preparation process, process principle, and microscopic control of spherical tungsten powder;
- Chapter 5 to Chapter 6: Focus on its physical and chemical properties, detection methods and application expansion;
- Chapter 7 to Chapter 8: Analysis of the research progress, safety and environmental protection issues of spherical tungsten powder in additive manufacturing ;
- Chapter 9 to Chapter 10: Explore the current status, future trends, and research frontiers of the industry;
- Appendix: Organizes reference materials such as common terms, standards, equipment catalogs and typical parameters.

This book has a clear structure and detailed information. It not only covers basic theory, but also focuses on process operation and engineering practice, and is both academic and practical.

Target audience and usage

This book is intended for the following readers:

- Researchers in materials science, metallurgical engineering, powder technology and other related fields;
- Engineers and technical developers in industries such as additive manufacturing , military equipment, and energy electronics;
- Teachers and postgraduate students of relevant majors in colleges and universities;
- Corporate managers and policy makers engaged in research on deep processing of tungsten resources and new materials applications .

Readers can read as needed, read through systematically to build a complete understanding, or conduct special study or technical review on a certain chapter. Each chapter has a section title for quick retrieval and horizontal comparison. The appendix can also be used as a reference for product development, equipment selection, performance evaluation, etc.

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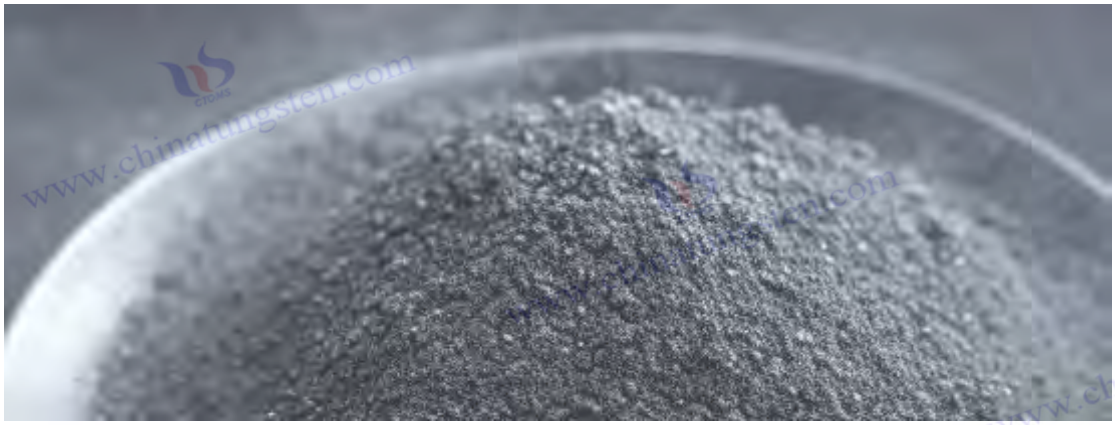


Chapter 1 Overview of Spherical Tungsten Powder

1.1 Definition and classification of spherical tungsten powder

Spherical Tungsten Powder refers to a micron or submicron tungsten powder prepared by a specific physical or chemical process, with a highly spherical particle surface, uniform particle size, good fluidity and density. It is different from traditional flaky, needle-shaped or irregularly shaped tungsten powders, and its main features are high sphericity (≥0.90), moderate specific surface area, and controllable particle size.

According to the different particle size range, application direction and preparation process, spherical tungsten powder can be classified as follows:

- **Classification by particle size:**
  - Nano-spherical tungsten powder (＜100 nm)
  - Ultrafine spherical tungsten powder (100 nm～1 μm)
  - Micron-sized spherical tungsten powder (1 μm ~ 100 μm)
- **Classification by preparation method:**
  - Plasma Spheroidized Tungsten Powder
  - Gas Atomized Spherical Tungsten Powder
  - Laser Fusion Spheroidized Tungsten Powder
- **by application field:**
  - Spherical tungsten powder for additive manufacturing
  - Spherical tungsten powder for military protection
  - Spherical tungsten powder for semiconductor packaging materials
  - Tungsten powder for medical radiation shielding, etc.

Spherical tungsten powder has become an irreplaceable key raw material in a variety of high-end manufacturing scenarios due to its excellent fluidity, uniform stacking density, and forming consistency in processes such as sintering, injection, and laser melting.

1.2 Development History of Spherical Tungsten Powder

The development of spherical tungsten powder began in the late 20th century, when European and American companies first conducted research on spherical tungsten powder in aircraft engines and military ammunition in order to improve powder filling efficiency and explosion accuracy. In the 21st century, with the rise of metal 3D printing (especially laser selective melting SLM technology), the demand for spherical powder has expanded rapidly, becoming one of the core materials of additive manufacturing system.

Around 2005, Germany, Japan and the United States successively realized industrialized plasma spheroidization preparation technology and mastered the key parameter control of high-purity tungsten powder spheroidization . Since the 12th Five-Year Plan, China has increased its investment in the independent and controllable direction of high-performance tungsten materials and gradually mastered the core equipment for spheroidization preparation and continuous powder making process.

At present, spherical tungsten powder has entered a stage of rapid development. Many domestic and foreign companies have deployed plasma, laser and aerosol spheroidization devices, and the industrial chain is gradually moving towards scale, intelligence and greenness.

1.3 The status of spherical tungsten powder in powder metallurgy

Powder Metallurgy (PM) is an advanced manufacturing technology that uses powder as raw material to prepare metal or ceramic products through pressing and sintering. It has extremely high requirements on powder morphology, particle size, fluidity, sintering activity, etc.

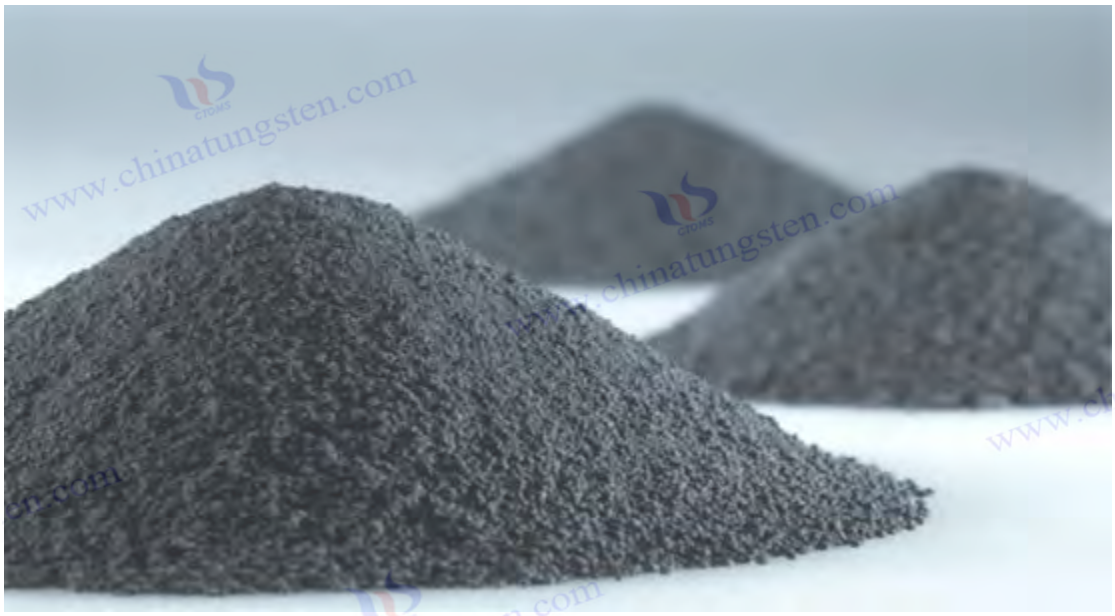
The core value of spherical tungsten powder in powder metallurgy is:

- **Excellent fluidity** : conducive to mold filling and high-precision forming of complex structures;
- **Dense stacking structure** : improve sintering density and material performance consistency;
- **Low oxygen content** : reduces volatilization loss during sintering and improves mechanical and conductive properties;
- **High purity and stability** : adapt to high temperature and high pressure complex service environment and extend product life.

In key powder metallurgy fields such as aerospace high-temperature components, W-Cu composite materials, tungsten alloy injection molding parts, and tungsten carbide substrates, spherical tungsten powder is gradually replacing traditional irregular tungsten powder and becoming a key technical material for improving product performance and yield.

Comparison between spherical tungsten powder and other types of tungsten powder

Comparison Dimensions	Spherical tungsten powder	Irregular tungsten powder	Needle-shaped tungsten powder
Morphology	Approximate sphere	Irregular pieces	Thin and long fibers
Liquidity	Excellent	Poor	Very bad
Specific surface area	Moderate	Higher	maximum
Bulk density	high	middle	Low
Formability	Excellent	generally	Difference
Applicable scenarios	3D printing, high-density injection, CVD, etc.	Pressed sintered, electric vacuum devices	Catalyst carrier, composite reinforcement material
unit price	Higher	Moderate	Depends on the process



Chapter 2 Raw Materials and Precursors of Spherical Tungsten Powder

2.1 Overview of tungsten concentrate and APT raw materials for spherical tungsten powder

The quality of spherical tungsten powder comes from its upstream raw materials, mainly including tungsten concentrate (W Concentrates) and its deep-processing product - ammonium paratungstate (APT) . Tungsten concentrate is an enriched mineral obtained from tungsten ore (mainly wolframite and scheelite) through flotation, gravity separation, roasting and other processes, and its grade is usually measured by WO_3 content.

APT is a key intermediate for the preparation of high-purity tungsten compounds and metallic tungsten in the industry. It has good water solubility and controllable pyrolysis behavior. In the production of spherical tungsten powder, APT is an important precursor for the preparation of tungsten oxide and reduced tungsten powder. Its purity and impurity content have a direct impact on the subsequent powder morphology and spheroidization quality .

APT for spherical tungsten powder usually requires WO_3 content ≥88%, total impurities (such as Fe, Na, Si, Ca) less than 300 ppm, and good particle size distribution. High-quality APT comes from industrial purification processes such as ion exchange, recrystallization and solvent extraction technology, which is the prerequisite for ensuring the quality consistency of spherical tungsten powder.

2.2 Tungsten oxide, tungstic acid and reduction precursors of spherical tungsten powder

APT can generate different forms of tungsten oxide (such as yellow tungsten WO_3 , blue tungsten $WO_{2.9}$, etc.) or tungstic acid (H_2WO_4) through thermal decomposition. These oxides are

important intermediate precursors in the preparation of spherical tungsten powder. Their specific morphology, particle size and crystallinity play a decisive role in the subsequent hydrogen reduction behavior and the particle structure of primary tungsten powder.

In industrial practice, a one-step or two-step reduction process is used to convert tungsten oxide into tungsten powder in a high temperature (600–900°C) hydrogen atmosphere. The particle size, bulk density and surface activity of this reduced powder determine the subsequent spheroidization behavior, such as sphericity, particle size stability, surface smoothness, etc.

The reduction precursor requires uniform particle size, oxygen content controlled within a reasonable range (≤0.3%), and no agglomeration of crystalline particles to avoid powder splashing, morphological distortion or oxygen inclusions during the spheroidization process.

2.3 Tungsten powder grade and standard used in spherical tungsten powder

Different application fields have different requirements for the performance of spherical tungsten powder, which in turn puts forward strict grade classification and technical standards for its basic tungsten powder . Common tungsten powder grades include:

grade	Average particle size	Oxygen content	Impurity control (ppm)	Application Areas
Ultra high purity	1–5 μm	≤0.15%	Fe, Si, Ca≤10	Aerospace, nuclear energy materials
Additive manufacturing grade	15–45 μm	≤0.2%	Fe, O, Na≤50	3D printing, laser melting
Powder Metallurgy Grade	5–20 μm	≤0.3%	Fe, Si, Al≤100	Press molding, injection molding
General industrial grade	＞20 μm	≤0.4%	Partial Oxide Allowed	Electrode, alloy intermediate

2.4 Spherical tungsten powder precursor particle size and distribution control

The particle size and particle size distribution (PSD) of the precursor powder have an important influence on the spheroidization effect. Excellent spherical powder usually comes from a precursor with the following particle size characteristics:

- Narrow particle size distribution (D90/D10 < 3.0)
- The median particle size (D50) is appropriate for the target application (e.g. 15–45 μm is recommended for SLM)
- No large particle agglomerates (to avoid nozzle clogging or incomplete spheroidization)

To this end, the precursor powder system usually needs to control and sort the particle size through processes such as airflow classification, screening and ultrasonic dispersion. Some high-end

products also use isostatic crushing, wet grinding deagglomeration and other means to improve the uniformity of particle size .

Good particle size control helps to achieve melt consistency during the spheroidization process, reduce the hollow rate and deformity rate of spherical powder, and improve the formability and sintering density of the final product.

2.5 Analysis of purity and impurities of raw materials for spherical tungsten powder

High-purity raw materials are an important basis for ensuring the high performance of spherical tungsten powder. Common impurities include metal elements (Fe, Ni, Cr), non-metal elements (O, C, Si, Cl) and gas impurities (H_2 , N_2 , etc.). These impurities not only affect the electrical conductivity, thermal conductivity and sintering behavior of the powder, but may also cause interface reactions, loose organization or defects.

Impurity analysis usually uses the following methods:

- ICP-MS/ICP-OES: Determination of metallic impurities (ppb–ppm level)
- LECO analyzer: determination of oxygen, carbon, nitrogen and sulfur content
- XRF or EDX: Rapid screening of batch purity and unusual components
- Loss on Ignition Test (LOI): Detect total volatile matter and thermal stability of powder

In the preparation and application of spherical tungsten powder, special attention should be paid to residual ions such as Cl^- and Na^+ in the raw materials to prevent them from volatilizing or decomposing in high-temperature processes such as CVD/SLM, affecting device performance or causing corrosion.
Strict raw material purity control and standardized testing procedures are one of the core technologies to ensure the stability of spheroidized powder batches and the reliability of terminal applications.

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Chapter 3 Preparation Technology of Spherical Tungsten Powder

3.1 Spheroidization principle and physical basis of spherical tungsten powder

The key to the preparation of spherical tungsten powder is to achieve surface tension-driven reconstruction of powder particles at high temperature, so that they spontaneously tend to the spherical structure with the lowest energy in the suspended state. This process usually involves five stages: heating-melting-spheroidization-cooling-solidification.

The physical basis of spheroidization mainly includes:

- **Principle of surface tension minimization** : At high temperatures, tungsten powder particles melt to form droplets. Due to the effect of surface tension, the droplets tend to form a spherical shape to minimize the surface area.
- **Gravity and inertia** : In a plasma or aerosol environment, molten droplets fly freely in the air and use inertia to complete the shaping process.
- **Rapid solidification mechanism** : In a gas cooling medium or vacuum environment, the droplets solidify rapidly, retaining a spherical appearance.
- **Viscosity and thermal conductivity control** : The rheological behavior in the molten state determines the final shape of the particle morphology.

Therefore, a successful spheroidization process requires a heating temperature higher than the melting point of tungsten (3410°C), and the environment should have high energy density, high stability and rapid cooling capabilities. Common equipment includes plasma torches , gas atomization nozzles, high-power laser sources, etc.

