Atomized Nb powder for superconducting

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Investigation of Nb atomized powder

Complicated shape parts made by Nb (Nb alloy) are required for SRF accelerator components, ex. HOM coupler.
Additive manufacturing (3D-printing) can produce such complicated parts easier.
Furthermore, higher performance components can be designed/produced by additive manufacturing.

→ULVAC investigates atomized Nb powder.

Request

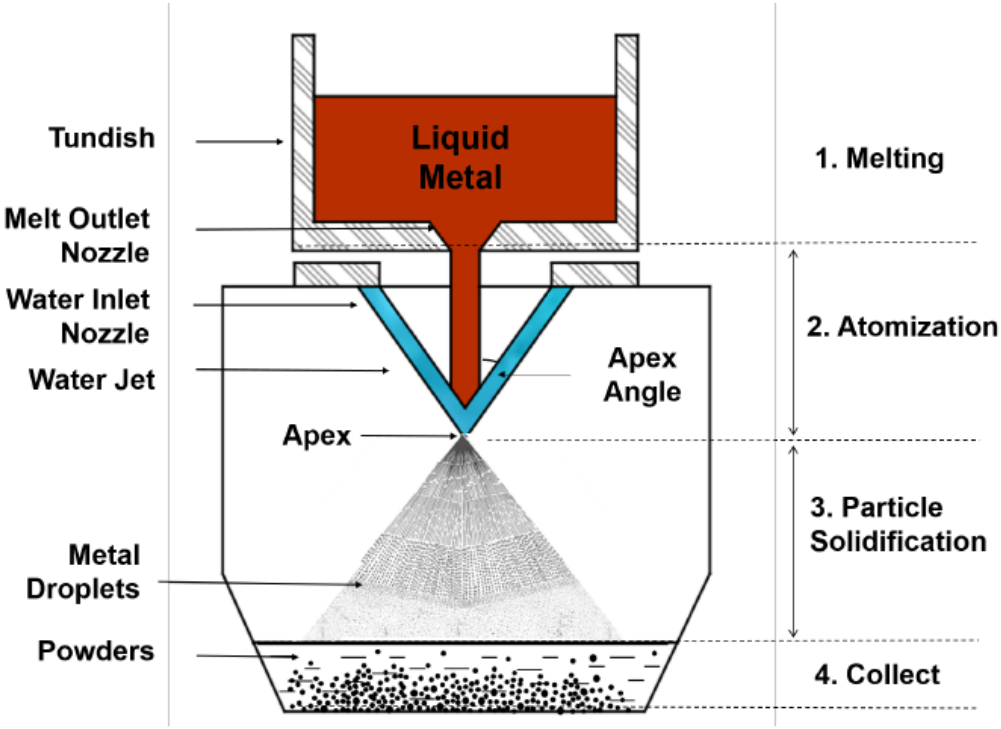
- ✓ High purity: RRR ~ 250 (OR more)
- ✓ Good sphere-shape
  More dense after melting
- ✓ Good grain size distribution
  Convenient to use different procedure (ex. EBM & LBM)
- ✓ No defect on the grain surface

Atomized powder

Example of atomization process

1. Melted metal is pulled into tundish
2. Melted metal is coming out from nozzle
3. High pressure gas/air/water is splayed to melted metal.
4. Sort powders by size

Can process good sphere-shape
→Suitable for additive manufacturing



Example of atomization process
Z. Jiao et al., "Influence of Apex Angle and Nozzle Design on Energy and Momentum Transfer During the Water Atomization Process", 2017

ULVAC case
Splayed gas: Ar
Chamber is vacuumed and Ar purged

Produced powder

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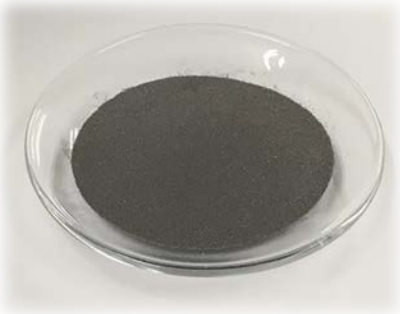
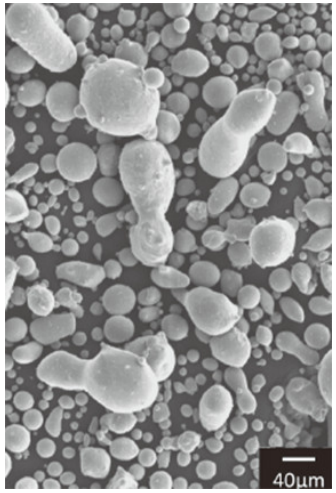


Classified Nb Powder.
(Diameter: 53 - 106 µm)



Example of Bad powder

	< 53 µm	53 – 106 µm	106 – 180 µm
Surface	Fig. 1	Fig. 2	Fig. 3
Cross	Fig. 4	Fig. 5	Fig. 6

500 µm

SEM images of Nb Powder.
Fig. 1-3: Surface morphology
Fig. 4-6: Polished cross section

