

Plasma Rotating Electrode Process Technologies and System (PREP)

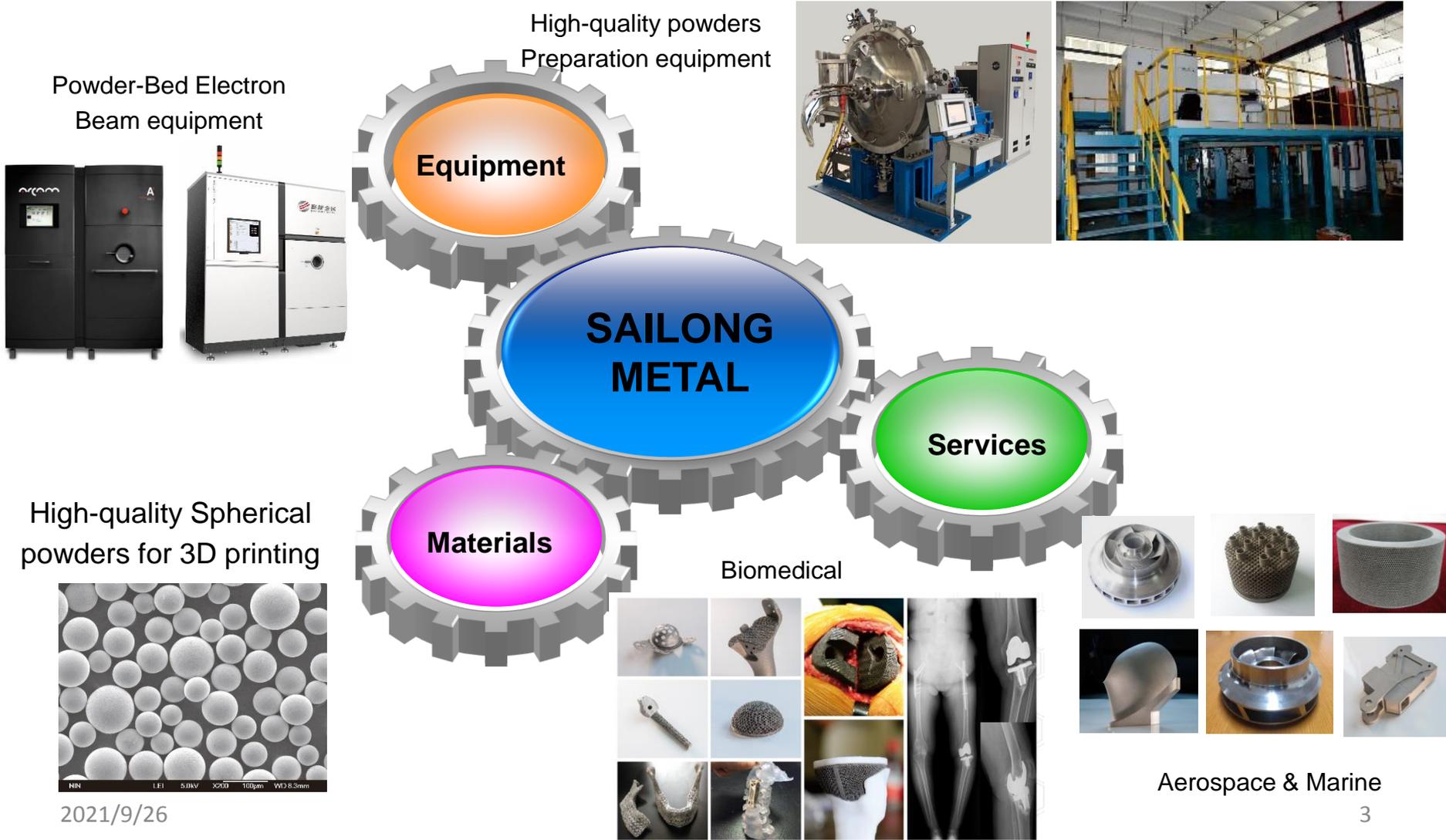
Contents

- **Comparison of Typical Metal Powder Preparation Technologies**
- **Plasma Rotating Electrode Process (PREP)**
- **Experimental Data: Metal Powders Practice**

One-step Solution Provider in Metal 3D Printing

What we can serve: Powders + Equipment + Services

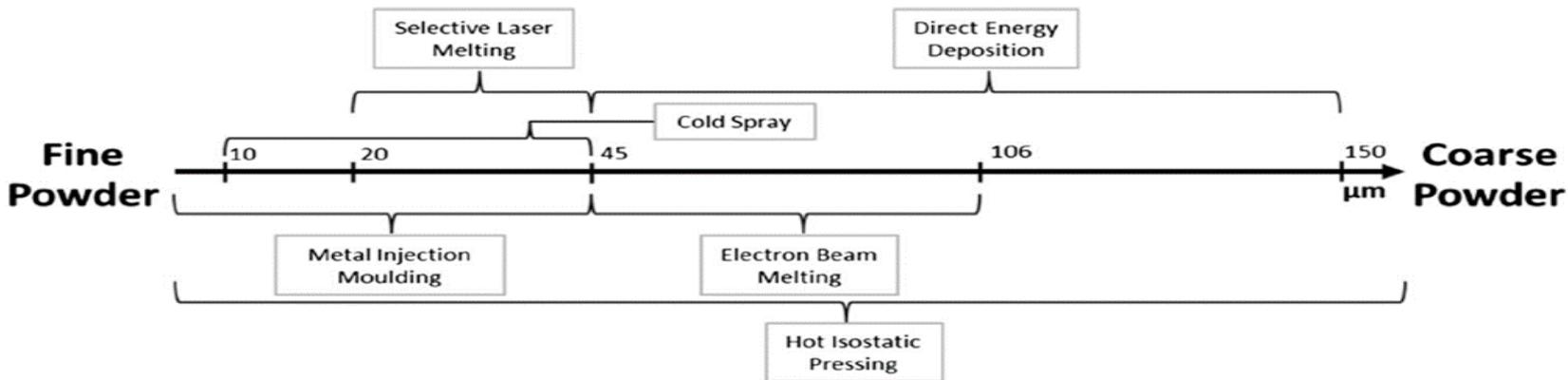
A Whole Industry Chain Development Model



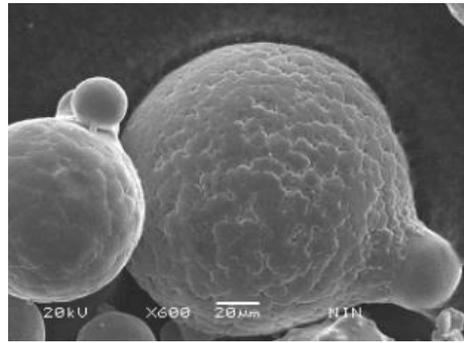
2021/9/26

Comparison of Typical Metal Powder Preparation Technologies

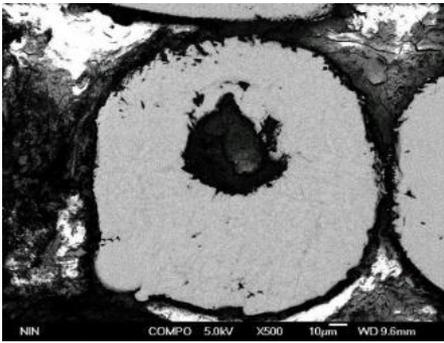
Requirements for High-quality Metal Powders



Low Quality Powder

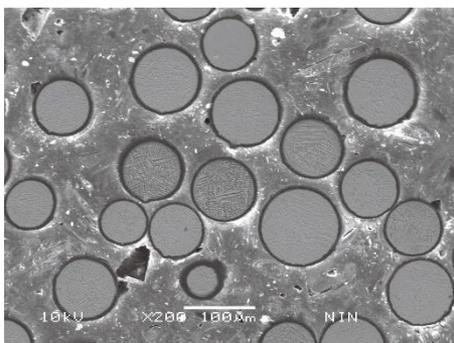
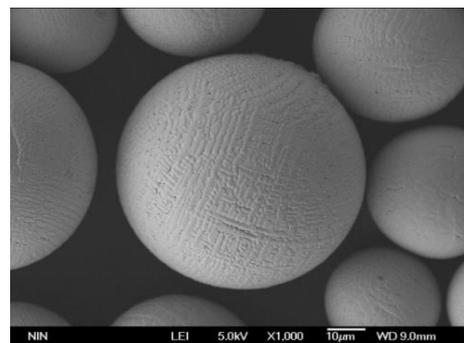