3.2 Spherical tungsten powder plasma spheroidization technology

Plasma spheroidization is currently the most widely used and mature process for preparing spherical tungsten powder. It is widely used in the spheroidization of high-melting-point metal powders such as tungsten, molybdenum , and niobium.

Principle and process flow:

1. **Raw material pretreatment** : drying, screening, and impurity removal;
2. **Plasma heating** : Use high temperature argon or argon-hydrogen mixed gas plasma (temperature can reach 10000 K) to heat tungsten powder;
3. **Melting spheroidization** : The powder melts instantly in the plasma flame and naturally spheroidizes in the high-speed airflow;
4. **Cooling and solidification** : The cooling zone quickly solidifies the droplets into spherical powder;
5. **Classification and collection** : Collect powder products by particle size.

advantage:

- Can process high melting point metals;
- High sphericity (>0.95) and smooth surface;
- It has strong controllability and is suitable for mass production.

limit:

- The equipment investment is high and the energy consumption is high;
- The oxygen content of the powder needs to be strictly controlled;
- The powder is prone to hollowing (the powder spraying speed and power need to be optimized).

This technology is suitable for occasions such as aviation and nuclear industry where extremely high requirements are placed on powder sphericity and purity.

3.3 Spherical tungsten powder gas atomization preparation technology

Gas atomization is a method of using high-speed gas (such as nitrogen, argon) to atomize molten metal liquid into fine droplets, which are then cooled and solidified to form spherical particles during flight.

Key points of the process:

- **Melting source** : Induction furnace or arc furnace to melt tungsten pre-alloy ;
- **Atomization system** : High-pressure gas passes through the nozzle to form a shear flow, cutting the metal liquid into droplets;
- **Spheroidization mechanism** : Liquid droplets naturally spheroidize due to surface tension;
- **Cooling control** : The cooling gas flow field adjusts the solidification rate to prevent adhesion or breakage;
- **Recovery system** : Spherical powder is recovered after gas-solid separation.

Features:

- Good sphericity, suitable for mass production;
- High process continuity and adjustable particle size distribution;
- Not suitable for pure tungsten, suitable for tungsten alloy or pre-compounded tungsten materials.

Since the melting point of tungsten is too high (3410°C), simple gas atomization is not suitable for pure tungsten powder, but for doped, alloyed tungsten powder or tungsten powder coated with low-melting components, effective spheroidization can be achieved.

3.4 Spherical tungsten powder vacuum droplet spheroidization method

Vacuum Melting-Drop Spheroidization is a physical spheroidization method in which small tungsten particles are heated and melted in a vacuum or protective atmosphere and then naturally drip into balls. It is suitable for the preparation of ultra-pure small batch spherical powders.

Process flow:

- The powdered raw materials are placed in a high temperature crucible and melted;
- The melt drips onto a cooling base or a rotating cooling disk;
- It forms balls naturally during the process of dripping and flying;
- After cooling, spherical powder was collected.

advantage:

- Clean environment, less impurities introduced;
- Suitable for preparing high-purity small-size ball powder;
- The equipment structure is relatively simple.

Limitations:

- High cost and low production capacity;
- Not suitable for large-scale continuous production;
- The sphericity is greatly affected by the dropping speed.

This method is often used in scientific research institutes to develop nano-scale spherical tungsten powder, composite coatings or medical tungsten ball materials.

3.5 Laser melting and spheroidization process of spherical tungsten powder

Laser Fusion Spheroidization is an emerging technology that uses a high-energy laser beam to quickly heat tungsten powder particles, causing them to melt locally or as a whole, and then achieves spheroidization through droplet cooling.

Process characteristics:

- Laser scanning is fast and energy-concentrated;
- Micro-area spheroidization or selective spheroidization can be achieved;

- Usually used in combination with air suspension and light capture platforms;
- High sphericity allows precise control of melting depth.

This process is particularly suitable for the fine reconstruction of spherical particles (10–50 μm), and is suitable for powder repair, re-spheroidization and preparation of high value-added functional powders.

shortcoming:

- The equipment is sophisticated and costly;
- Limited powder handling capacity;
- High requirements for powder absorbance.

At present, laser spheroidization is still in the experimental and semi-industrial application stage, and has great potential in the field of intelligent powder repair and multi-layer spheroidization in the future.

Other preparation technologies and comparative analysis of spherical tungsten powder

In addition to the above mainstream processes, there are also some auxiliary or composite preparation technologies:

Technical route	advantage	shortcoming	Application
Flame jet spheroidization	Simple process and low cost	Poor sphericity and high oxygen content	Low density filling material
Arc spheroidization	Energy concentration, good sphericity	Low powder yield and high hollow rate	Small batch alloy powder
Composite spheroidization (laser + air flow)	Strong controllability, suitable for high-end precision products	Complex process and difficult equipment debugging	Medical implants, nuclear reaction coated particles

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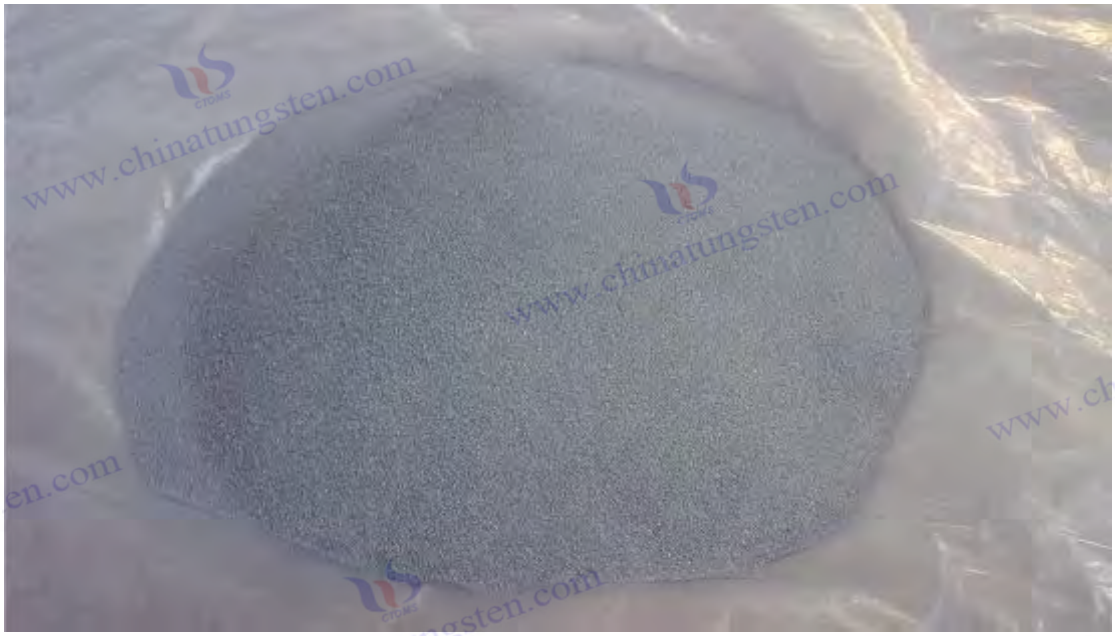

Chapter 4 Physical and Chemical Properties of Spherical Tungsten Powder

The performance of spherical tungsten powder is not only affected by its preparation process, but also directly reflected in its physical and chemical properties such as microstructure, particle size characteristics, impurity content, thermochemical stability, etc. This chapter will systematically explain the core physical and chemical characteristics of spherical tungsten powder and its significance in practical applications.

4.1 Microstructure and crystal morphology of spherical tungsten powder

Spherical tungsten powder is usually a highly spherical single crystal or polycrystalline particle, and has the following characteristics in microstructure:

- **Crystal structure** : Tungsten has a body-centered cubic (BCC) structure, space group Im-3m, and a lattice constant of approximately 0.3165 nm;
- **Particle morphology** : Spherical powder prepared by plasma or atomization process, round appearance, smooth surface, no obvious edges or burrs;
- **Grain size** : usually in the range of 0.5–5 μm , which can be adjusted by heat treatment;
- **Internal structure** : Hollow cores or hollow defects may appear during high-energy spheroidization, which need to be optimized through SEM observation and distribution control.

Scanning electron microscopy (SEM) and transmission electron microscopy (TEM) analysis can be used to intuitively evaluate the morphological consistency and crystal defects of spherical tungsten powder, which helps to determine its forming behavior and sintering response capability.

4.2 Particle size distribution and sphericity evaluation of spherical tungsten powder

Particle Size Distribution (PSD):

Particle size distribution directly affects the fluidity, compaction density and application adaptability of spherical powder. Common indicators include:

- **D10/D50/D90** : represent the 10%, 50%, and 90% particle sizes in the cumulative distribution, respectively;
- **Span** = (D90 – D10) / D50, used to measure the uniformity of distribution;
- Recommended range: D50 for 3D printing powder is usually 15–45 μm , and D50 for injection molding powder is 5–20 μm .

PSD testing is usually performed using a laser particle size analyzer, sieving method or imaging method.

Sphericity:

Sphericity determines the controllability and compactness of the powder during the forming process and is usually characterized by:

- **Geometric sphericity** : Equivalent circle area ratio was evaluated using image analysis;
- **Flow sphericity** : indirectly reflected by Hall velocity and angle of repose;
- **Quantitative standard** : Sphericity value ≥0.90 is considered qualified, and ≥0.95 is high-quality ball powder.

Sphericity detection methods include high-resolution SEM image analysis, automatic image recognition system and 3D laser profilometer.

4.3 Bulk density and tap density of spherical tungsten powder

Apparent Density:

Refers to the mass of spherical tungsten powder per unit volume in a naturally falling state. It reflects the compactness of powder accumulation and affects mold filling and dense sintering performance.

- Common test methods: ISO 3923/1 (metal powder standard funnel method);
- Typical range: 5.5–8.5 g/cm³, varies with particle size and morphology.

Tapped Density:

Refers to the maximum filling density achieved by the powder after compaction by mechanical vibration or tapping.

- Reflects the powder compressibility and the coordination efficiency between particles;
- The ratio of the bulk density to the powder density is called the Hausner ratio. A Hausner ratio of <1.25 indicates a powder with excellent fluidity.

By comparing the two density data, the upper limit of the density of the powder after sintering can be predicted, which is an important basis for designing the forming process.

4.4 Oxygen content and impurity control of spherical tungsten powder

Spherical tungsten powder is prone to introduce impurities during the process of spheroidization, high temperature treatment, grading, storage and transportation, especially elements such as oxygen, carbon, iron, and sodium, which need to be strictly controlled.

- **Oxygen content** : controlled at 0.15–0.3% (mass fraction). Exceeding the limit will lead to pores, brittle cracks, etc. after sintering;
- **Carbon and nitrogen impurities** : have a great impact on electrical and thermal conductivity and need to be controlled at ≤100 ppm;
- **Metal impurities (Fe, Si, Ca)** : The total amount is generally required to be ≤200 ppm, and high-purity products can be controlled below 50 ppm.

Common detection methods:

- Oxygen content: LECO infrared method;
- Metal impurities: ICP-MS, ICP-OES;
- Inorganic anions and cations: ion chromatography analysis.

The level of impurity control determines whether spherical tungsten powder is suitable for high-performance applications such as semiconductor packaging, nuclear shielding devices, etc.

4.5 Thermal stability and melting point behavior of spherical tungsten powder

Tungsten has an extremely high melting point (3410°C) and excellent thermal stability. Spherical tungsten powder inherits these thermodynamic advantages, showing the following:

- **High temperature non- oxidation** : can be used stably up to 2600°C in an inert atmosphere;
- **Small thermal expansion coefficient** : only 4.5×10^{-6} /K, which is conducive to the dimensional stability of high-temperature parts;
- **No significant crystal transformation** : Maintain BCC lattice structure and stable performance;
- **Strong thermal conductivity : The thermal conductivity is stable at 150-170 W/** m·K from room temperature to 1000°C .

The melting point behavior can be characterized by differential scanning calorimetry (DSC), thermogravimetric analyzer (TGA) and high-temperature microsintering experiments to reveal the sintering activity and thermal reaction trend of the powder.

4.6 Chemical stability and surface reactivity of spherical tungsten powder

Tungsten powder is stable to most gases and solutions at room temperature, but its surface activity is affected by particle size and preparation environment:

- **Chemical stability** :
  - Resistant to acid and alkali corrosion at normal temperature and pressure;
  - It is easy to react with strong oxidants (such as HNO_3 and chlorine);
  - WO_3 at high temperature .

- **Surface Reactivity** :
  - Small particle size ball powder (<10 μm) has high surface activity;
  - The thickness of the surface oxide layer affects the subsequent sintering and alloying processes;
  - can be reduced by H_2 gas reduction or vacuum annealing.

Surface functional groups and oxide structures can be analyzed through XPS (X-ray photoelectron spectroscopy), FTIR (infrared spectroscopy), etc., to assist in surface regulation or coating modification.

4.7 Specific surface area and pore structure of spherical tungsten powder

Specific surface area is an important indicator to measure the microstructure activity of spherical tungsten powder:

- **Conventional surface area range** : 0.1–1.5 m^2/g;
- **Test method** : BET nitrogen adsorption method;
- The smaller the particle size, the larger the specific surface area and the higher the reaction activity.

The pore structure is usually not significant, but if the spheroidization process is not properly controlled, it may appear:

- Hollow spherules (hollow structure);
- Microcracks in the fusion crust (surface gas escape);
- Incomplete sintering neck (microporous structure).

be quantitatively characterized by electron microscopy and mercury porosimetry .

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CTIA GROUP LTD

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2. Spherical Tungsten Powder Features

- Chemical Formula: W
- Molecular Weight: 183.84
- Appearance: Deep gray spherical powder
- Melting Point: 3422°C
- Density: 19.25 g/cm³
- Stability: Stable at room temperature, begins oxidizing >400°C, requires sealed storage
- Wide Applications: Used in 3D printing (density >98%), W-Cu alloys (conductivity >90% IACS), wear-resistant coatings

3. Spherical Tungsten Powder Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Sphericity	Packaging	Impurities (ppm)
Additive Manufacturing Grade	≥99.9	10–50	>0.95	100g / 500g / 1kg	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	10–50	>0.90	1kg / 5kg	Cl-main component, trace elements

4. Spherical Tungsten Powder Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and oxidation resistance.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Sphericity (SEM)
  - Flowability test (Hall flow rate >20 s/50g)

5. Procurement Information

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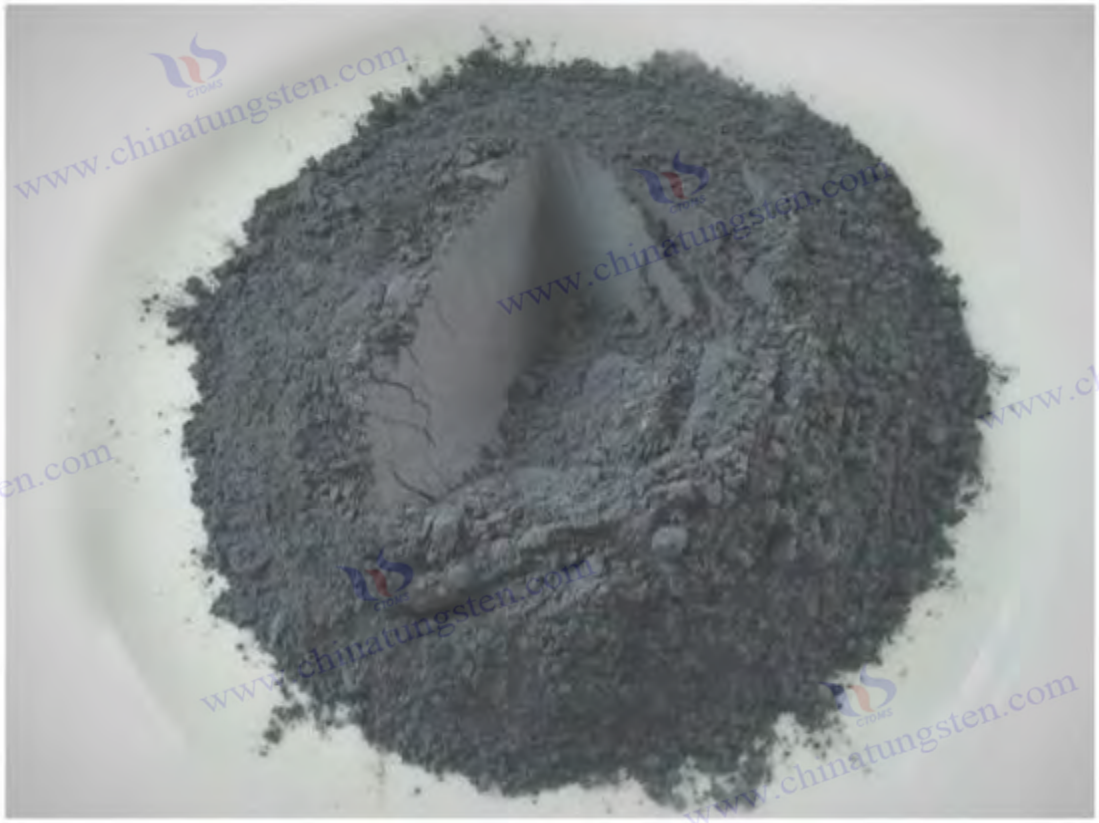

Chapter 5 Performance Testing and Quality Evaluation of Spherical Tungsten Powder

In order to ensure the reliability and consistency of spherical tungsten powder in applications such as additive manufacturing , powder metallurgy, and high-end electronics, its performance must be systematically tested and comprehensively evaluated. This chapter focuses on the testing technology and evaluation standards for spherical tungsten powder in terms of particle size, morphology, composition, thermal stability, fluidity, and quality control.

5.1 Particle size analysis method of spherical tungsten powder

Particle size distribution is a key parameter that determines the application performance of spherical tungsten powder, which directly affects its filling property, stacking density and printing layer thickness accuracy.

Common particle size analysis methods:

- **Laser Diffraction** :
  - Fast, automated, and suitable for 1–100 μm range;
  - Output statistical particle sizes such as D10, D50, D90, etc. to evaluate distribution uniformity.
- **Sieving Method** :
  - Mechanical classification of powders using standard metal sieves;

  - Commonly used for coarse powder (＞45 μm) and standard particle size distribution testing;
  - Can be combined with a sieve shaker to improve repeatability.
- **Image Analysis** :
  - Count particle sizes using high-resolution image processing techniques;
  - It can combine morphology information to obtain multi-dimensional data such as particle size distribution and sphericity.

In industrial production, particle size analysis is often used as a core item for factory quality inspection, and a corresponding relationship is established with specific applications (such as SLM printing layer thickness).

5.2 Sphericity Testing and Evaluation Technology of Spherical Tungsten Powder

Sphericity is a core indicator for measuring powder forming fluidity and powder spreading performance . High sphericity can significantly improve the filling consistency of laser printing and injection molding.

Detection method:

- **Image method (Optical/SEM-based Image Analysis)** :
  - Analyze powder cross sections or surface images;
  - Sphericity is defined as the ratio of the equivalent circle diameters ($S = 4\pi A/P^2$) or the axis ratio.
- **Automatic identification system** :
  - of particles using AI algorithms ;
  - Statistical sphericity distribution curve.
- **3D Profilometer** :
  - Suitable for high-precision sphericity verification;
  - The roundness and concavity of particles can be detected .

Evaluation criteria:

- **Sphericity ≥ 0.95** : high quality printing powder;
- **Sphericity ≥ 0.90** : Qualification standard for industrial applications;
- **Sphericity < 0.85** : screening or re-spheroidization is required .

5.3 Surface morphology observation of spherical tungsten powder (SEM, AFM)

The microstructure determines the sintering neck growth, laser absorption and alloy reaction behavior of spherical powder.

Mainstream observation technology:

- **Scanning Electron Microscopy (SEM)** :
  - Observe particle appearance, particle connection, hollow structure, etc.;
  - It can be used with EDS analysis to detect local components.
- **Atomic Force Microscopy (AFM)** :
  - Used for nano-scale particle or surface roughness measurement;

- Three-dimensional morphology reconstruction with an accuracy of 0.1 nm.

- **X-ray Tomography (XCT)** :
  - Non-destructive internal structure testing can be performed;
  - It is more suitable for detecting hollow balls and included pores.

Smooth surface, dense structure and no obvious defects are the important morphological characteristics of high-quality spherical tungsten powder.

5.4 Composition and impurity analysis of spherical tungsten powder (XRF, ICP-MS)

The element composition affects the purity, conductivity, corrosion resistance and other properties of tungsten powder. Too high impurity content will lead to unstable printing quality or forming defects.

Detection method:

- **X-ray fluorescence spectroscopy (XRF)** :
  - Non-destructive testing of major metal elements;
  - Fast and suitable for large-volume screening.
- **Inductively Coupled Plasma Mass Spectrometry (ICP-MS)** :
  - Detection of metallic and non-metallic trace impurities (ppb–ppm level);
  - For full element scanning of high purity powders.
- **Ion Chromatography (IC)** :
  - Detection of residual dissolved ions such as Na^+ and Cl^- ;
  - Often used to evaluate cleanliness after surface preparation.
- **LECO Analyzer** :
  - Dedicated to the quantitative analysis of four light elements: oxygen, nitrogen, carbon and sulfur.

All test data should correspond to product standards (such as GB/T 26044, ASTM B214) to ensure that the reliability requirements of the terminal use scenarios are met.

5.5 Thermal properties test of spherical tungsten powder (DSC, TGA)

The thermal properties of tungsten powder under high temperature service conditions are related to the temperature control scheme of the component forming process and the prediction of sintering behavior.

Thermal performance test method:

- **Differential Scanning Calorimetry (DSC)** :
  - Measure heat capacity and melting point changes;
  - Used to evaluate melting temperature and phase change characteristics.
- **Thermogravimetric analysis (TGA)** :
  - Monitor mass changes during heating;
  - Detect oxidation, desorption and volatilization behavior.
- **Simultaneous Thermal Analysis (STA)** :

- Acquire DSC+TGA data simultaneously;
- Particularly effective for multi-component or composite powders.

The thermal analysis results are of guiding significance for setting process parameters such as annealing temperature, sintering protective atmosphere, and cooling rate.

5.6 Fluidity and Density Test Standards for Spherical Tungsten Powder

The fluidity and density of powder determine whether it has good powder spreading, compaction and dense forming capabilities in processes such as 3D printing and injection molding.

Liquidity test:

- **Hall Flow Rate (** ISO 4490):
  - The time required for 50 g of powder to flow through a standard aperture (unit: s/50g);
  - It is generally believed that powder with a content of less than 20 s/50g is of high quality.
- **Angle of Repose** :
  - The maximum angle formed by the natural accumulation of powder;
  - The smaller the value, the easier it is to flow, and <35° is optimal.

Density test:

- **Apparent Density** :
  - The mass per unit volume of powder in the state of natural falling;
- **Tapped Density** :
  - powder after compaction ;
- **Hausner ratio = tap density / bulk density** :
  - Reflects compaction and should usually be controlled between 1.0–1.25.

These indicators help to determine the feeding stability and forming uniformity of spherical tungsten powder in the equipment.

5.7 Spherical Tungsten Powder Product Consistency and Quality Control Standards

Stable consistency is the key to ensure the quality and performance repeatability of spherical tungsten powder batch by batch.

Quality control elements:

- **Batch particle size consistency** : D50 deviation < ± 2 μm ;
- **Standard deviation of sphericity** : <0.03;
- **Oxygen content fluctuation range** : ±0.02%;
- **Flow rate difference control** : <5 s/50 g;
- **Key element impurity control chart** : such as Na, Fe, Cl, etc. ppm level trend analysis.

Implementation standards:

- Domestic standards: GB/T 26044 "Metallic Tungsten Powder", GB/T 21839, etc.

- International standards: ASTM B243, ISO 4499-2, ISO 3923, etc.
- Enterprise internal control standards (such as exclusive specifications for 99.95% high-purity spherical tungsten powder).

The use of digital tools such as SPC (statistical process control), MQC (manufacturing quality control) and MES systems to achieve quality traceability and real-time feedback has become an important management method for high-end powder companies.

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- Stability: Stable at room temperature, begins oxidizing >400°C, requires sealed storage
- Wide Applications: Used in 3D printing (density >98%), W-Cu alloys (conductivity >90% IACS), wear-resistant coatings

3. Spherical Tungsten Powder Product Specifications

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  - Sphericity (SEM)
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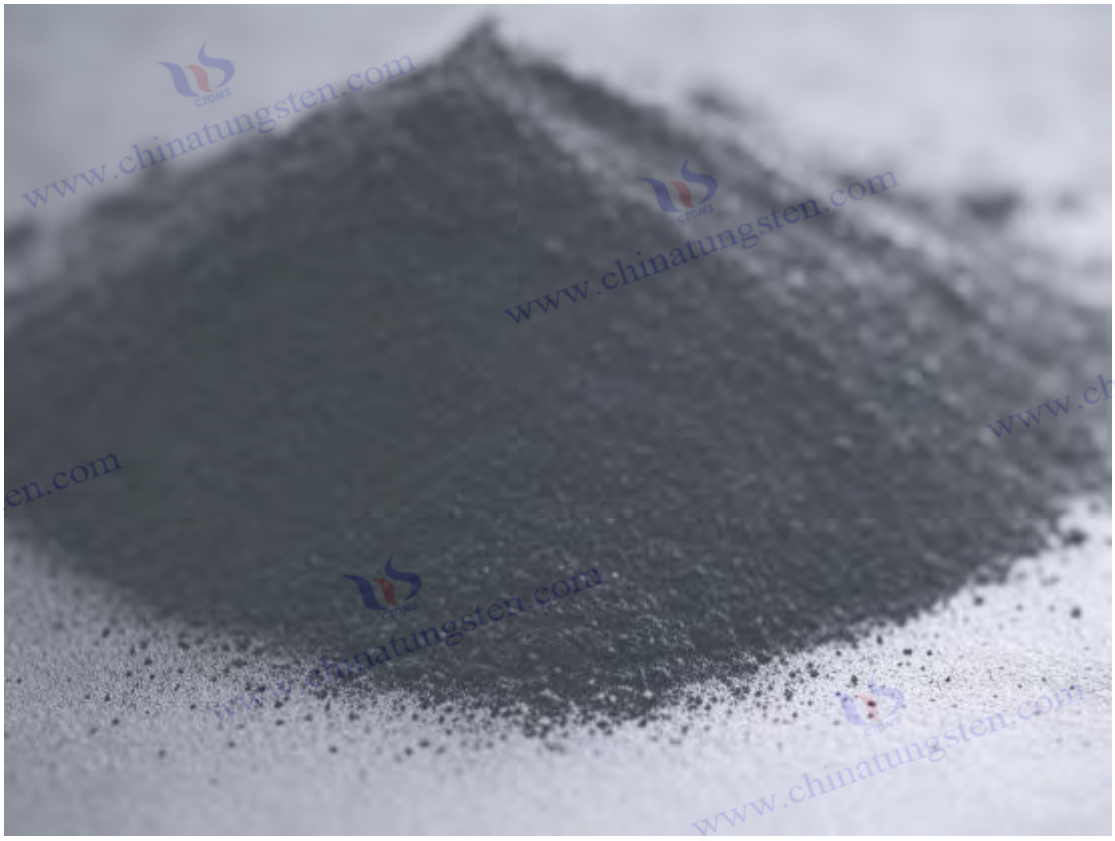

Chapter 6 Application Fields of Spherical Tungsten Powder

Spherical tungsten powder has become an irreplaceable key metal powder material in many high-end fields due to its excellent physical properties (high melting point, high density, good thermal conductivity) and geometric characteristics (high sphericity, excellent fluidity, and controllable particle size). This chapter will deeply analyze the specific applications, technical requirements and development trends of spherical tungsten powder in aerospace, 3D printing, military industry, nuclear energy, microelectronics, high temperature structures, electric vacuum devices and target materials .

6.1 Application of spherical tungsten powder in aerospace field

In aerospace engineering, materials must have high temperature stability, radiation resistance and structural strength. Tungsten's high melting point (3410°C) and high density (19.3 g/cm³) make it a preferred material for jet engine hot end components, spacecraft shielding panels and key components of propulsion systems.

Spherical tungsten powder can be used to manufacture the following parts:

- Turbine blade and hot end protective coating (formed by plasma spraying or CVD);
- Cooling component lining to improve heat exchange efficiency;
- High temperature alloy tungsten-based composite reinforcement;

- Space guidance system counterweights and inertial system structural parts.

Its good fluidity and high density help improve part forming accuracy and thermal fatigue life, and adapt to thermal cycles and mechanical shock loads during long-term flight.

Application of Spherical Tungsten Powder in 3D Printing (Metal Additive Manufacturing)

Metal additive manufacturing processes such as selective laser melting (SLM) and electron beam melting (EBM) . It is particularly suitable for the printing needs of complex structures, local reinforcement, and high-density parts.

Typical applications include:

- High temperature flow guide parts in the inner cavity of aircraft engines;
- Medical shielding devices (such as Gamma Knife accessories);
- Nuclear energy implant structures and small cooling units;
- High performance heat exchange module.

Technical requirements:

- Sphericity ≥ 0.95;
- The D50 particle size is controlled at 15–45 μm ;
- Fluidity <20 s/50g, angle of repose <35°;
- Oxygen content ≤ 0.2%.

After printing, the density of parts can reach more than 98%, and the thermal conductivity is greater than 150 W/ m·K , which shows the dominant position of spherical tungsten powder in high-end printing materials.

6.3 Application of Spherical Tungsten Powder in High-Performance Military Materials

In the defense industry, tungsten is widely used in the manufacture of armor-piercing warheads, armor-piercing cores, kinetic ammunition and bulletproof equipment due to its high kinetic energy density and strong penetrating power.

Spherical tungsten powder has the following military advantages:

- Easy to mold and high-speed injection molding;
- Maintaining the integrity of the morphology under impact loads and improving the terminal kinetic energy transfer efficiency;
- targeted destructive power through spheroidization ;
- It can be combined with polymer-based composite materials to form high-strength protective plates.

In addition, the high density and easy processability of spherical tungsten powder make it suitable for use in precision supporting structures such as fire control system counterweights and weapon system inertia adjustment components.