Satellite powders



Porous powders

High Quality Powder



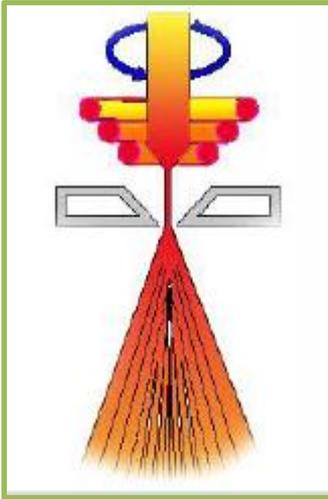
High quality metal powder requirements:

- ✓ Shape: high sphericity, no satellite and Porous powders
- ✓ Suitable particle size distribution
- ✓ Low oxygen content
- ✓ Low impurity content
- ✓ High flowability
- ✓ High apparent density

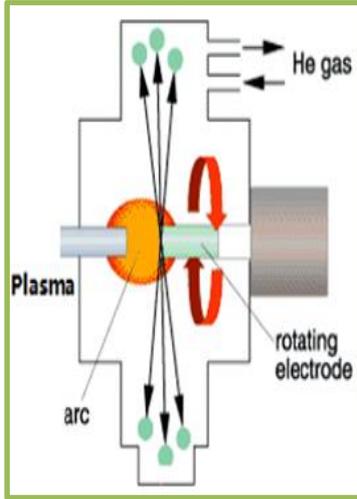
Typical Metal Powder Preparation Technologies



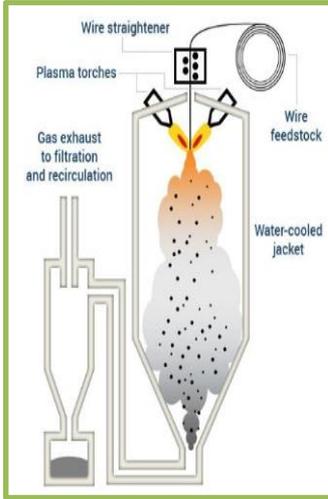
Vacuum Inert Gas
Atomization (VIGA)



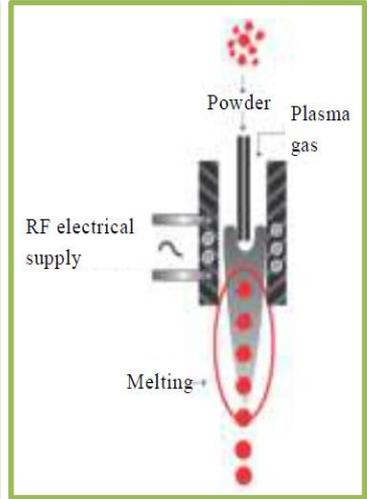
Electrode Induction Gas
Atomization (EIGA)



Plasma Rotating Electrode
Process (PREP)

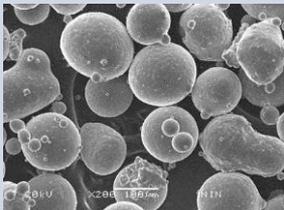
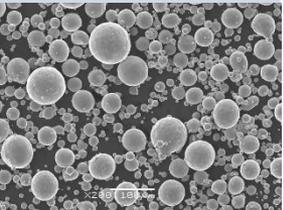
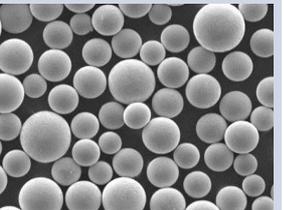
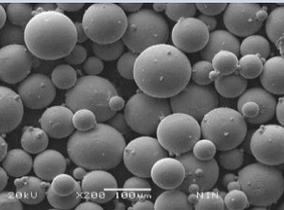
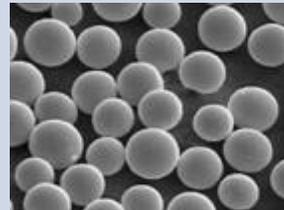


Plasma Atomization
(PA)

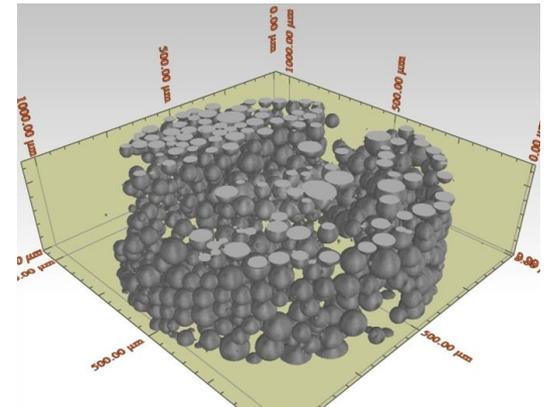
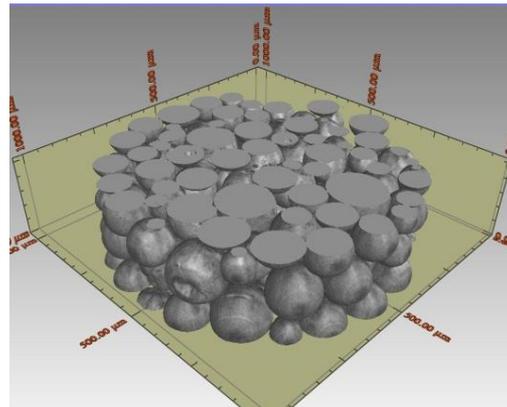
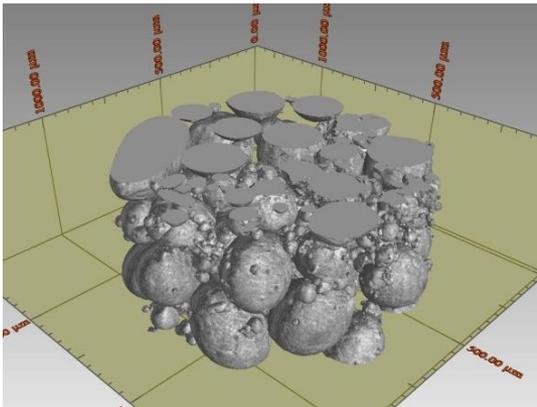
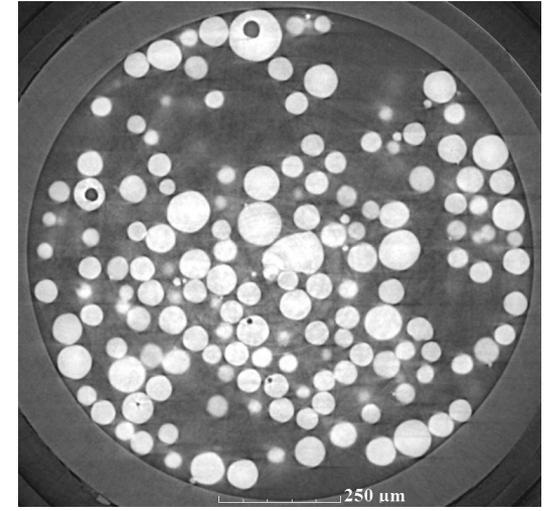
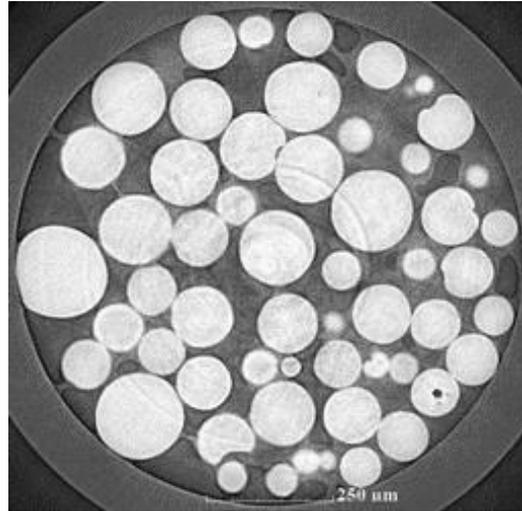
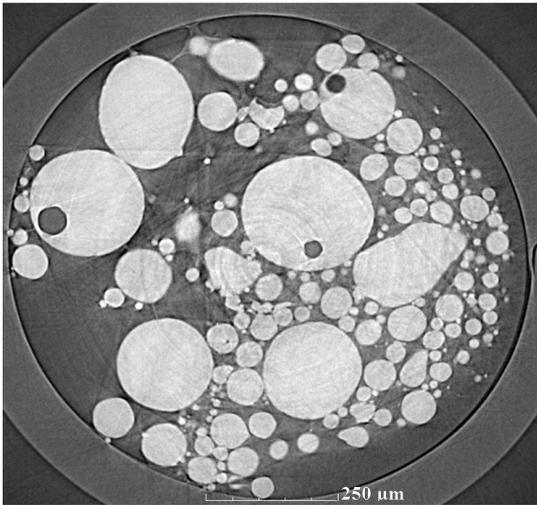


Plasma Spheroidization
(PS)

Typical Metal Powder Preparation Technologies

Powder Making Process	VIGA	EIGA	PREP	PA	PS
Raw Material	Elemental materials, ingots, bars, etc.	Precision machined bars	Precision machined bars	Wire material	Irregular powders
Powder Particle Size Distribution	Wide particle size distribution, certain percentage of fine powders (-325 mesh)	Wide particle size distribution, certain percentage of fine powders	Narrow particle size distribution and low percentage of fine powders	Wide particle size distribution, higher percentage of fine powders than VIGA and EIGA	Highly related to the raw powders, certain percentage of fine powders
Productivity	about 100kg/8h	about 100kg/8h	150~200kg/8h	<100kg/8h	<100kg/8h
Powder Morphology	Nearly spherical, Sphericity>80%	Nearly spherical, Sphericity>80%	Spherical, sphericity>90%	Spherical, sphericity>85%	Spherical, sphericity>85%
Powder Characteristics	Certain percentage of satellite and porous powders with a slightly higher oxygen content	Certain percentage of satellite and porous powders with a slightly higher oxygen content	Fewer satellite and porous powders, lowest oxygen content	Small amounts of satellite and porous powders, slightly higher oxygen content	Very small amounts of satellite and porous powders with high oxygen content
Limitations	Contamination by impurities	Large gas consumption	Low percentage of fine powders	Raw materials for filaments	Raw powders
SEM Pictures					

Pictures of Shape and Porosity

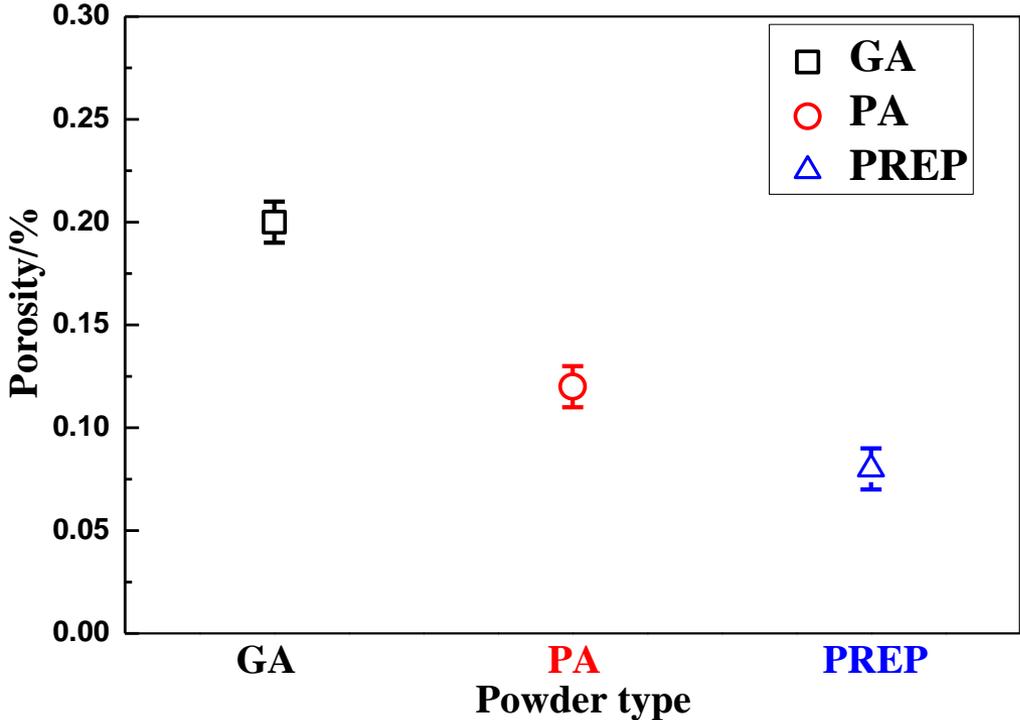


GA

PREP

PA

Statistics of Internal Porosity



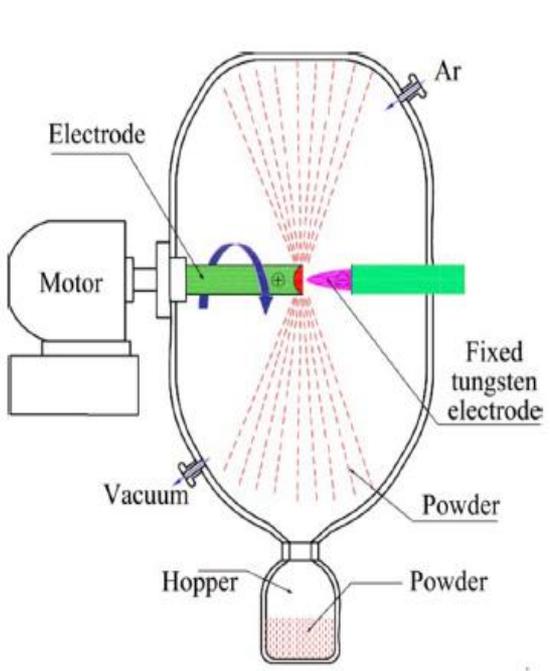
Porosity	GA	0.20 ± 0.01 vol.%
	PA	0.12 ± 0.01 vol.%
	PREP	0.08 ± 0.01 vol.%

Plasma Rotating Electrode Process (PREP)

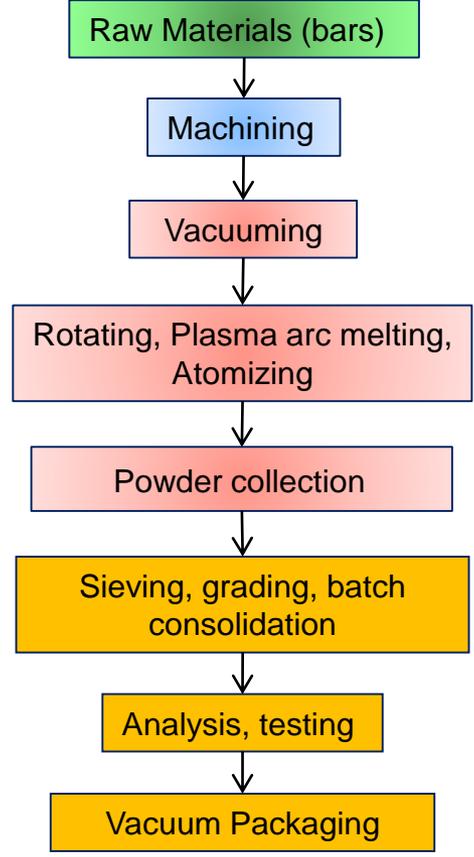
Principle and Process of PREP Technologies

In 1985, the Northwest Institute of Non-Ferrous Metals independently designed and developed the first PREP equipment in China.

The high-speed rotating electrode (raw material) is melted by the plasma arc under the protection of the high purity inert atmosphere, and the molten metal is thrown out by big centrifugal force to be atomised by the inert atmosphere and condensed into spherical powders when contacting to the internal wall of the cold chamber.