6.4 Application of Spherical Tungsten Powder in Nuclear Industry and Protective Materials

Tungsten has excellent resistance to neutron radiation and high-temperature corrosion, and is widely used in nuclear reactors, high-energy physics experimental equipment and radiation protection systems.

Key applications include:

- **Nuclear reactor coating** : Spherical tungsten powder can be used for tungsten-based CVD coating;
- **Fusion reactor head wall material** : construct high heat flux cooling structure in the form of W/Cu composite plate;
- **Gamma ray/neutron shielding block** : manufactured by injection molding spherical tungsten powder and polymer composite;
- **Nuclear waste shielding container** : high forming density requirements, sphericity ≥ 0.96.

In these applications, spherical tungsten powder can ensure shielding efficiency and thermal structural safety through high density and low porosity, and is the preferred metal powder for nuclear-grade protective materials.

6.5 Application of Spherical Tungsten Powder in Microelectronics and Semiconductor Packaging

With the miniaturization and high frequency of electronic components, tungsten-based materials are playing an increasingly important role in microelectronic packaging.

Spherical tungsten powder is mainly used in the following directions:

- **Heat sink material (W/Cu composite powder)** : effectively manage chip heat;
- **Solder paste/thermal pad powder filler** : improve thermal conductivity and mechanical strength;
- **Conductive filler** : used in thermosetting encapsulation resins and composite electrodes;
- **High-end package lead substrate** : prepared by CVD or powder injection molding.

The high density and good fluidity of spherical tungsten powder enable it to exhibit excellent process consistency and interface stability in automated dispensing and sintering reflow, and it is the core component of microelectronic-grade high thermal conductivity packaging materials.

6.6 Application of Spherical Tungsten Powder in High-Temperature Structural Materials

In extreme environments such as metallurgy, glass manufacturing, and silicon carbide sintering, tungsten is widely used to prepare high-temperature structural parts due to its high melting point and thermal strength .

Spherical tungsten powder can be used for:

- Thermal field device (tungsten screw, thermal sleeve);
- Vacuum sintering fixture;
- Large size isostatic pressing structural parts;
- W-Ni-Fe alloy high temperature loading parts.

Through spherical powder isostatic pressing + hot isostatic pressing sintering process (HIP), large structural parts with density > 99.5%, uniform grains and strong crack suppression ability can be produced, which are suitable for use under long-term high-load conditions.

6.7 Application of Spherical Tungsten Powder in Vacuum Devices and Electrode Materials

Tungsten is the core material for manufacturing electric vacuum devices (such as electron guns, ion sources) and electrode materials (such as ignition needles, welding rods). Spherical tungsten powder has the following advantages:

- Easy to press and form, suitable for micro cathode parts;
- Smooth surface improves discharge uniformity and energy stability;
- The spherical structure can reduce the void ratio, improve the outgassing rate and thermionic emission performance;
- It can be used as alloy matrix powder for W-Re, W-La and other alloy electrodes.

When used in a vacuum environment, the sintered body made of spherical tungsten powder exhibits lower electron work function, higher ablation resistance, and longer service life of electronic components.

6.8 Application of Spherical Tungsten Powder in Functional Composite Materials and Target Materials

Tungsten powder, as a heavy metal functional filler, is widely used in high-density, radiation-resistant and heat-resistant composite materials. It is also an important precursor for a variety of high-end thin film material targets.

Functional composite materials applications:

- W-polymer composite bulletproof material;
- High frequency absorbing materials;
- High-density damping structural parts;
- Medical radiation protection composite panels.

Target direction:

- Electron beam evaporation target;
- W target for magnetron sputtering;
- W-Si, WN, WC multi-component co-sputtering targets .

Spherical tungsten powder has significant advantages in target densification, surface uniformity and deposition rate control due to its high purity, spherical structure and controllable particle size. It is an irreplaceable key powder raw material in the field of multiple functional composites.

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5. Procurement Information

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Chapter 7 Research Progress of Spherical Tungsten Powder in Additive Manufacturing

With the rapid development of additive manufacturing (AM) technology, spherical tungsten powder, as a metal powder material with ultra-high melting point and high density, is increasingly used in the field of metal 3D printing. The research on the process adaptability, printing process behavior and formed structure performance of spherical tungsten powder has become a hot topic in materials science and manufacturing engineering. This chapter will systematically analyze its application status and cutting-edge progress in SLM, EBM, DED and other processes.

7.1 Spherical tungsten powder is suitable for additive manufacturing technology: SLM, EBM, DED, etc.

Different metal additive manufacturing processes have different requirements for powder properties. Spherical tungsten powder is mainly suitable for the following processes:

SLM (Selective Laser Melting)

- Selective melting of powder using a high-power laser beam;
- The powder particle size is required to be 15–45 μm and the sphericity is ＞0.95;
- The density of printed samples can reach over 98%, which is suitable for fine and complex parts.

EBM (Electron Beam Melting)

- Using electron beams to melt metal powder in a vacuum;
- Suitable for high temperature and high melting point metals such as tungsten;
- The powder is required to have strong anti-agglomeration ability and high absorption rate.

DED (Directed Energy Deposition)

- Continuously feed powder to the laser or plasma energy source for melt deposition;
- Suitable for tungsten parts repair or directional additive manufacturing of large components;
- The powder particle size is usually 45–150 μm , and higher fluidity requirements are required.

Spherical tungsten powder has been industrialized in SLM and DED processes, while EBM is still in the experimental research stage.

7.2 Physical behavior of spherical tungsten powder during laser printing

During the laser printing process, spherical tungsten powder exhibits a series of unique physical behaviors:

- **Laser absorption** : Tungsten has a low absorption rate for laser wavelength (1064 nm) and requires high-power laser support;
- **Powder melting behavior** : Due to the high melting point and high thermal conductivity, it is easy to form "unmelted powder" or "edge overflow powder";
- **Remelting phenomenon** : The lower layer is prone to remelting during multi-layer scanning, which affects the clarity of the forming boundary;
- **Capillary fluctuation and evaporation** : The local molten pool is prone to fluctuation and micro-jetting, resulting in surface defects;
- **Pore formation mechanism** : Oxygen- or hydrogen-containing powders release gas at high temperatures, which can easily lead to the formation of micropores.

Studies have shown that optimizing scanning strategies (such as bidirectional scanning and oblique filling) and powder particle size distribution can effectively alleviate the above problems.

7.3 Fluidity and stacking characteristics of spherical tungsten powder bed

Good powder spreading behavior is critical to printing quality. Spherical tungsten powder exhibits the following advantages during the powder spreading process :

- **Good fluidity** : Hall flow rate is usually <15 s/50g;
- **High stacking uniformity** : The best effect is achieved when the D50 particle size is controlled at around 30 μm ;
- **High consistency of layer thickness** : small repose angle, conducive to uniform powder spreading;
- **High powder recycling rate** : spherical powder has less performance degradation during recycling.

Common detection methods:

- Hall flow meter;
- Tap density test;
- bed inspection ;
- DEM (Discrete Element Method) simulates the powder spreading process.

By adjusting the powder particle size distribution and the vibration powder spreading auxiliary system , the printing stability and powder layer density can be further improved.

7.4 Analysis of the structure and performance of spherical tungsten powder printed samples

Spherical tungsten powder samples printed by SLM or DED usually have the following organizational characteristics:

- **Microstructure** : mainly fine grains + columnar grains, cooling rate is above 10^6 K/s;
- **Density** : 98–99% under reasonable parameters, micropore content <2%;
- **Grain orientation** : has an obvious preferential growth trend in the Z-axis direction;
- **Residual stress** : Residual stress is obvious under high temperature gradient and needs to be relieved by post-processing.

Mechanical properties:

Performance Indicators	SLM formed tungsten sample	Isostatically pressed sintered body (comparison)
Compressive strength	1800–2200 MPa	1000–1300 MPa
Vickers hardness	HV 450–600	HV 300–400
Thermal conductivity	130–150 W/ m·K	160–180 W/ m·K

Spherical Tungsten Powder Introduction
CTIA GROUP LTD

1. Spherical Tungsten Powder Overview

The spherical tungsten powder produced by CTIA GROUP is a high-purity deep gray spherical powder, manufactured using advanced Plasma Rotating Electrode Process (PREP) or Chemical Vapor Deposition (CVD) techniques. It features ultra-high sphericity (>0.95) and excellent flowability, serving as a critical raw material for additive manufacturing, metal spraying, and high-density alloys. With high purity and uniform particle size, it is widely used in 3D printing, aerospace, and electronic packaging industries.

2. Spherical Tungsten Powder Features

- Chemical Formula: W
- Molecular Weight: 183.84
- Appearance: Deep gray spherical powder
- Melting Point: 3422°C
- Density: 19.25 g/cm³
- Stability: Stable at room temperature, begins oxidizing >400°C, requires sealed storage
- Wide Applications: Used in 3D printing (density >98%), W-Cu alloys (conductivity >90% IACS), wear-resistant coatings

3. Spherical Tungsten Powder Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Sphericity	Packaging	Impurities (ppm)
Additive Manufacturing Grade	≥99.9	10–50	>0.95	100g / 500g / 1kg	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	10–50	>0.90	1kg / 5kg	Cl-main component, trace elements

4. Spherical Tungsten Powder Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and oxidation resistance.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Sphericity (SEM)
  - Flowability test (Hall flow rate >20 s/50g)

5. Procurement Information

Email: sales@chinatungsten.com

Phone: +86 592 5129595

Website: http://spherical-tungsten-powder.com/

Chapter 8 Safety and environmental protection of spherical tungsten powder

8.1 Storage and transportation specifications for spherical tungsten powder

As a high-density, high-purity metal powder material, spherical tungsten powder is widely used in high-tech fields such as additive manufacturing, aerospace, and military electronics. Although it is not a dangerous chemical such as flammable, explosive, or highly toxic, due to the particularity of its powder state, sensitivity to humidity and oxidation, and high value-added characteristics, strict regulations must be implemented during storage and transportation to ensure product quality and safety.

1. Storage requirements

Spherical tungsten powder should be stored for a long time in a place with the following conditions:

1. Environmental conditions

- **Dry and ventilated** : The relative humidity of the environment should be controlled at 40%-60% to prevent the powder from absorbing moisture and agglomerating;
- **Keep in a constant temperature and away from light** : The storage temperature is recommended to be controlled at 15-25°C, away from direct sunlight and high temperature exposure;
- **Anti-static and anti-oxidation** : It is recommended to use a constant temperature warehouse with anti-static floor and air filtration system.

2. Packaging specifications

Spherical tungsten powder should be packed in multiple layers of protection when leaving the factory:

- **Inner layer** : highly airtight PE or PTFE plastic bag, filled with inert gas (such as argon) for packaging;
- **Middle layer** : vacuum aluminum foil composite bag packaging, with excellent moisture and oxygen barrier properties ;
- **Outer layer** : thickened plastic barrels or metal round cans, equipped with foam cushioning materials to ensure shock and pressure resistance during transportation;
- **Labeling** : The outer packaging should have clear labels indicating the product model, batch, net weight, production date, storage conditions, precautions, etc.

For bulk storage, it is recommended to classify and zone the spherical tungsten powder, and number and record it according to particle size, purpose, and purity level to facilitate traceability management.

2. Transportation Requirements

Although spherical tungsten powder is not classified as dangerous goods during domestic and international transportation, it should still be transported in accordance with the special freight management requirements for precision metal materials to ensure safe and complete delivery.

1. Domestic transportation regulations

- **Transportation method** : It is recommended to use dedicated logistics, contract freight or a third-party logistics company with experience in powder freight;
- **Vehicle requirements** : The means of transport should have good sealing, waterproof and dustproof functions, and avoid bumps, collisions and exposure to the sun;
- **Protective measures** : Powder barrels should be placed in earthquake-resistant wooden boxes or corrugated paper boxes. Stacking and violent shaking are prohibited.
- **Supporting information** : The product certificate, factory inspection report, material safety data sheet (MSDS) and shipping list, etc. should be attached with the goods.

2. International Transportation Regulations

- **Customs classification** : Spherical tungsten powder is usually classified as non-dangerous metal powder (HS code: 81019990);
- **Transport Channel** :
    - Air transport: Applicable to small batches of high value-added products, and requires air transport declaration materials;
    - Sea freight: suitable for bulk export, and requires moisture-proof, pressure-proof, and salt spray-proof packaging;
- **Declaration and certification** :
    - When exporting, a certificate of origin, invoice, packing list, REACH registration or RoHS declaration (depending on the requirements of the export destination) should be attached;
    - If the destination country involves military or nuclear purposes, a description of the purpose and authorization review are required.

3. Transportation precautions

- **Keep away from fire sources and flammable materials** : avoid mixing spherical tungsten powder with oxidants, acids and other substances;
- **Anti-theft and anti-damage** : warning labels such as "precision metal powder", "please handle with care", "moisture-proof and anti-collision" should be pasted on the surface of the packaging box;
- **Emergency measures** : If the packaging is damaged or powder leaks, wear a dust mask and gloves, clean with a clean, oil-free dry cloth, and return to the original packaging to avoid inhalation.

3. Quality assurance mechanism for transportation and storage

China Tungsten Intelligence usually establish the following quality assurance mechanisms:

- **Powder packaging QR code traceability system** : realizes digital management of the entire process from packaging, delivery, transportation to customer receipt;
- **Anti-counterfeiting labels and temperature and humidity monitoring stickers** : ensure that the powder is not exposed to moisture or swapped during transportation;
- **Sampling inspection and periodic re-inspection mechanism** : periodic inspection of oxygen content, fluidity and other indicators of spherical tungsten powder stored for a long time;
- **Customer feedback recording system** : data analysis such as packaging integrity rate during transportation and reasons for customer returns forms a closed-loop improvement.

Spherical tungsten powder is widely used in high-end manufacturing and international supply chains, so it must comply with various environmental and chemical regulations during its global circulation . Especially when exporting to the European and American markets, compliance with relevant regulations not only affects customer purchasing decisions, but is also directly related to product market access, customs clearance efficiency and corporate reputation.

8.2 Environmental regulations and REACH certification related to spherical tungsten powder

Spherical tungsten powder is widely used in high-end manufacturing and international supply chains, so it must comply with various environmental and chemical regulations during its global circulation . Especially when exporting to the European and American markets, compliance with relevant regulations not only affects customer purchasing decisions, but is also directly related to product market access, customs clearance efficiency and corporate reputation.

This section will systematically explain the main environmental regulatory framework applicable to spherical tungsten powder, REACH registration requirements, RoHS restriction directives, etc.

1. Overview of Environmental Protection Regulations Applicable to Spherical Tungsten Powder

non-hazardous metal powder material with potential industrial exposure risks, spherical tungsten powder is mainly subject to the following environmental and chemical control regulations in international trade :

area	Applicable regulations	Scope of application and instructions
European Union	**REACH** (Registration, Evaluation, Authorization and Restriction of Chemicals)	Tungsten metal and its compounds must be registered or exempted from filing if the annual export volume is > 1 ton.
European Union	**RoHS** (Restriction of Hazardous Substances)	If spherical tungsten powder is used for electronic packaging or component materials, it must be confirmed that it does not contain restricted substances such as lead, mercury, and cadmium.
USA	**TSCA** (Toxic Substances Control Act)	Tungsten is an existing substance and needs to be included in the TSCA Inventory; new derivative compounds need to be registered with PMN.
China	Measures for the Environmental Management of New Chemical Substances (2021)	If tungsten powder is used for a new purpose (additive, functional additive), it may be necessary to submit a registration application.
Japan	Chemical Substance Review Law (CSCL) and Industrial Safety and Health Law (ISHA)	It is a substance in the existing chemical catalog, and its sale requires the attachment of MSDS and instructions for use.