PREP Principle



PREP Process

Characteristics of PREPed Metal Powders

PREPed Spherical Metal Powders



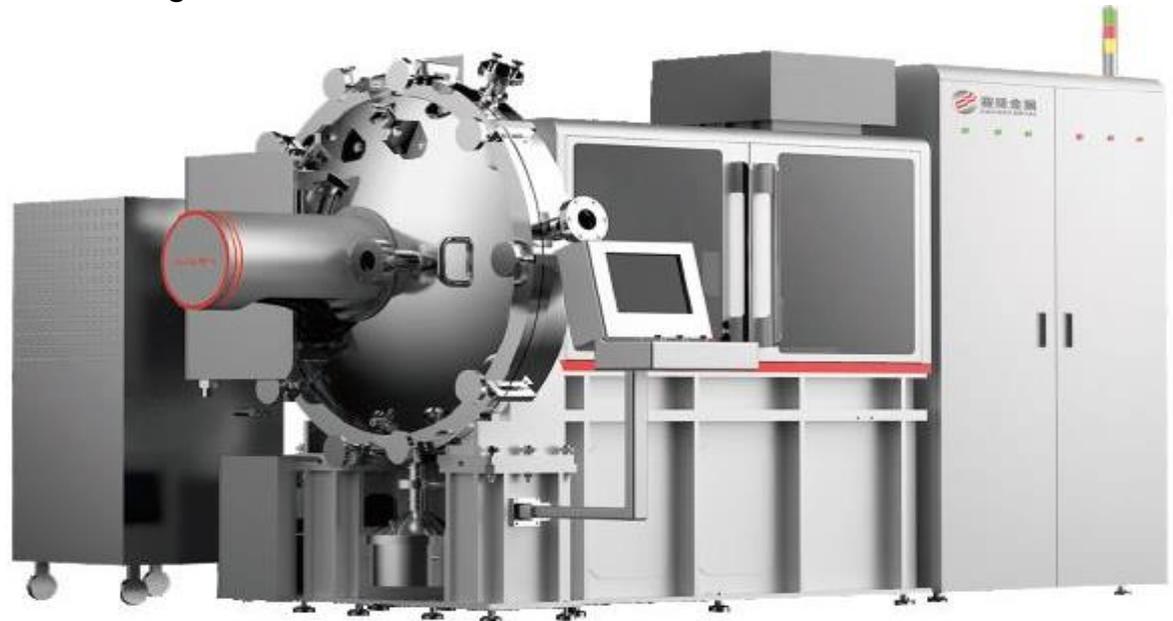
Characteristics of PREPed Metal Powders:

- ✓ Low increment of oxygen and other impurities (high purity)
- ✓ Perfectly spherical and essentially satellite-free
- ✓ Narrow particle size distribution, high flowability and high apparent/packing density
- ✓ Low internal porosity

Compact PREP Equipment: SLPA-D

Sailong's compact PREP equipment (SLPA-D) is purposely designed for R&D of novel alloy powders and small batch production of high quality powders with the following characteristics:

- ✓ High powder sphericity (over 90%), low porosity and satellite powders
- ✓ High purity (low oxygen content) due to atomizing in the inert atmosphere
- ✓ High rate of fine powders output due to significant increase in working speed
- ✓ Suitable for diversified powder demands
- ✓ Ergonomics friendly, easy to operate
- ✓ Simple and professional interface design
- ✓ Environment friendly
- ✓ Low cost



Technical Parameters and Constructure: SLPA-D

Main Technical Parameters	
Rotating speed of electrode rod	up to 50,000rpm (Adjustable)
Diameter of Eelectrode rod	Φ30mm
Powder Morphology	Spherical Rate ≥95%
Particle Size Distribution	$D_{50} \leq 43\mu\text{m}$ (High temperature alloy)
Capacity	≥10kg (8h, depending metal type)
Oxygen Increment	≤100ppm (Ti alloy ≤100ppm; High-temperature alloy ≤50ppm)
Atmosphere	Ar or He (high purity)
Maximum power	120kW
Floor Space	4m×3m×2.5m
Powder Materials	Ti&Alloys、Ni&Alloys、Co&Alloys Stainless steels, high entropy alloys, Al&Alloys, Cu& Alloys and refractory alloys

Main Technical Parameters
Plasma gun system
High speed rotary shaft system and dynamic sealing mechanism
Feeding system
Powder collection system
Atomizing chamber
Vacuum system
Cooling system
Gas supply system
Power supply and E-control system



Good Human-computer Interaction Experience

Hardware Configuration :

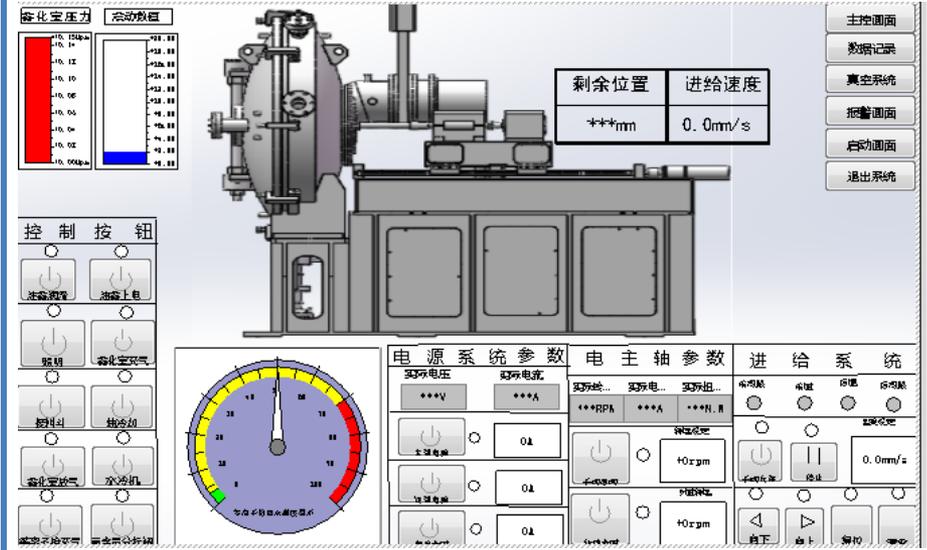
Core Control Components

The latest series of PLCs and IPCs from Siemens for industry-leading computing control and communication technology.

Key Drive Components

The feed system uses the latest Siemens drives and service motors for precise control.

High-speed rotating system, using Delta's top series frequency converters for ultra-high speed controlled operation.



Complete UI design :

Fully closed-loop design:

full closed-loop control of all operating buttons, key fully closed control of components.

Integrated design: the whole machine is divided into the main control system, the vacuum system, alarm system, data acquisition system, a total of 4 major systems, realizing the online operation of each component.

Intelligent design: by using machine vision and other cutting-edge technology, the main arc diameter and length can be real-time online measurement, recording and intelligent adjustment.



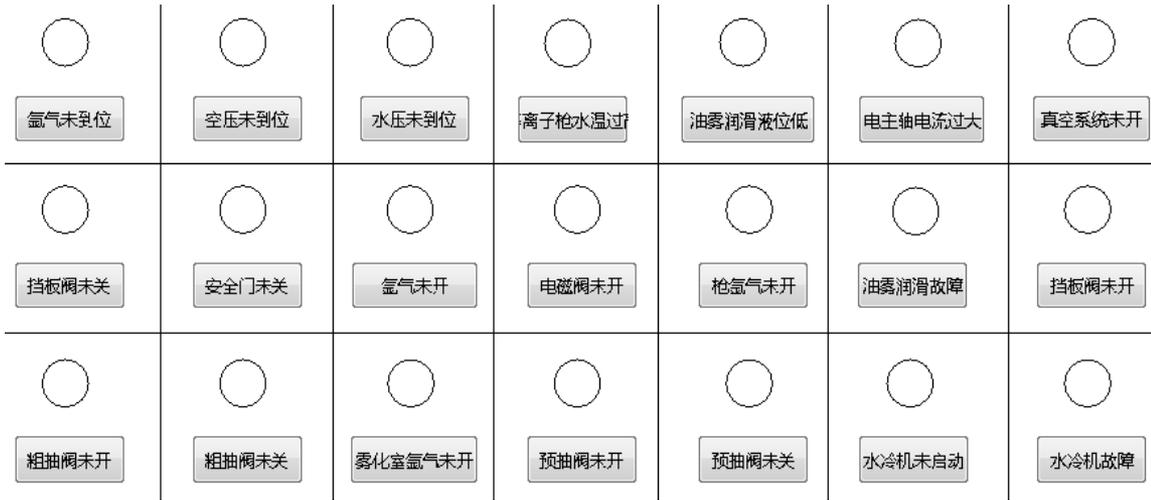
Ergonomic Design

Three-level Security

Level 1 Enables the protection of key components, including molecular pumps, mechanical pumps, electric spindles, feed motors, PLCs, etc..

Level 2 Enables automatic fault detection of key componentsection and det alarming of key components, including motors, cylinders, etc.

Level 3 Enables misuse, indiscriminate operation and other undesirable alarm indication of bad equipment use behaviour.



Online Recording of Process Data

- ◆ Enabling real-time online display of core data.
- ◆ Enabling real-time recording of core data.
- ◆ Enabling real-time preservation of core data.
- ◆ Core data includes: spindle speed, torque, Main arc current, etc.

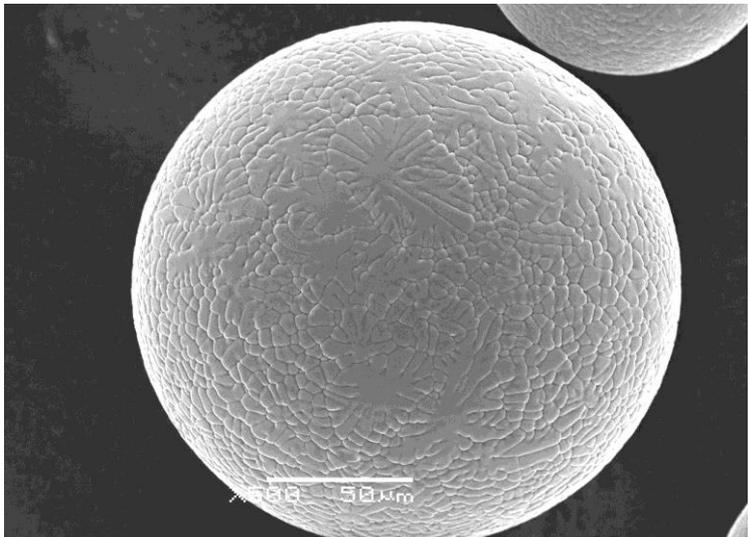
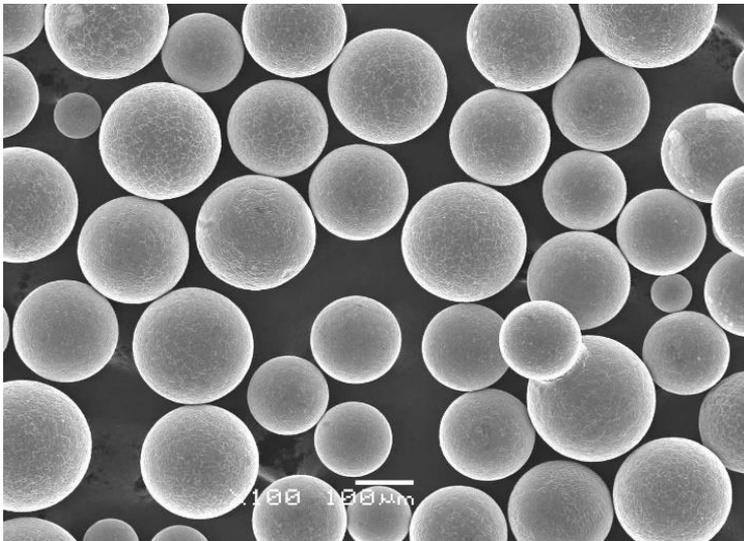
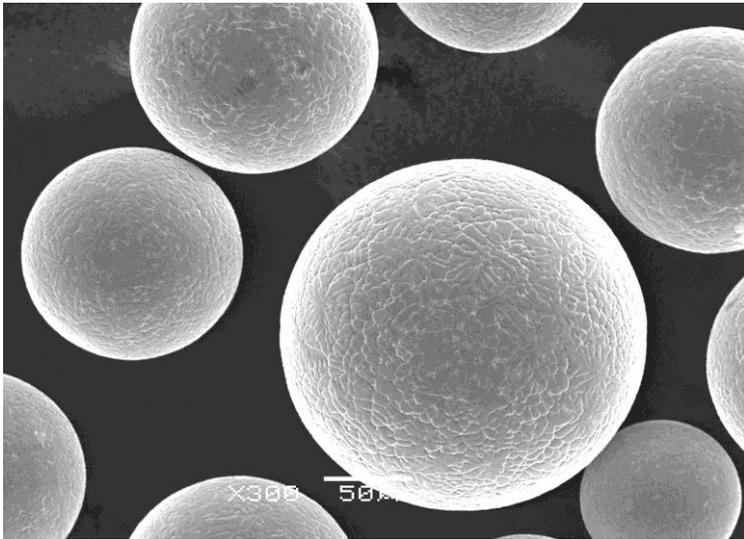
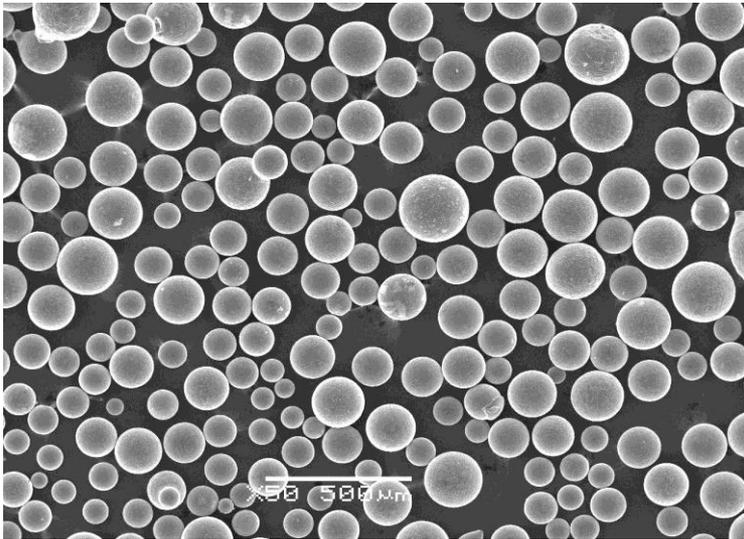
Spindle speed/rpm	Spindle torque	Spindle current	Ar pressure
12001	1.3	19.62	0.05
11997	1.3	19.58	0.06
11994	1.23	18.01	0.07
11997	1.16	17.91	0.09
11994	0.91	19.97	0.11
12275	1.41	20.94	0.12
12501	1.08	19.38	0.13
12495	1.14	19.4	0.14
12504	0.71	19.57	0.14
12496	1.2	20.31	0.14
12888	1.83	20.52	0.14
13009	1.19	17.81	0.14
12997	0.98	17.03	0.14
12993	1.16	19.54	0.14
13003	0.96	18.65	0.14

Video of Melting and Atomizing (PREP)