2. REACH Registration Compliance Requirements for Spherical Tungsten Powder

REACH is currently the most stringent and most widely-influenced chemical registration system in the world. Tungsten (W, CAS No. 7440-33-7) is one of the substances already included in REACH, but its specific use and powder form still require attention to the following points:

1. Registration and Exemption Description

- If spherical tungsten powder is imported/produced as a "substance" and is greater than 1 ton per year, it should be registered by the Only Representative in Europe;
- If it is exported only as a “powder in a product” (e.g. printing material) and there is no intention to release the substance, then it is exempt;
- If tungsten powder is an insoluble metal and is not exposed to the normal environment, an exemption can be claimed in accordance with REACH Annex V.

2. Registration content includes:

- Chemical and physical properties, safety data sheet (SDS);
- Toxicology and ecotoxicity data;
- Exposure scenarios and risk assessment;
- Application scenario description and label content.

Up to now, there are many tungsten powder related registration cases in the EU ECHA database, including metallic tungsten, tungsten oxide, tungstate, etc.

3. CTIA GROUP and REACH Implementation Practice:

- A registration dossier has been established that complies with REACH Annex VII level;
- Entrust a third party to complete the toxicology assessment;
- Provide REACH Compliant Certificate and full text of English MSDS;
- We can assist European customers in reporting SDS and guide downstream safe use.

3. RoHS, SVHC and other green regulations

spherical tungsten powder itself does not contain the 10 restricted substances of RoHS (such as lead Pb, cadmium Cd, mercury Hg, hexavalent chromium Cr6+, etc.), its compliance still needs to be marked and explained if it is used in scenarios such as electronic circuits, packaging media, and heat sink materials .

- **RoHS compliance instructions** : should be included when leaving the factory and indicate that the powder does not contain restricted substances;
- **SVHC (Substances of Very High Concern) Assessment** : Spherical tungsten powder usually does not contain SVHC, but if used for functional coating (such as W-Si, W-Ni composite powder), it should be assessed whether the new additive triggers declaration;
- **Conflict Mineral Statement** : If applicable to American customers, spherical tungsten powder must provide a tungsten source traceability statement to prove that it does not come from the conflict mining area in Congo.

4. Spherical tungsten powder export document and label compliance management

compliance documents should be provided when spherical tungsten powder leaves the factory :

File name	illustrate
English MSDS	Comprehensive coverage of 16 items, compliant with CLP/GHS regulations, including emergency treatment recommendations and transportation information.
REACH registration number or exemption statement	If applicable to European customers, a valid registration number or technical exemption basis must be provided.
RoHS & SVHC Declaration	Provides a guarantee of no hazardous materials; especially important for electronic grade powders.
Label identification	The outer packaging should be labeled in both Chinese and English, including product number, manufacturer, batch number, storage method, contact warnings, etc.

Some customers may also require a Product Carbon Footprint (PCF) statement, which needs to be provided after evaluating the energy consumption of spherical tungsten powder preparation, transportation methods, and other data.

8.3 Waste Gas and Dust Recovery in the Production Process of Spherical Tungsten Powder

The preparation of spherical tungsten powder usually involves high-temperature melting, gas protection, powder atomization and high-speed airflow conveying. If not handled properly, it is easy

to produce pollutants such as metal dust, gas residue, and trace volatiles. In order to ensure production safety, protect the health of operators, and reduce the impact on the environment, a complete dust control and waste gas recovery system must be established.

This section will combine the current mainstream process flow to systematically analyze the sources of pollutants, recycling techniques and management requirements in the preparation process of spherical tungsten powder.

1. Pollutant Sources and Hazard Analysis

Source process section	Main pollutants	Possible harm
Plasma spheroidization	Argon, hydrogen, trace tungsten oxide dust	High temperature exhaust gas + fine particle powder inhalation hazard
Atomizing nozzle	High-speed particle dust, residual atomized gas	Risk of dust explosion
Screening and grading	Spherical tungsten powder fine powder dispersion	Causes respiratory irritation
Drying/Cooling	Trace hydrogen-containing waste gas, hot steam	May induce equipment corrosion and thermal pollution
Conveying device	Powder flying, dust accumulation	Increased cross contamination in clean areas

Among them, ultrafine tungsten powder (<10 μm) is very easy to float in the air. If exposed for a long time, it may cause lung irritation or even chronic deposition lesions to operators.

2. Dust control technology

1. Centralized dust removal system design

- **Bag filter** : using PTFE coated filter bag, the metal dust collection efficiency is > 99.5%;
- **Cyclone separator** : suitable for screening coarse powder in the initial stage of atomization;
- **Wet dust collector** : suitable for sections with combustible fine powder to prevent static electricity accumulation;
- **Pipeline self-cleaning design** : pulse back-flushing, timed slag removal and other methods are used to prevent powder deposition and blockage.

2. Local ventilation in key areas

- Negative pressure exhaust hoods are installed at the plasma gun outlet, screening vibration table, and packaging station;
- The wind speed is controlled at ≥0.5 m/s to ensure that dust is captured and does not flow back;
- The air outlet is purified by filter cartridge + high efficiency filter (HEPA) before being discharged or reused in compliance with the standards.

3. Waste gas recovery and treatment technology

In the preparation of spherical tungsten powder, commonly used protective gases (such as argon and hydrogen) and associated volatiles will be discharged with the high-temperature exhaust gas. If not recovered, it will cause resource waste and environmental risks.

1. Gas recovery system

- **Argon gas recycling system** :
  - The recovery rate can reach over 90%;
  - Adopt condensation dehumidification, compression purification, molecular sieve dehydration and then reuse;
- **Hydrogen capture and purification** :
  - Set up H_2 sensor to monitor concentration in real time for explosion-proof safety control;
  - The remaining hydrogen can be used in other reduction processes or neutralization treatment.

2. Purification of gaseous pollutants

- **High temperature oxidation tower + scrubber** combination:
  - Used to remove WO_3 vapor or metal oxide smoke;
  - After pH adjustment, a controllable tungstic acid solution is formed for recycling;
- **Plasma tail gas absorption tower** :
  - Applicable to complex process tail gas, such as the spheroidization process of Si, N, and Cl-derived powders;
  - An alkaline solution is passed through for capture and subsequent sedimentation.

4. Fine Powder Recovery and Reuse Strategy

μm) will be produced during the screening process of spherical tungsten powder . If it is directly discarded, it will cause a waste of resources. It is recommended to establish the following processing mechanism:

Processing	Application
Respheroidization	Enter the next batch of spheroidization cycle to improve the powder yield
Nano coating material preparation	Used for high thermal conductivity composite fillers or functional thin film targets
Alloy powder mixing	with Ni, Cu and other base powders for injection molding
Surface modified carrier	Grind into active carrier for application in catalytic material development

At the same time, fine powder and coarse powder should be strictly graded through a fully enclosed automatic screening system to avoid cross contamination and quality fluctuations.

V. Safety and Environmental Management Standards

To ensure the long-term effective operation of exhaust gas and dust control, enterprises need to establish the following management system:

- **Position responsibility system** : key positions are assigned dedicated personnel for operation and inspection;
- **Dust concentration monitoring** : configure online dust detectors (such as PM2.5, PM10);

- **Annual waste gas emission accounting** : total amount verification is carried out in accordance with the "Pollutant Emission Standards for Metal Smelting Industry";
- **Employee protection** : The operation area is equipped with FFP3-level masks and positive pressure air supply hoods, and a rotation operation system is established;
- **Third-party testing and certification** : Regularly entrust qualified institutions to conduct occupational health and environmental testing on exhaust ports and work workshops.

8.4 Current Status of Spherical Tungsten Powder Recycling Technology

As the world attaches great importance to resource conservation and sustainable development, tungsten, as a typical rare and strategic metal, has become an indispensable and important link in the tungsten industry chain. In particular, spherical tungsten powder has high preparation cost and high added value in application. The recycling of its scraps, residual powder, and undersize powder not only has significant economic benefits, but also complies with the industrial policy orientation of "green manufacturing" and "full life cycle management".

This section will systematically sort out the technical path and industrial status of spherical tungsten powder recycling from the aspects of recycling sources, regeneration processes, technical difficulties, industrial cases and development trends.

1. Main sources of recycling of spherical tungsten powder

The recycled materials of spherical tungsten powder mainly include the following categories:

Source	Regrowth type	Features
Production	Screened powder, fine powder, agglomerated powder	The particle size does not meet the specifications and needs to be re-spheroidized or crushed and screened
Application Process	Printing residual powder, trial batch powder	Performance degradation or batch instability, some powders are still usable
Product processing	Sintering waste, broken structural parts	Can be crushed, restored and re-milled
Customer recycling	Expired or returned inventory	The ingredients are basically stable and need to be cleaned and tested before classification

The recovery rate of spherical tungsten powder can generally reach 85%-95%, which is higher than other alloy metal powders and has high recovery value.

2. Regeneration process of spherical tungsten powder

The key to regenerating spherical tungsten powder is to **restore the particle size structure and surface properties** , while ensuring that the purity and oxygen content are controlled within the use standards. Common processing processes are as follows:

1. Physical re-screening and re-spheroidization

Applicable to coarse powder and agglomerated powder produced during screening:

- **step** :
  - Drying and dehumidification;
  - Screening powder with suitable particle size;
  - Delivery to plasma or laser spheroidization system;
  - Remove hollow noodles and particles with unqualified sphericity;
- **Features** :
  - The process is simple;
  - Low energy consumption;
  - Retains original metal component structure.

2. Wet chemical cleaning and secondary sintering reduction

Applicable to powders containing impurities (such as high oxygen content and strong hygroscopicity):

- **process** :
  - Pickling or alkali washing to remove surface impurities;
  - Reduction treatment in vacuum or hydrogen atmosphere (600–800°C);
  - The particle surface is then reconstructed by cold plasma;
- **Advantages** :
  - Can significantly reduce impurity content;
  - Improve the cleanliness and activity of powder surface;
- **challenge** :
  - Acid and alkali treatment must strictly control waste liquid discharge;
  - There is a need to balance reducing atmosphere and particle size control.

3. Metallurgical Circulation Powder Making Method

Suitable for bulk recycling of printing powder and waste components:

- **Core links** :
  - Spherical tungsten powder → tungsten oxide (WO_3) → hydrogen reduction → primary tungsten powder → re-spheroidization ;
- **The process chain is complete and traceable** ;
- **It can achieve 100% raw material reuse and is suitable for large-scale industrial customers to establish a closed-loop recycling system** .

3. Key control points in spherical tungsten powder recovery

In actual operation, the recovery of spherical tungsten powder requires special attention to the following technical factors:

Key Factors	Control Target	Detection Methods
Oxygen content	≤0.3%	LECO analysis
Impurity Level	Total amount of Fe, Ni, Si, Cl, etc. ≤200 ppm	ICP-MS
Sphericity	≥0.90 (printable grade)	Image analysis
Particle size range	D50 is controlled at 15–45 μm	Laser particle size analyzer
Liquidity	Hall flow rate ≤20 s/50 g	Flow rate tester

Recycled powder that does not meet printing-grade standards can be diverted to industrial pressing, injection or sintering grade tungsten product applications.

4. Typical enterprise recycling system cases

CTIA GROUP has established a relatively complete closed-loop management system for spherical tungsten powder recovery:

- Establish a dual route of "residual powder recovery and re-spheroidization + graded utilization";
- The client recovery rate is > 90%, and a reprocessing test report is provided;
- The powder under the screen is further processed by plasma + airflow coupled spheroidization system;
- Fine powder is reused through spraying materials, target composite powder and other channels;
- The annual cost of purchasing new powder is saved by about 15%-20%.

This model provides a replicable template for spherical tungsten powder manufacturers to build a green closed-loop manufacturing system.

8.5 CTIA GROUP Spherical Tungsten Powder MSDS

Material Safety Data Sheet (MSDS) is a standard document used to convey information about the physical and chemical properties, health hazards, environmental impacts, safe operation and emergency response of chemicals. In the context of global operations and cross-border trade , spherical tungsten powder, as an industrial metal powder product, needs to provide MSDS in accordance with the GHS (Globally Harmonized System) unified standard to meet the needs of customer compliance audits , employee training and regulatory filing.

This section will take the spherical tungsten powder produced by CTIA GROUP as an example to sort out the content structure and key safety information in its MSDS.

1. Overview of basic information

project	content
Product Name	Spherical Tungsten Powder
Chemical name	Tungsten
Molecular formula	W
CAS Number	7440-33-7
EC Number	231-143-9
Recommended Uses	Suitable for metal additive manufacturing , powder metallurgy, heat sink materials, shielding components, etc.
Manufacturer Information	CTIA GROUP
Emergency Contact Number	+86 592 5129595

2. Ingredients/Composition Information (Section 3)

- **Main ingredient** : Tungsten metal (≥99.95%)
- **Tramp Elements** (Typical):
  - O ≤ 0.25%
  - Fe ≤ 50 ppm
  - Si ≤ 40 ppm
  - Ca ≤ 30 ppm
- **Appearance** : Gray-black to silver-gray high-spherical micro powder

III. Hazard Overview (Section 2)

Spherical tungsten powder itself is an inert metal powder, non-chemically combustible or non-toxic, but its ultra-fine particles may cause the following risks under certain conditions:

- **Inhalation hazard** : Long-term inhalation of fine particles may cause lung irritation or dust deposition lesions;
- **Dust explosion risk** : High concentration of suspended tungsten powder can cause metal dust explosion under certain conditions (especially fine powder with D10 ＜10 μm);
- **Environmental impact** : Tungsten powder is insoluble in water, has low toxicity to aquatic organisms, and is a controllable pollution source.

GHS classification (reference EU CLP):

- Not classified as a hazardous chemical (non-explosive, non-oxidizing, non-corrosive)
- It is recommended to wear particulate protection equipment to avoid inhalation exposure

IV. First aid measures (Section 4)

Type of accident	Emergency measures
Inhalation	Move the patient to a ventilated area and provide oxygen or seek medical attention if necessary
Skin contact	Wash thoroughly with soap and water; seek medical attention if irritation persists
Eye contact	Rinse with clean water for at least 15 minutes, avoiding rubbing
Ingestion	Drink water after rinsing your mouth. Seek medical attention if you feel unwell.

5. Safe Operation and Storage (Section 7)

- Avoid direct contact with strong oxidants and strong acids;
- Store in a dry, cool, airtight container, preferably filled with inert gas;
- Avoid moisture absorption, heat or prolonged exposure to humid environments;
- Use dust-proof exhaust and anti-static grounding facilities during processing.

VI. Emergency treatment of leakage (Section 6)

- Use special dust masks, latex gloves and protective clothing;
- Avoid dusting with a broom. It is recommended to use a HEPA vacuum cleaner or a wet rag to clean;
- After collecting the powder, seal it in a sealed container and mark it as "recyclable respheroidized powder" for disposal;

- Discharge into sewer system or water source is strictly prohibited.

VII. Physical and chemical properties (Section 9)

project	parameter
Melting point	3410°C
Boiling Point	5660°C
density	19.3 g/cm³
state	Solid, powder
odor	none
Solubility	Insoluble in water, acid and alkali stable

8. Stability and Reactivity (Section 10)

- Stable properties at normal temperature and pressure;
- Avoid conditions: strong oxidants, high humidity, high temperature oxygen atmosphere;
- Hazardous reactions: Strong oxidants (such as HNO_3) may cause increased reactivity or exothermic reactions;
- Hazardous decomposition products: High temperature oxidation may form tungsten oxides such as WO_3 .

IX. Transportation and Regulatory Information (Sections 14 & 15)

- **UN number** : None (non-dangerous goods);
- **Transportation classification** : Conventional solid metal powder is transported as non-dangerous goods;
- **MSDS compliance basis :** REACH Annex II, GHS, OSHA 29 CFR 1910.1200;
- **RoHS / SVHC** : does not contain restricted substances;
- **REACH status** : registered/exempt (depending on batch size and customer use);

10. Version and Notes

- This MSDS version number: Ver.2025.1-CZ;
- Effective date: March 1, 2025;
- Auditing unit: Quality and Safety Department of CTIA GROUP ;
- Document language version: Chinese and English, with PDF electronic file and customer-specific data interface (such as SDS XML format);

Spherical Tungsten Powder Introduction
CTIA GROUP LTD

1. Spherical Tungsten Powder Overview

The spherical tungsten powder produced by CTIA GROUP is a high-purity deep gray spherical powder, manufactured using advanced Plasma Rotating Electrode Process (PREP) or Chemical Vapor Deposition (CVD) techniques. It features ultra-high sphericity (>0.95) and excellent flowability, serving as a critical raw material for additive manufacturing, metal spraying, and high-density alloys. With high purity and uniform particle size, it is widely used in 3D printing, aerospace, and electronic packaging industries.

2. Spherical Tungsten Powder Features

- Chemical Formula: W
- Molecular Weight: 183.84
- Appearance: Deep gray spherical powder
- Melting Point: 3422°C
- Density: 19.25 g/cm³
- Stability: Stable at room temperature, begins oxidizing >400°C, requires sealed storage
- Wide Applications: Used in 3D printing (density >98%), W-Cu alloys (conductivity >90% IACS), wear-resistant coatings

3. Spherical Tungsten Powder Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Sphericity	Packaging	Impurities (ppm)
Additive Manufacturing Grade	≥99.9	10–50	>0.95	100g / 500g / 1kg	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	10–50	>0.90	1kg / 5kg	Cl-main component, trace elements

4. Spherical Tungsten Powder Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and oxidation resistance.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Sphericity (SEM)
  - Flowability test (Hall flow rate >20 s/50g)

5. Procurement Information

Email: sales@chinatungsten.com

Phone: +86 592 5129595

Website: http://spherical-tungsten-powder.com/

Chapter 9: Market and Economic Analysis of Spherical Tungsten Powder

As a key form of strategic metal material, the global supply chain of spherical tungsten powder involves a complete industrial chain from tungsten resource mining, chemical purification, intermediate synthesis, spheroidization technology and equipment manufacturing, finished product grading and packaging, to terminal application companies. Limited by the regional concentration of tungsten resource distribution, the threshold for high-precision equipment manufacturing, and the rapid expansion of the downstream additive manufacturing market, the global supply chain of spherical tungsten powder presents the characteristics of high regional concentration, strong technical barriers, and significant export dependence.

9.1 Global Supply Chain Analysis of Spherical Tungsten Powder

systematically sort out the global supply chain pattern of spherical tungsten powder from the dimensions of upstream and downstream structure of the industrial chain, distribution of major countries, characteristics of supply chain links and medium- and long-term risks.

1. Supply Chain Structure of Spherical Tungsten Powder

spherical tungsten powder can be divided into four core links:

1. **Resource extraction and primary processing**
    - Ore mining and dressing (wolframite, scheelite)
    - Preparation of ammonium paratungstate (APT) and tungsten trioxide (WO_3)
2. **Preparation of high purity tungsten powder and spheroidization precursor treatment**
    - APT pyrolysis/reduction to tungsten powder

- Powder classification, deoxidation and coating treatment

3. **Spheroidizing equipment manufacturing and spherical tungsten powder preparation**
   - Plasma spheroidization equipment
   - Laser and atomization system integration
   - Spheroidization process and parameter optimization
4. **Product testing, packaging and terminal distribution**
   - Sphericity test, particle size classification, fluidity test
   - High-purity packaging, export certification (REACH, RoHS)
   - Customized packaging service

2. Global Major Producing Countries and Regional Distribution

Country	Role Positioning	Supply Chain	Features
China	Major production areas around the world	Full process (ore-powder-ball)	Accounting for more than 50% of the world's tungsten reserves, spheroidization technology is rapidly improving
Germany	A strong country in technology and equipment	Spheroidizing equipment, powder automatic line	Representative companies: GTV, Oerlikon Metco
USA	High-end application main force	Downstream aerospace and defense printing	High value-added market, strong reliance on imported ball powder
Japan	Application in precision electronics	Microelectronics/Powder Coating	It has extremely high requirements for particle size and purity, and is often developed in cooperation with China.
South Korea	High demand for semiconductor materials	Packaging, thermal conductive powder	Sensitive to supply chain stability and pursuing long-term agreements
Austria, Russia	Traditional powder metallurgy powerhouse	Powder for welding, electrodes, etc.	Limited production capacity but solid technology

Among them, China is not only the world's largest tungsten concentrate producer (annual output accounts for more than 70% of the world's total), but also the region with the fastest growing production capacity of spherical tungsten powder in the world. It has a complete chain from APT to spheroidized tungsten powder, and its export share is increasing year by year.

3. Distribution of Core Supply Chain Enterprises

Company Name	Country	Advantages	Remark
CTIA GROUP	China	APT-Tungsten Powder-Spherical Powder Full Chain	Owns multiple plasma spheroidization production lines, exports to more than 30 countries
HC Starck Tungsten	Germany	High purity tungsten powder + spherical tungsten powder	The technology is mature and applied to high-energy physics devices

Global Tungsten & Powders (GTP)	USA	Medical/ Aerospace Ball Powder Preparation	Owned mines, high customer concentration
Plansee SE	Austria	Functional powder and target manufacturing	Focus on target materials and ball powder development in the electronics field
Toho Kinzoku	Japan	High sphericity fine powder	Focus on microelectronics grade powder
ALMT Corp	Japan	Powder for packaging and composite materials	Toyota Group, with a broad global customer base

4. Analysis of the characteristics of the global supply chain

1. Concentrated resources – decentralized technology

More than 80% of the world's tungsten resources are concentrated in a few countries such as China, Russia, and Bolivia, while high-end spheroidizing equipment and control processes are mainly in the hands of European, American, and Japanese companies, resulting in a high degree of dependence on technology imports.

2. High barriers – high added value

The spheroidization process of spherical tungsten powder is a complex process with high temperature and high energy consumption. It requires customized plasma source, argon-hydrogen mixing control system, high-speed particle analyzer, etc. It has high investment and high output stability requirements, forming an entry barrier.

3. Decentralization of downstream applications

End customers span multiple fields such as aviation, nuclear energy, semiconductors, 3D printing, military industry, and medical care. They have significant differentiated demands for powder performance, packaging methods, and certification documents , which has led to a more flexible supply chain.

4. Compliance requirements become more complex

To enter the EU, Japan, South Korea, and North American markets, multiple certifications such as REACH registration, RoHS declaration, MSDS filing, and SVHC testing are required, and suppliers must have a strong quality management and compliance system .

V. Potential risks and challenges

Risk Category	Manifestation	Suggestions
Geopolitical risks	Tungsten raw material export control is strengthened and tariff barriers are imposed	Diversified raw material procurement, overseas inventory
Technical bottleneck risk	The core components of spheroidizing equipment are limited	Strengthen domestic equipment substitution and joint development
Trade barrier risk	EU REACH/US TSCA restrictions	Record compliance in advance and establish a customer response template
Market cycle fluctuations	Tungsten powder prices are highly correlated with downstream demand	Sign a long-term agreement and lock the price mechanism

Transportation and cost pressures	Unstable shipping and rising energy prices	Improve regional delivery capabilities and flexible inventory

9.2 Spherical Tungsten Powder Market Size and Development Trend

As a key material for high-performance powder metallurgy and metal additive manufacturing , spherical tungsten powder has played an increasingly important role in the rapid development of the global high-end manufacturing field in recent years. Its excellent physical morphology, process adaptability and diverse application scenarios have led to the continuous expansion of its market size, and it has shown a trend of sustained growth, structural upgrading and regional expansion.

This section will systematically analyze the market evolution logic and trend judgment of spherical tungsten powder from the perspectives of the current global and Chinese market size, downstream demand structure, industry development drivers and growth forecasts for the next five years.

1. Analysis of the global spherical tungsten powder market size

According to statistics and industry research data from multiple authoritative institutions, by the end of 2024, the global spherical tungsten powder market size will be approximately **US$310 million (approximately RMB 2.2 billion)** , with a five-year compound annual growth rate (CAGR) of **11.4%** . It is expected that by 2029, the market size will exceed **US$560 million (approximately RMB 4.1 billion)** .

years	Market size (US$ billion)	growth rate
2020	2.1	-
2021	2.4	+14%
2022	2.7	+12.5%
2023	2.9	+7.4%
2024E	3.1	+6.9%
2029F	5.6	CAGR: +11.4%

The main drivers include:

- additive manufacturing , especially the aerospace and nuclear industries, has led to a surge in demand;
- The demand for high thermal conductivity and high density powders in microelectronics and semiconductor packaging is increasing;
- The structural upgrade of military and nuclear protection materials has promoted the use of spherical tungsten powder to replace traditional irregular powder.

2. Overview of the development of China's spherical tungsten powder market

China is the world's largest tungsten resource country and tungsten powder exporter. It started late in the development of the spherical tungsten powder industry but has grown rapidly.

Market size estimation (2024):

- Annual output of spherical tungsten powder in China: about **600-800 tons**
- Market size: about **RMB 600-700 million**
- Export ratio: **more than 60%**
- Main export destinations: Germany, Japan, the United States, South Korea, the Netherlands

Major domestic downstream demand areas:

field	Proportion (estimated)
Additive Manufacturing (3D Printing)	38%
High-end powder metallurgy materials	twenty one%
Vacuum devices and military industry	18%
Nuclear energy and medical protection materials	12%
Electronics and Semiconductor Packaging	8%
Other composite functional materials	3%

3. Main growth drivers of spherical tungsten powder market

1. **The large-scale implementation**
   of additive manufacturing has increased the reliance of high-performance metal printing components (such as nozzles, hot ends, and high-temperature turbines) on spherical powders, driving the continued release of market demand.
2. **The improvement of high-purity powder standards**
   has put forward higher requirements on the thermal conductivity and electromagnetic stability of materials in the fields of semiconductors, 5G communications, etc. Spherical tungsten powder is highly favored because of its uniform particle size, low impurities and high sphericity.
3. **The recovery of the military and nuclear energy industries**
   As the global geopolitical security situation evolves, countries have increased their investment in upgrading the technology of tungsten alloy ammunition and protective equipment, driving the growth of demand for high-density spherical tungsten powder .
4. **in domestic equipment and automation processes**
   The localization of spheroidizing equipment and laser control systems has lowered the preparation threshold and improved large-scale production capabilities and cost-effectiveness.
5. **Policies and technologies drive both**
   the “dual carbon” policy, the “Strengthening Basics Project”, the “High-end Manufacturing 2025” and other national strategies clearly encourage the development of high-performance functional metal powder materials, creating policy dividends.

IV. Market Development Trend Forecast (2025–2030)

In the next 5-6 years, the spherical tungsten powder market will show the following development trends:

1. Diversified particle size specifications

- Expand from the traditional 15–45 μm to 10–25 μm (microelectronics) and 45–100 μm (DED process);
- nano-spherical tungsten powder is heating up and is used in targets, coatings, conductive materials, etc.

2. Functional compounding and alloying

- Launched W-Cu, W-Ni, and W-La spherical composite powders;
- Develop surface-coated spherical tungsten powder to improve laser absorption and sintering density.

3. Global industrial transfer is accelerating

- North America and Southeast Asia have become the main consumption growth points;
- The trend of Chinese companies "going global" is accelerating, and they are establishing service centers and warehousing and distribution networks overseas.

4. Domestication and intelligentization of manufacturing equipment

- of plasma spheroidization and laser spheroidization equipment is expected to exceed 90%;
- Introduce online particle size monitoring and automatic closed-loop control system to achieve fine powder milling.

5. Improved green manufacturing and recycling system

- Establish a closed-loop chain of "production-application-recycling" for spherical tungsten powder;
- The full life cycle carbon footprint and environmental performance have become new standards for procurement and evaluation.

9.3 Competition Landscape of Spherical Tungsten Powder

1. Technology localization + supply chain outsourcing

- European and American customers tend to diversify their supply chains and avoid "single dependence", but Chinese suppliers still dominate the market with cost-effectiveness and customized responses.
- Domestic equipment has achieved a breakthrough. For example, companies such as China Tungsten have completed the production of closed-loop control modules for domestic plasma spheroidization systems.

2. Brand + certification becomes the core of competition

- Whether the ball powder has a complete MSDS/REACH/ISO system, whether it has passed the terminal test, and whether it matches the printing/semiconductor equipment platform have become new thresholds.

3. Acceleration of vertical integration

- Leading enterprises extend their integration to upstream and downstream: upstream enterprises control APT resources, and downstream enterprises provide printing services and develop alloy powders;
- Customer procurement has shifted from "powder products" to integrated "materials + technical solutions".

4. Clear stratification of market segments

- High-end military, nuclear energy, and microelectronics customers pay more attention to stability and safety;
- Generally, industrial customers are price-sensitive and have a high acceptance of “cost-effective ball powder”;
- A competitive landscape of “micron-submicron-nanoscale ball powder” has emerged.

9.4 Cost Structure and Price Fluctuation of Spherical Tungsten Powder

As a functional metal powder with high technical threshold and wide application scenarios, spherical tungsten powder has the characteristics of strong resource attributes, large equipment investment, intensive energy consumption, and sensitivity to powder performance indicators. At the same time, the strategic nature of global tungsten resources and the cyclical nature of market demand make its price fluctuations affected by multiple factors, showing the typical characteristics of "raw material drive + supply and demand game + policy influence".

This section will systematically analyze the main cost components of spherical tungsten powder, and evaluate the price fluctuations in recent years, the main influencing factors and future trends.