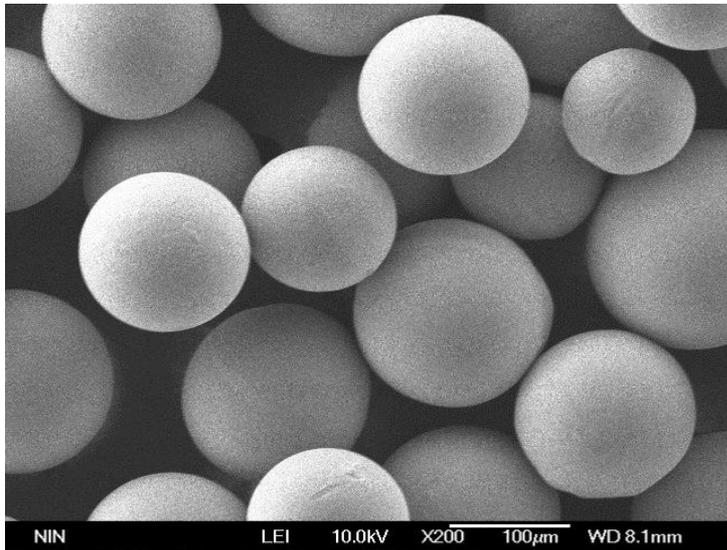
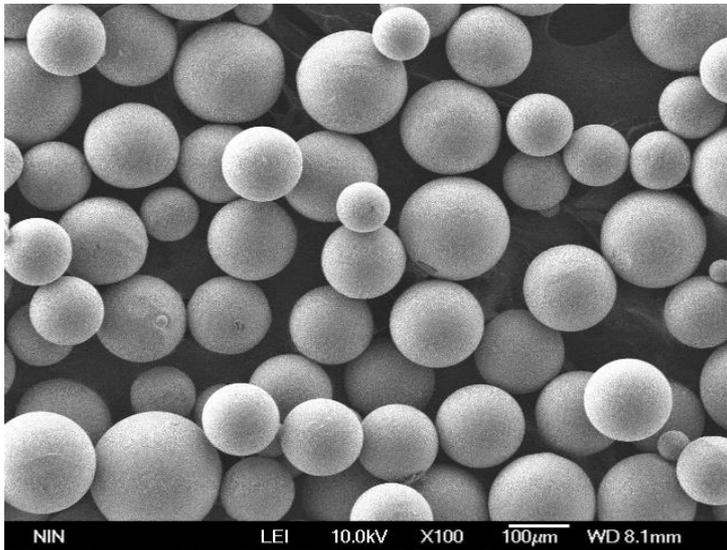
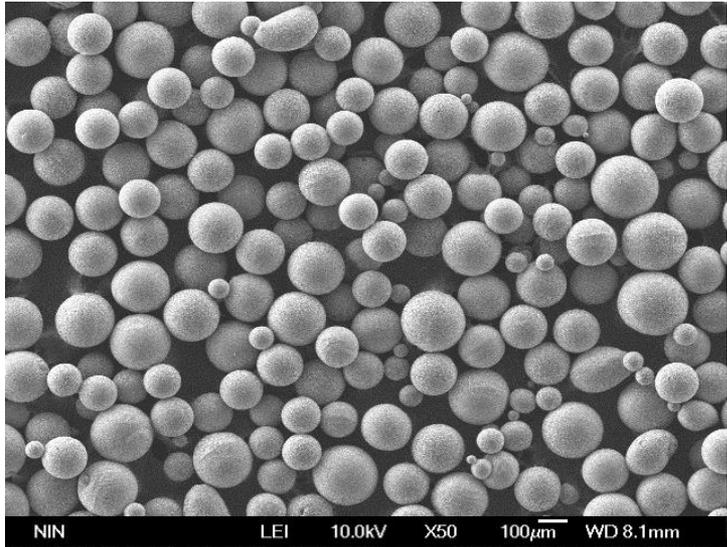
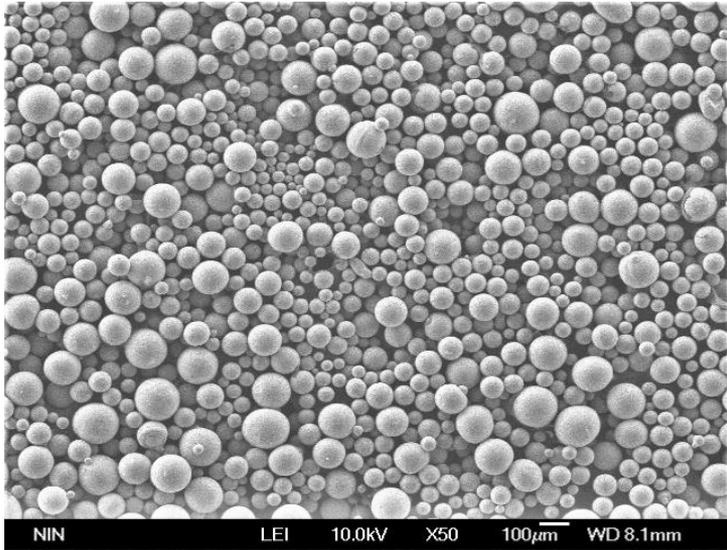


Experimental Data: Metal Powders Practice

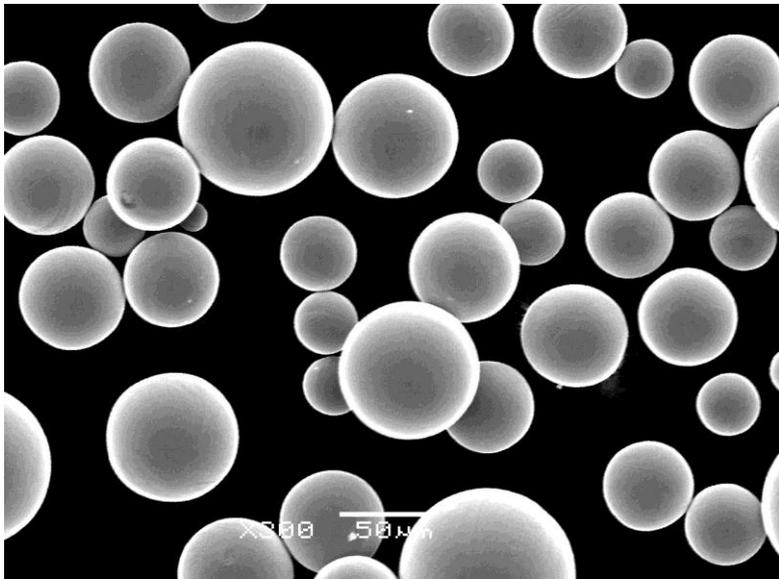
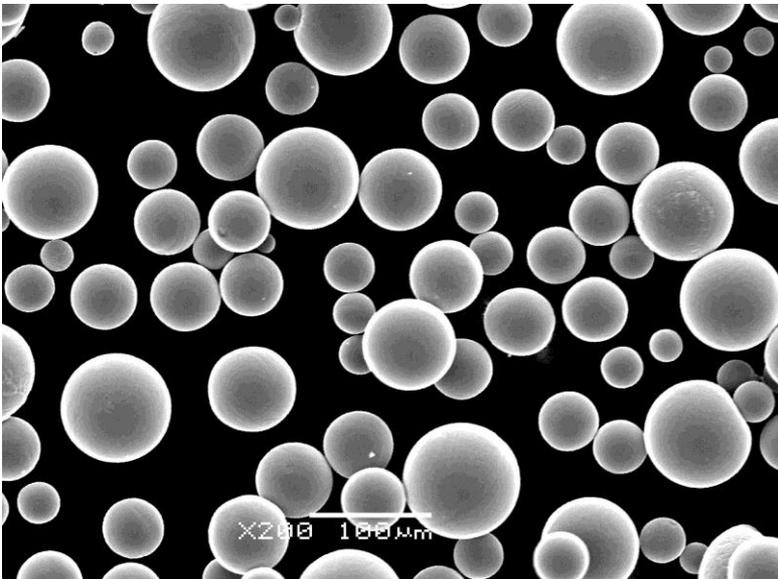
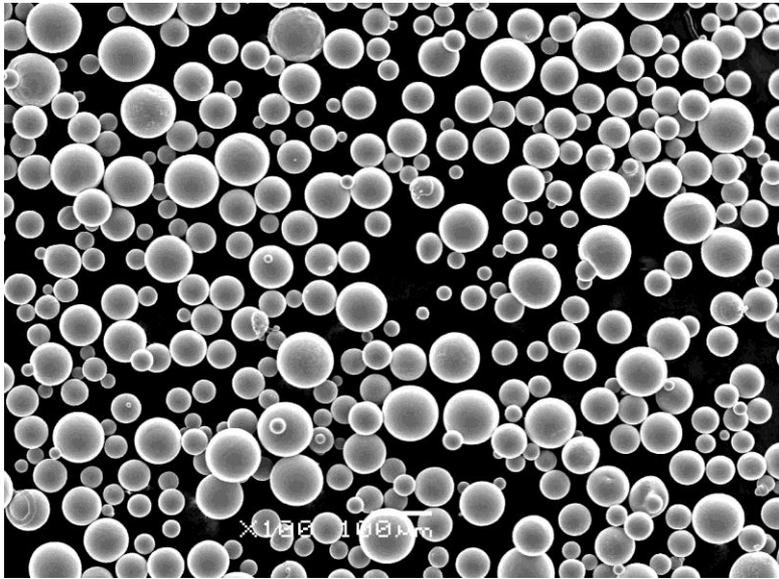
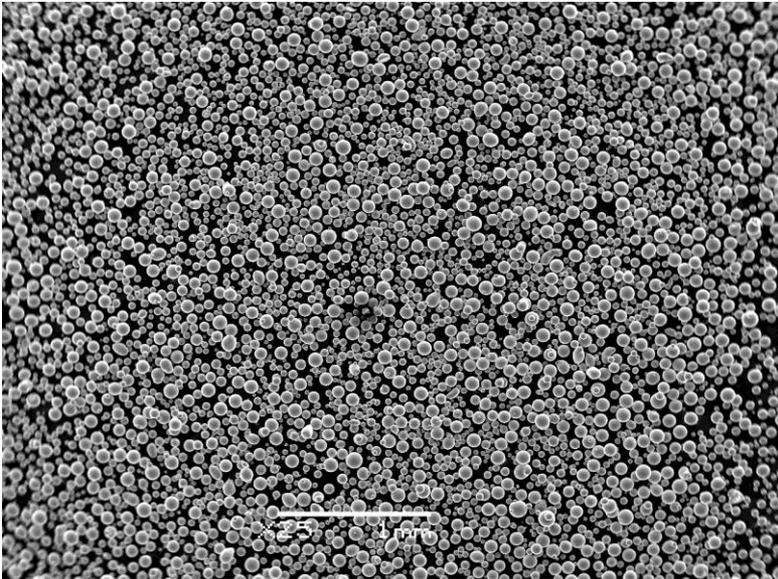
SEM: Al-alloy powders