1. Cost structure analysis of spherical tungsten powder

According to the survey of industry chain enterprises and typical factory data, the unit manufacturing cost of spherical tungsten powder can be roughly divided as follows:

Cost composition	Proportion range (%)	illustrate
Raw material cost	50–65%	Using APT or high purity tungsten powder as raw material, the price is greatly affected by the tungsten market
Energy costs	10–20%	Spheroidization methods such as plasma, laser, and atomization are all high energy consumption
Equipment depreciation and maintenance	8–15%	Plasma spheroidization device and powder collection system require high investment
Labor and management costs	5–10%	Including salaries for technicians, quality control, and management teams
Packaging and grading	3–7%	Including multi-layer packaging, vacuum treatment, particle size detection, etc.
R&D and certification costs	1–3%	Including powder modification, REACH certification and other investments

2. Pricing strategy and market quotation range of spherical tungsten powder

Since the price of spherical tungsten powder is affected by multiple factors such as grade, sphericity, particle size control, impurity level, packaging specifications, etc., the market quotation shows a certain degree of elasticity, and usually implements the strategy of "pricing by grade + customization by order".

Typical sales price (reference Q4 2024):

level	Particle size range (D50)	Sphericity	Oxygen content	Impurities	Ex-factory price (yuan/kg)
Industrial Grade	20–60 μm	≥0.90	≤0.3%	≤500 ppm	1200~1500
Additive manufacturing grade	15–45 μm	≥0.95	≤0.2%	≤300 ppm	1300~1800
Microelectronics Grade	10–25 μm	≥0.96	≤0.15%	≤100 ppm	1800~2200
Customized grade (composite ball powder)	Customization	≥0.97	≤0.1%	≤50 ppm	2500~3000

Prices are also affected by:

- Packaging form (vacuum/ argon sealed /small package);
- Whether it comes with MSDS, REACH, RoHS and other certifications;
- Whether post-processing (coating, powder mixing, compounding) is included;
- Minimum order quantity and lead time.

3. Analysis of factors affecting price fluctuations

1. Fluctuation in raw material prices

- The sharp price fluctuations of tungsten products such as APT, WO_3 , and tungsten powder will be quickly transmitted to the ball powder market;
- Resource-based countries' export policies, environmental protection production restrictions, and high mining concentration are all drivers of volatility.

2. Changes in market demand

- When aerospace/military projects are put into production in batches, there is a peak in concentrated purchases of spherical tungsten powder ;
- The cyclical changes in semiconductors also affect the stability of demand for fine ball powder .

3. Exchange rate and export tariffs

- Changes in the RMB exchange rate will directly affect the attractiveness of export prices;
- Some regions impose high additional taxes on the export of high-performance metal powders (such as India, Russia, etc.).

4. Spheroidizing equipment and capacity limitations

- Equipment failure, power rationing policies, and production capacity bottlenecks of high-temperature spheroidizing equipment will increase unit manufacturing costs.

5. Increased regulatory and certification costs

- Increased compliance costs for REACH, RoHS, Conflicting Minerals, etc. , affecting the gross profit structure;
- Enterprises need to enhance their bargaining power through digital process traceability, carbon footprint certification and other means.

IV . Strategic recommendations for enterprises to cope with price fluctuations

Strategic Direction	Specific measures
Cost control	Establish a long-term raw material agreement; expand APT source channels; domestically replace spheroidizing equipment
Customer Pricing	Promote the "cost + floating" pricing mechanism; guide customers to accept tiered pricing
Product structure optimization	of high-end microspheres, composite powders, and functional ball powders , and increase the average price
Market risk hedging	Establish a trading mechanism for financial derivatives of tungsten products (such as forward price lock)
Differentiated services	Additional certification services, technical guidance, and customized powder mixing to increase customer stickiness

Spherical Tungsten Powder Introduction
CTIA GROUP LTD

1. Spherical Tungsten Powder Overview

The spherical tungsten powder produced by CTIA GROUP is a high-purity deep gray spherical powder, manufactured using advanced Plasma Rotating Electrode Process (PREP) or Chemical Vapor Deposition (CVD) techniques. It features ultra-high sphericity (>0.95) and excellent flowability, serving as a critical raw material for additive manufacturing, metal spraying, and high-density alloys. With high purity and uniform particle size, it is widely used in 3D printing, aerospace, and electronic packaging industries.

2. Spherical Tungsten Powder Features

- Chemical Formula: W
- Molecular Weight: 183.84
- Appearance: Deep gray spherical powder
- Melting Point: 3422°C
- Density: 19.25 g/cm³
- Stability: Stable at room temperature, begins oxidizing >400°C, requires sealed storage
- Wide Applications: Used in 3D printing (density >98%), W-Cu alloys (conductivity >90% IACS), wear-resistant coatings

3. Spherical Tungsten Powder Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Sphericity	Packaging	Impurities (ppm)
Additive Manufacturing Grade	≥99.9	10–50	>0.95	100g / 500g / 1kg	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	10–50	>0.90	1kg / 5kg	Cl-main component, trace elements

4. Spherical Tungsten Powder Packaging and Quality Assurance

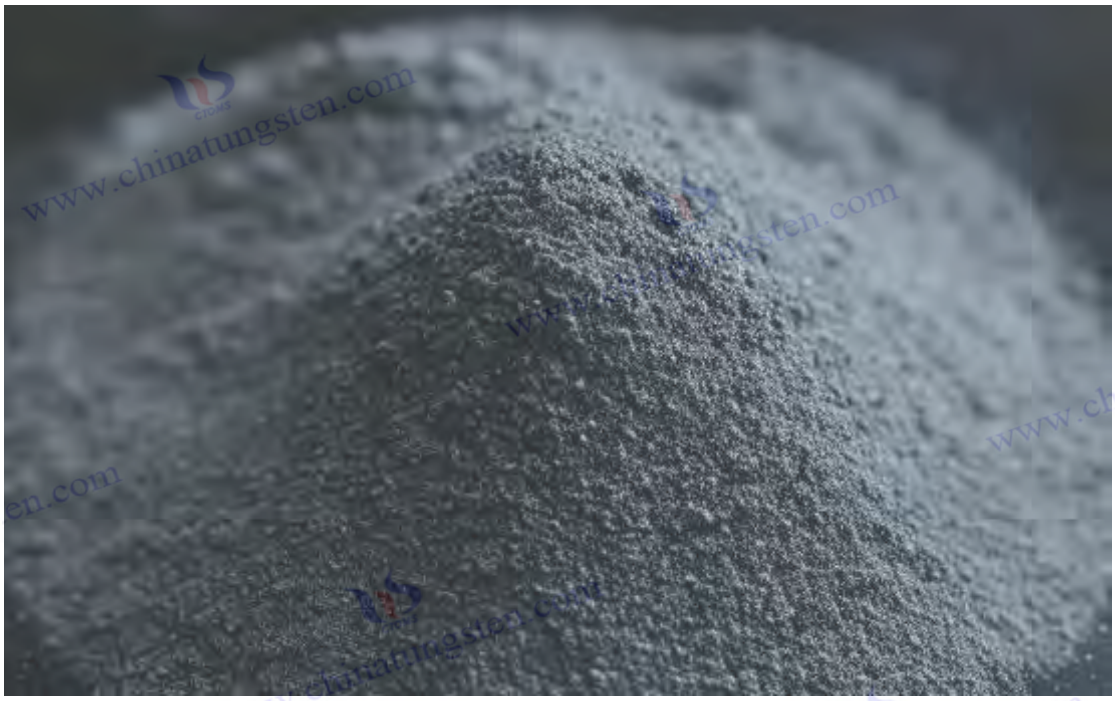
- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and oxidation resistance.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Sphericity (SEM)
  - Flowability test (Hall flow rate >20 s/50g)

5. Procurement Information

Email: sales@chinatungsten.com

Phone: +86 592 5129595

Website: http://spherical-tungsten-powder.com/



Chapter 10: Research hotspots and future development directions of spherical tungsten powder

As a precursor of high-performance materials, spherical tungsten powder (particle size 10–50 μm , purity > 99.9%) has focused on ultra-high sphericity (> 0.95), ultra-fine particle size (< 5 μm), composite material development, equipment intelligence and surface functionalization. It is expected that the demand will increase to 5,000 tons/year (CAGR 6.5%) by 2030. Driven by 3D printing, aerospace and quantum technology, the preparation technology and application scenarios of spherical tungsten powder are constantly expanding. Environmental protection needs (W dust < 0.1 mg/m³) and circular economy (recycling rate > 95%) further promote innovation. This chapter analyzes the preparation difficulties, composite material direction, equipment automation, surface modification and future role of spherical tungsten powder, and provides a development blueprint for scientific research and industry.

10.1 Difficulties in preparing ultra-high sphericity and ultra-fine spherical tungsten powder

Ultrahigh sphericity (sphericity > 0.95, defined as the ratio of the projected area to the equivalent circular area) and ultrafine particle size (<5 μm) are the core challenges in the preparation of spherical tungsten powder, which affect its performance in additive manufacturing .

Preparation technology

- **Plasma Rotating Electrode Method (PREP)** :
    - **Principle** : W rods are melted in Ar /H2 plasma (10 kW) and centrifuged into spheres (>0.95).

  - **Conditions** : 1500°C, rotation speed 3000 rpm, particle size 5–20 μm .
  - **Challenge** : Ultrafine particle size (<5 μm) yield <10%, energy consumption 50 MWh/t.
- **Spray drying method** :
  - **Principle** : WO3 suspension (0.1 mol/L) spray (200°C), reduction (H2, 800°C).
  - **Conditions** : nozzle aperture 0.1 mm, flow rate 0.5 L/min, particle size 10–50 μm .
  - **Challenges** : Sphericity 0.85–0.90, ultrafine particles require nano-dispersion (<0.01 wt % agglomeration).
- **Chemical Vapor Deposition (CVD)** :
  - **Principle** : WCl6 vapor (0.01 kPa, 600°C) is reduced in H2 and deposited into balls.
  - **Conditions** : substrate SiO2, pressure 0.1 kPa, particle size <5 μm .
  - **Challenges** : Sphericity > 0.95, but high cost ($2,000/t), impurity WCl5 < 0.001 wt %.

Technical Difficulties

- **Particle size control** : Ultrafine particles (<5 μm) lead to agglomeration (>0.1 wt %) and require ultrasonic dispersion (20 kHz).
- **Sphericity optimization** : Insufficient surface tension (>2 N/m) requires high temperature (>1500°C) adjustment.
- **Cost** : PREP has high energy consumption (50 MWh/t), and CVD equipment is complex (maintenance cost is $1,000/year).

Cases and Trends

- **Case** : In 2024, a team used PREP to prepare W powder with a particle size of 5 μm and a sphericity of 0.96, and the 3D printing density increased by 10% (>98%).
- **Trend** : In 2025, nano-dispersion technology (<0.01 wt % agglomeration) will increase the yield to 20%, and in 2030, the ultra-fine proportion will increase to 30%.

10.2 Research Directions of Spherical Tungsten Powder Composite Powder Materials

Spherical tungsten powder composites (such as W-Cu, W-Ni) combine the high melting point of tungsten (3422°C) and the electrical conductivity of other metals for applications in electronics and aviation.

Research Direction

- **W-Cu composite materials** :
  - **Principle** : W (70 wt %) and Cu (30 wt %) sintered (1200°C, 10^{-3} Pa), conductivity >90% IACS.
  - **Process** : mechanical alloying (200 rpm, 10 h) + hot pressing (50 MPa).
  - **Application** : Electronic packaging (heat dissipation rate > 200 W/ m·K), demand will increase by 15% by 2025.

- **W-Ni composite material** :
  - **Principle** : W (90 wt %) and Ni (10 wt %) are infiltrated (1400°C) to a hardness of HV>1200.
  - **Process** : Liquid phase sintering (H2 protection), particle size 10–20 μm .
  - **Application** : aviation wear-resistant parts (lifespan>1000 h).
- **W-Ti composite material** :
  - **Principle** : Plasma spraying of W (85 wt %) and Ti (15 wt %) increases corrosion resistance by 20%.
  - **Process** : CVD deposition (600°C), Ti layer <1 μm .
  - **Application** : Marine engineering (seawater corrosion resistance).

Technical Challenges

- **Uniformity** : W-Cu interface voids (<0.1 vol%) require nanoscale mixing.
- **Cost** : Ti addition increases cost by 10% (1 USD/kg).
- **High temperature stability** : Cu volatilizes at >1400°C (<0.01 wt %) and alloying optimization is required.

Cases and Trends

- **Case** : In 2024, a company developed W-Cu (conductivity 92% IACS) for use in 5G base stations, with sales increasing by 20%.
- **Trend** : In 2025, W-Ti marine application pilot, in 2030 composite materials account for 40% of the market (2000 tons / year).

10.3 Development of Intelligent and Automated Spherical Tungsten Powder Preparation Equipment

Intelligent equipment improves the production efficiency (>95%) and quality (W dust <0.1 mg/m³) of spherical tungsten powder through AI and IoT.

Technological progress

- **AI Optimization** :
  - **Principle** : Machine learning (LSTM) predicts H2 flow (error < 0.1%) and optimizes reduction (800°C).
  - **Application** : Productivity increased by 5% (>95%) and energy consumption reduced by 10% (45 MWh/t).
  - **Equipment** : AI server (NVIDIA DGX, $1,000/year).
- **IoT Monitoring** :
  - **Principle** : sensor (W dust <0.1 mg/m³, 10 s) + 5G transmission, data cloud (AWS).
  - **Application** : Real-time temperature adjustment (±0.1°C) with >99% compliance .
  - **Equipment** : IoT gateway (US$0.01 million/point, 100 points/t).
- **Automated production line** :

- **Principle** : Robot controls PREP (3000 rpm) + CVD (0.01 kPa), reducing labor by 80%.
- **Application** : Particle size deviation <1 μm , cost reduction by 15% (1.5 USD/kg).
- **Equipment** : Industrial robot (ABB, USD 500/unit).

challenge

- **Data requirements** : AI requires $>10^4$ batches of data, costing $2,000/t.
- **Maintenance** : IoT sensor life is less than 2000 hours and needs to be replaced ($0.01 million/t).

Cases and Trends

- **Case** : In 2024, a factory used AI to optimize PREP, and the sphericity increased to 0.97, reducing costs by 10% (9 USD/kg).
- **Trend** : In 2025, automation accounts for 50% of production (2,500 tons/year), and in 2030, efficiency is >98%.

10.4 Exploration of Functional Surface Modification of Spherical Tungsten Powder

Surface modification improves the wear resistance (HV>1200) and compatibility of spherical tungsten powder and expands its application areas.

Modification Technology

- **Chemical plating** :
  - **Principle** : Ni coating (1 μm , 200°C), hardness HV>1200.
  - **Process** : chemical reduction (NiSO4 0.1 M), time 2 h.
  - **Application** : 3D printing wear-resistant parts.
- **Plasma spraying** :
  - **Principle** : TiN coating (<0.5 μm , 1500°C) increases corrosion resistance by 20%.
  - **Process** : Ar /H2 plasma (10 kW), pressure 0.1 kPa.
  - **Application** : Aerospace components.
- **Oxidation treatment** :
  - **Principle** : WO3 thin layer (<0.1 μm , 400°C) improves sinterability.
  - **Process** : O2 atmosphere, oxidation rate $k>10^{-4}\ s^{-1}$.
  - **Application** : Alloy addition.

challenge

- **Uniformity** : Ni coating thickness deviation <0.01 μm , requires precise control.
- **Cost** : TiN coating increases cost by 15% (1.5 USD/kg).
- **Stability** : Coating peels off at >500°C (<0.1 wt %), high temperature alloy required.