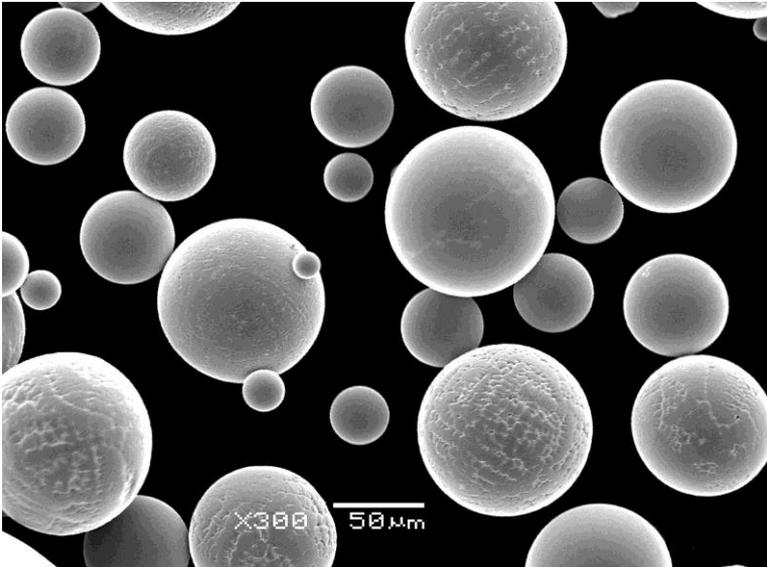
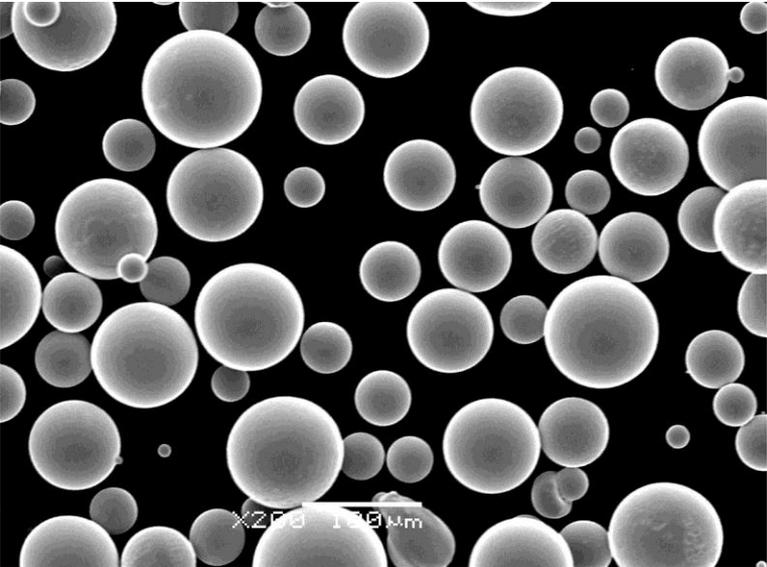
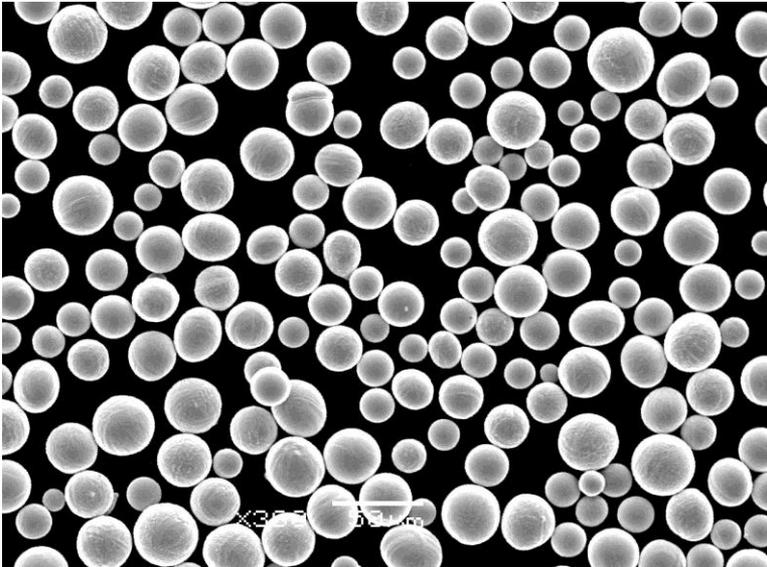
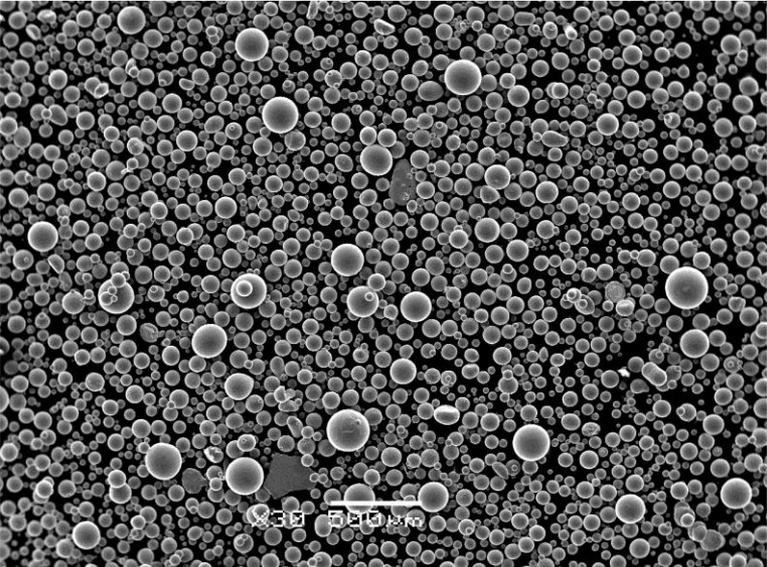
SEM: Ti-alloy powders