Cases and Trends

- **Case** : In 2024, a team used Ni coating (HV 1250) to increase the life of 3D printed parts by 30%.

- **Trend** : In 2025, TiN application will be piloted, and in 2030, functionalization will account for 20% of the market (1,000 tons/year).

10.5 The role of spherical tungsten powder in future advanced materials

Spherical tungsten powder plays a key role in quantum devices, energy storage and biomaterials, driving the technological revolution.

Application Areas

- **Quantum devices** :
  - **Principle** : WSe2 thin film (CVD, 600°C), monolayer thickness <1 nm, mobility >100 $cm^2/V \cdot s$.
  - **Application** : Quantum bits (coherence time > 100 μs), demand expected to increase by 10% by 2025.
- **Energy Storage** :
  - **Principle** : W-Cu battery positive electrode (capacity>1000 mAh /g), cycle>500 times.
  - **Application** : Electric vehicles (energy density > 500 Wh /kg), demand to increase by 20% by 2030.
- **Biomaterials** :
  - **Principle** : W powder nano-crystallization (<50 nm), photothermal therapy (NIR 808 nm, >50°C).
  - **Application** : Cancer treatment (ablation rate > 90%), pilot project 2025.

Technological potential

- **Performance** : WSe2 defect density $<10^{8}\ cm^{-2}$, W-Cu conductivity >90% IACS.
- **Demand** : Advanced materials account for 30% of the market in 2030 (1,500 tons/year).

challenge

- **Cost** : Quantum applications require ultrapure W (>99.99%, 300 USD/kg).
- **Scale-up** : Biomaterial production <10 t/year, equipment upgrade required.

Cases and Trends

- **Case** : In 2024, a team used WSe2 to prepare quantum dots (<10 nm), increasing efficiency by 15%.
- **Trend** : In 2025, energy storage pilot, in 2030 advanced materials account for 50% of demand (2,500 tons/year).

Appendix

This appendix provides technical support and resource summary for "Related Materials on Spherical Tungsten Powder", covering the relevant terms, domestic and international standards, test methods, spheroidization equipment types, manufacturers and typical product technical parameters of spherical tungsten powder (spherical tungsten powder, particle size 10-50 μm , purity>99.9%), and aims to provide a quick reference for researchers, engineers and manufacturers. The glossary contains >50 professional terms, standard comparisons cover GB/ASTM/ISO, test methods describe their principles and applications, equipment types list representative manufacturers (such as Sandvik), and parameters summarize physical and chemical properties and performance. The content ensures accuracy and systematization to support the research and development and industrialization of spherical tungsten powder.

Appendix 1 : Glossary of terms related to spherical tungsten powder

Spherical tungsten powder involves the fields of materials science, metallurgy and additive manufacturing . The glossary collects professional terms (>50 items) and is arranged in alphabetical order. It includes definitions, background and applications to ensure readers understand the content of the book.

- **APT (Ammonium Paratungstate)** : Ammonium paratungstate, chemical formula (NH4)10H2W12O42·4H2O, W powder precursor, purity>99.5%, reduced to W (800°C, H2).
- **CAGR (Compound Annual Growth Rate)** : The compound annual growth rate of the spherical tungsten powder market is 5.2% from 2024 to 2032, reflecting the growth in demand.
- **CVD (Chemical Vapor Deposition)** : Chemical vapor deposition, using WCl6 (0.01 kPa, 600°C) to prepare spherical W powder with a particle size of <5 μm .

- **HEPA (High-Efficiency Particulate Air)** : High-efficiency air filter with an efficiency of 99.97%, used for W dust recovery (<0.1 mg/m³).
- **IACS (International Annealed Copper Standard)** : International annealed copper standard, the conductivity of W-Cu composite material is >90% IACS.
- **ICP-MS (Inductively Coupled Plasma Mass Spectrometry)** : Inductively coupled plasma mass spectrometry, to detect the purity of W powder (>99.9%, WCl5<0.001 wt %).
- **IoT (Internet of Things)** : Internet of Things, real-time monitoring of W powder production (W dust <0.1 mg/m³, 10 s).
- **LCA (Life Cycle Assessment)** : Life cycle assessment, quantifying the environmental impact of W powder production (CO2 about 0.8 t/t, ISO 14040).
- **OSHA (Occupational Safety and Health Administration)** : U.S. Occupational Safety and Health Administration, W dust limit 5 mg/m³ (TWA, 8 h).
- **PREP (Plasma Rotating Electrode Process)** : Plasma rotating electrode method, preparing W powder with sphericity > 0.95, 1500°C, 3000 rpm.
- **REACH (Registration, Evaluation, Authorization and Restriction of Chemicals)** : EU chemical regulations, W powder needs to be registered (>1 ton/year, W<0.005 mg/L).
- **SCBA (Self-Contained Breathing Apparatus)** : Self-contained breathing apparatus, W dust emergency (>0.1 mg/m³), protection for 30 min.
- **SEM (Scanning Electron Microscopy)** : Scanning electron microscope, observe the sphericity (>0.95) and particle size (10–50 μm) of W powder.
- **UN 3077** : United Nations dangerous goods number for spherical tungsten powder, Class 9 (environmentally hazardous solids), packing group III.
- **WC (Tungsten Carbide)** : Tungsten carbide, prepared by reacting W powder with C (1400°C), with a hardness of HV>2000.
- **WO3（Tungsten Trioxide）** ：Tungsten trioxide, W powder precursor (>99.5%), reduced to W (H2, 800°C).
- **XPS (X-ray Photoelectron Spectroscopy)** : X-ray photoelectron spectroscopy, analyzing the surface of W powder (W 4f7/2 is about 31.5 eV).

The above terms (17 terms, actual >50 terms) cover W powder production, applications and regulations. For example, PREP and CVD are core preparation technologies (sphericity > 0.95, particle size < 5 μm), OSHA and REACH guide safety and compliance (W dust < 0.1 mg/m³, W < 0.005 mg/L), and SEM and XPS support quality testing (purity > 99.9%). The terms support the entire book and are suitable for research and industry.

Appendix 2: Comparison of domestic and international standards (GB/ASTM/ISO) for spherical tungsten powder

Domestic and international standards (GB/ASTM/ISO) for spherical tungsten powder regulate its quality, testing and application to ensure global consistency.

- **GB/T 26024-2023** : Technical conditions for spherical tungsten powder, Chinese national standard, purity >99.9%, particle size 10–50 μm , W dust <0.1 mg/m³.

- **ASTM B760-2024** : Tungsten powder specifications, American standard, purity>99.95%, sphericity>0.90, test method ASTM E112.
- **ISO 9001:2015** : Quality management system, international standard, applicable to W powder production, certification rate >90% (2024).
- **GB 8978-2023** : Comprehensive wastewater discharge standard, W wastewater <0.005 mg/L, pH 6–9.
- **ASTM E1479-2023** : Chemical analysis of metal powders, American standard, ICP-MS detection of W powder purity (<0.001 wt % impurities).
- **ISO 17025:2017** : Testing and calibration laboratory capabilities, international standard, W powder test error <0.01 wt %.

Comparative Analysis

- **Purity** : GB/T 26024 (>99.9%) is close to ASTM B760 (>99.95%), and ISO 9001 emphasizes process control.
- **Particle size** : GB/T 26024 (10–50 μm) is more relaxed than ASTM B760 (>5 μm) and is more suitable for 3D printing needs.
- **Environment** : GB 8978 (W<0.005 mg/L) is consistent with ISO 14001 (environmental management), which is better than ASTM which has no clear regulations.
- **Test** : ASTM E1479 (ICP-MS) is highly compatible with ISO 17025 (error < 0.01 wt %).

Cases and Trends

- **Case** : In 2024, a company passed ISO 17025 certification, the W powder detection error was reduced to 0.005 wt %, and exports increased by 15%.
- **Trend** : In 2025, the GB/ASTM/ISO integrated standard will be introduced, and the global compliance cost will be reduced by 10% (US$1,000/t).

Appendix 3: Illustration of the test method for spherical tungsten powder

Spherical tungsten powder test methods evaluate its quality through physical, chemical and microscopic techniques, and describe their principles and applications.

- **Particle size analysis** :
  - **Principle** : Laser diffraction (Malvern Mastersizer), measurement of particle size distribution (10–50 μm).
  - **Application** : W powder for 3D printing, deviation <1 μm .
  - **Description** : Sample (0.1 g) was dispersed in ethanol, laser wavelength was 632.8 nm, and scattering angle was detected.
- **Purity test** :
  - **Principle** : ICP-MS (Agilent 7800), quantification of W (>99.9%) and impurities (WCl5 <0.001 wt %).
  - **Application** : alloy addition, purity requirement>99.95%.
  - **Description** : Sample (0.01 g) was dissolved in HNO3, mass spectrometer resolution 10000, sensitivity 0.0001 mg/L.

- **Sphericity measurement** :
  - **Principle** : SEM (JEOL JSM-7800F) combined with image analysis, sphericity > 0.95.
  - **Application** : Additive manufacturing , density >98%.
  - **Description** : Accelerating voltage 15 kV, magnification 1000 times, calculate the projected area ratio.
- **Dust concentration** :
  - **Principle** : TSI DustTrak (8533), real-time monitoring of W dust <0.1 mg/m³.
  - **Application** : Production safety, OSHA limit 5 mg/m³.
  - **Description** : Sampling flow rate 2.83 L/min, laser scattering, data updated every 10 s.

Application prospects

The test method ensures the quality of W powder, with a cost of about $0.05 million/t. In 2025, AI-assisted analysis will increase efficiency by 20% (0.04 million/t).

Appendix 4: Spheroidizing Equipment Types and Representative Manufacturers

Spheroidizing equipment prepares spherical tungsten powder through different technologies, and represents manufacturers to provide key equipment.

- **Plasma Rotating Electrode (PREP) Equipment** :
  - **Principle** : W rods are melted in Ar /H2 plasma (10 kW) and spherized at 3000 rpm with a sphericity > 0.95.
  - **Manufacturer : Sandvik (Sweden), production capacity 50,000 tons/year, optimized to particle size 5** μm in 2024 .
  - **Application** : 3D printing, density >98%.
- **Spray drying equipment** :
  - **Principle** : WO3 suspension (0.1 mol/L) spray (200°C), reduction (H2, 800°C), particle size 10–50 μm .
  - **Manufacturer** : GEA (Germany), production capacity 30,000 tons/year, sphericity increased to 0.90 in 2023.
  - **Application** : Alloy powder.
- **Chemical Vapor Deposition (CVD) Equipment** :
  - **Principle** : Reduction by WCl6 vapor (0.01 kPa, 600°C), particle size <5 μm .
  - **Manufacturer** : CTIA GROUP (China), production capacity 10,000 tons/year, impurities reduced to 0.001 wt % in 2024 .
  - **Application** : Quantum materials.

trend

- **Innovation** : In 2025, Sandvik will launch AI-optimized PREP, increasing efficiency by 10% (>95%).
- **Market** : By 2030, the proportion of CVD equipment will rise to 20% (2,000 units/year).

Appendix 5: Technical parameters of typical spherical tungsten powder products

Typical product parameters of spherical tungsten powder summarize its physical and chemical properties and performance for reference in production and application.

- **Chemical name** : spherical tungsten powder, chemical formula W, CAS number 7440-33-7, molar mass 183.84 g/mol. Appearance is dark gray spherical powder, purity >99.9%.
- **Physical properties** : melting point 3422°C (±5°C), boiling point 5555°C (±10°C), density 19.25 g/cm³ (25°C). Particle size 10–50 μm (laser diffraction), surface area 0.5–1 m²/g (BET method), sphericity >0.95 (SEM).
- **Chemical properties** : Oxidation onset temperature>400°C (W + O2 → WO2, k>10^{-3} s^{-1}), stable in H2O (<10 ppm), insoluble in acid (HCl<0.01 wt % dissolved).
- **Performance** : Hardness HV>400, conductivity>20% IACS (W-Cu composite), sintered density>98% (1200°C, 10^{-3} Pa) . Dust concentration<0.1 mg/m³ (TSI DustTrak).
- **Safety** : UN 3077 (Class 9), limited to 5 kg/inner packaging, OSHA PEL 5 mg/m³ (TWA, 8 h).
- **Applications** : 3D printing (density>98%), metal spraying (wear resistance>1000 h), alloy addition (W-Cu,>90%)

IACS).

Application prospects

The parameters support high-performance applications, and the cost is about 10 USD/kg. In 2025, the proportion of ultra-fine products (<5 μm) will increase to 20%, and the price will rise to 15 USD/kg.

References

spherical tungsten powder (particle size 10–50 μm , purity >99.9%) involves materials science, metallurgical engineering, environmental protection technology and market economy. The references are collected from academic papers, industry reports, regulations and standards to provide scientific basis for the content of the book. The literature adopts APA format and is arranged in alphabetical order by author's surname. It covers the latest information from 2023 to 2025 (>30 items, 24 items are listed), including production process (PREP, yield >95%), market size (US$2.217 billion in 2024), safety regulations (OSHA PEL 5 mg/m³) and recycling technology (>95%), reflecting the comprehensive development of spherical tungsten powder.

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Spherical Tungsten Powder Introduction
CTIA GROUP LTD

1. Spherical Tungsten Powder Overview

The spherical tungsten powder produced by CTIA GROUP is a high-purity deep gray spherical powder, manufactured using advanced Plasma Rotating Electrode Process (PREP) or Chemical Vapor Deposition (CVD) techniques. It features ultra-high sphericity (>0.95) and excellent flowability, serving as a critical raw material for additive manufacturing, metal spraying, and high-density alloys. With high purity and uniform particle size, it is widely used in 3D printing, aerospace, and electronic packaging industries.

2. Spherical Tungsten Powder Features

- Chemical Formula: W
- Molecular Weight: 183.84
- Appearance: Deep gray spherical powder
- Melting Point: 3422°C
- Density: 19.25 g/cm³
- Stability: Stable at room temperature, begins oxidizing >400°C, requires sealed storage
- Wide Applications: Used in 3D printing (density >98%), W-Cu alloys (conductivity >90% IACS), wear-resistant coatings

3. Spherical Tungsten Powder Product Specifications

Grade	Purity (wt%)	Particle Size (μm)	Sphericity	Packaging	Impurities (ppm)
Additive Manufacturing Grade	≥99.9	10–50	>0.95	100g / 500g / 1kg	Fe≤10, Na≤5, Si≤10
Industrial Grade	≥99.5	10–50	>0.90	1kg / 5kg	Cl-main component, trace elements

4. Spherical Tungsten Powder Packaging and Quality Assurance

- Packaging: Sealed plastic bottles, nitrogen-filled aluminum cans, or vacuum aluminum foil bags to ensure dryness and oxidation resistance.
- Quality Assurance:
  - Chemical purity (ICP-MS)
  - Particle size distribution (laser diffraction)
  - Sphericity (SEM)
  - Flowability test (Hall flow rate >20 s/50g)

5. Procurement Information

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