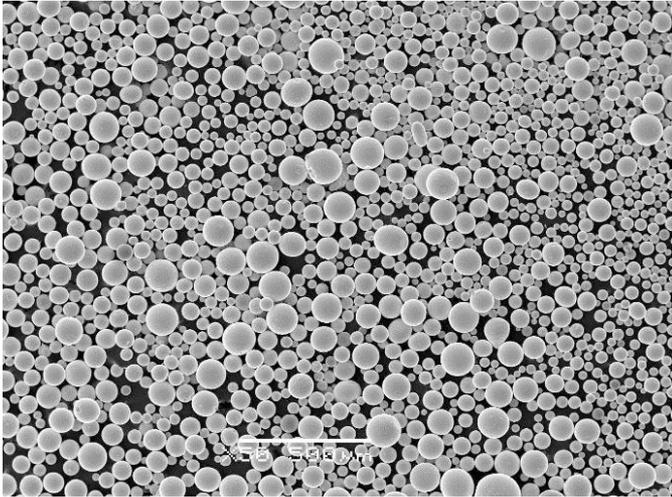
SEM: High purity Ti powders



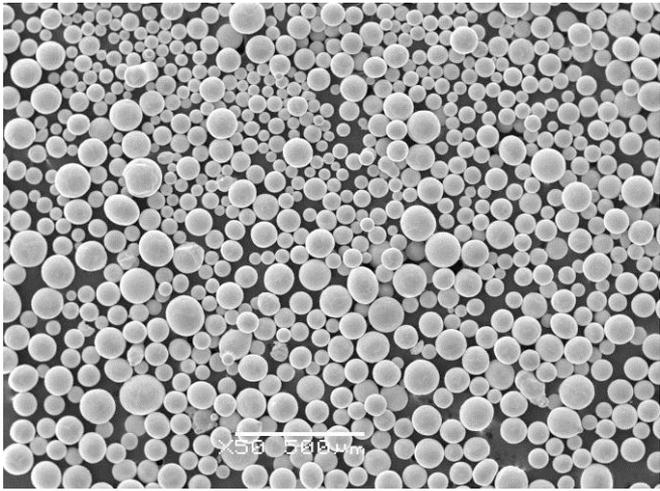
SEM: High-temperature alloy powders



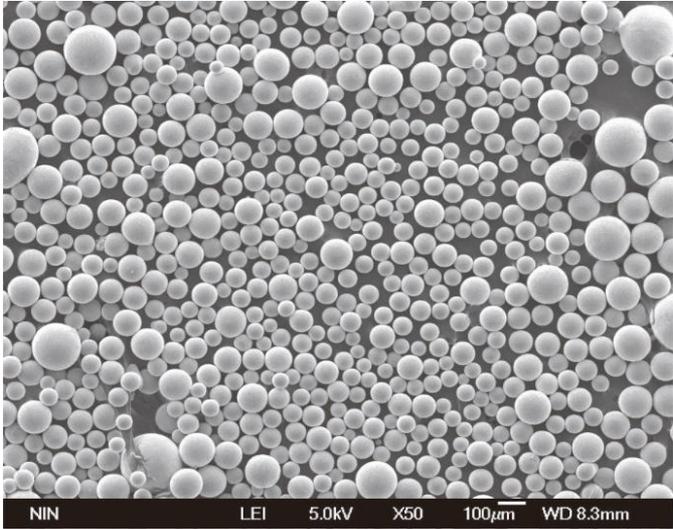
SEM: Refractory Metal and Alloy powders



Ta powders

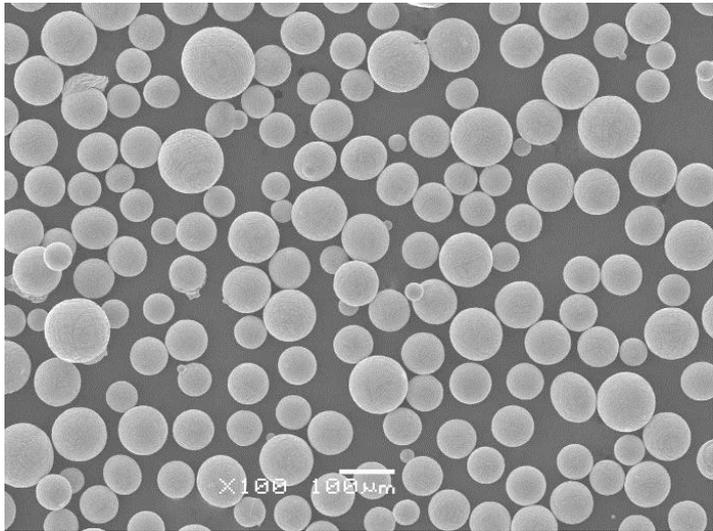


Nb521 powders

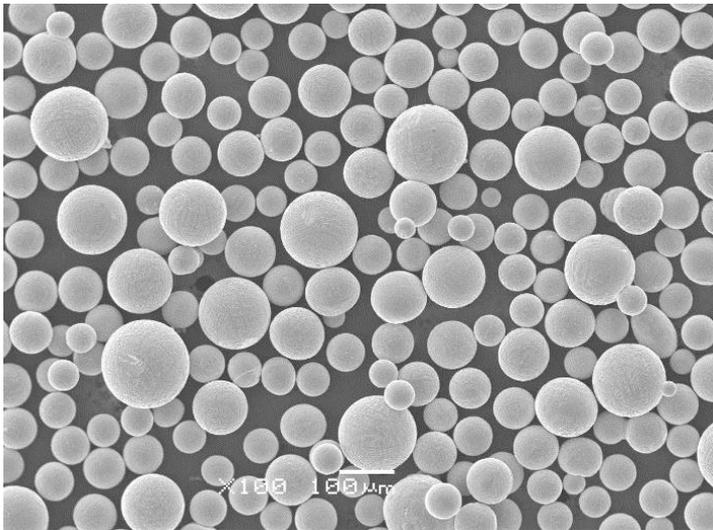


CoCrMo powders

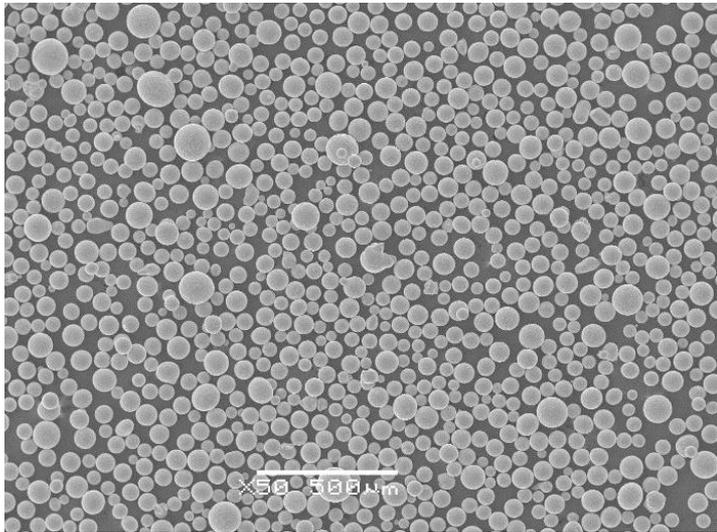
SEM: Steel Alloy powders



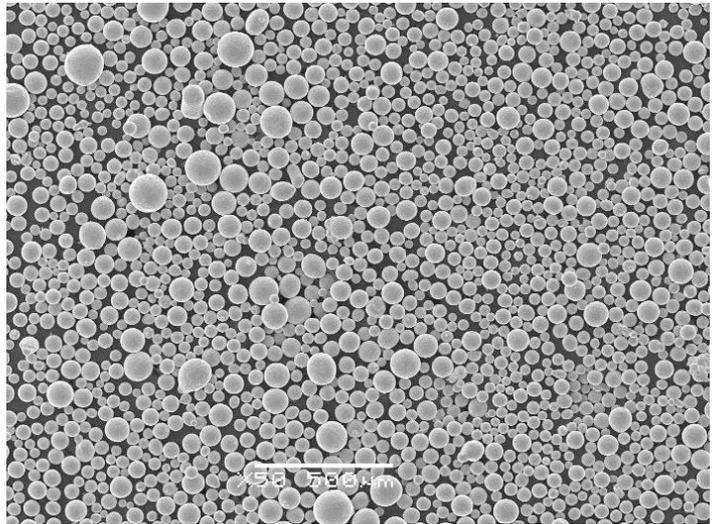
GCr15 powders



30Cr powders



Steel C45 powders



316L powders

SEM: Steel Alloy powders produced by SLPA-D

Experimental Data: Properties of Powders

TC4 Powders produced by SLPA-D

Mesh	Micron	Percentage (%)
+100	>150	7.39
-100~+140	106~150	11.81
-140~+200	75~106	18.89
-200~+270	53~75	45.98
-270~+325	45~53	9.10
-325	<45	7.83
Oxygen content (wt%)		0.06-0.18
Flowability (s/50g)		20-35

IN718 Powders produced by SLPA-D

Mesh	Micron	Percentage (%)
+100	>150	0.09
-100~+140	106~150	1.57
-140~+200	75~106	8.80
-200~+270	53~75	10.52
-270~+325	45~53	15.58
-325	<45	63.44
Oxygen content (wt%)		≤ 0.007
Flowability (s/50g)		12-20

Thank you for your attention!

Contact: Luke Zhang

Email: zhangls112@163.com