Each powder is well separated and has good sphere-shape

Powder characteristic

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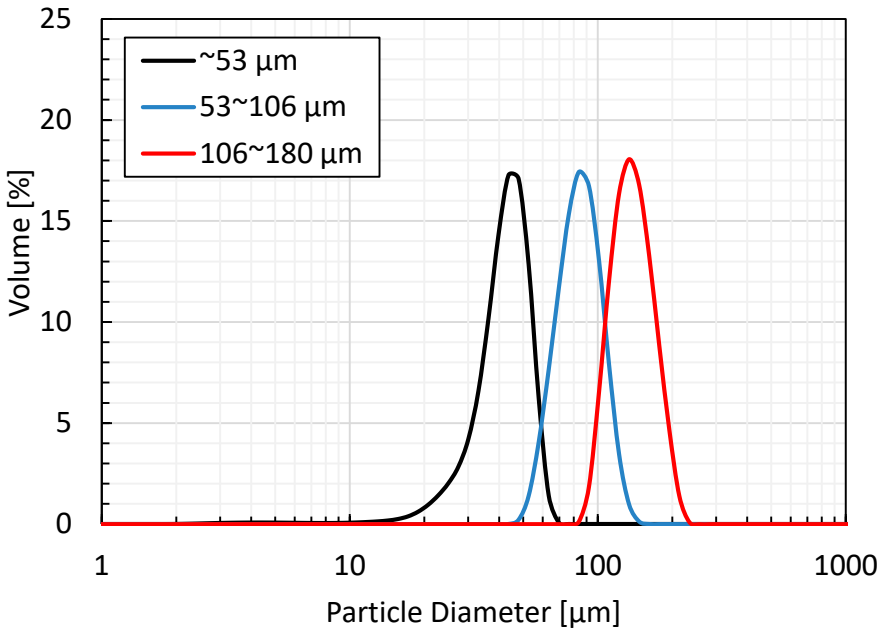
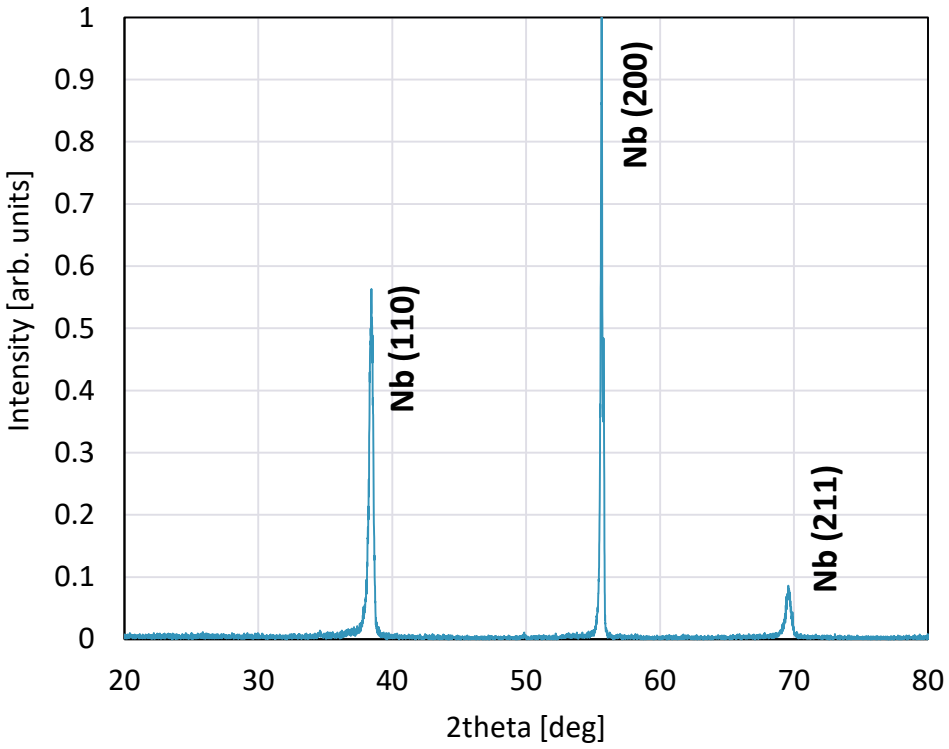


D (µm)	< 53 µm	53 - 106 µm	106 -180 µm
＜10％	30.2	66.9	112.4
＜50%	44.9	88.5	143.2
＜90%	56.9	114.4	186.7
Mean	42.2	87.9	143.9

Particle size distributions of Nb powder
*Method: Laser diffraction analysis



XRD pattern of Nb powder.

- **Particles are well sorted by size.**
- **Only Nb is observed by XRD analysis.**

Chemical components

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Element	Ingot	Feedstock	Powder	Ref. ASTM type5 Grade
Al	Not Measured	<10 ppm wt.	<10 ppm wt.	50 ppm wt.
Si	<10 ppm wt.	<10 ppm wt.	10 ppm wt.	50 ppm wt.
Ti	<5 ppm wt.	<5 ppm wt.	<5 ppm wt.	50 ppm wt.
V	Not Measured	<10 ppm wt.	<10 ppm wt.	—
Cr	Not Measured	<10 ppm wt.	<10 ppm wt.	—
Mn	Not Measured	<5 ppm wt.	<5 ppm wt.	—
Fe	<10 ppm wt.	<10 ppm wt.	<10 ppm wt.	50 ppm wt.
Ni	<10 ppm wt.	<10 ppm wt.	<10 ppm wt.	30 ppm wt.
Cu	Not Measured	<10 ppm wt.	<10 ppm wt.	—
Zr	<10 ppm wt.	<10 ppm wt.	<10 ppm wt.	100 ppm wt.
Mo	<10 ppm wt.	10 ppm wt.	10 ppm wt.	—
Hf	Not Measured	<10 ppm wt.	<10 ppm wt.	—
Ta	60 ppm wt.	60 ppm wt.	70 ppm wt.	1000 ppm wt.
W	10 ppm wt.	10 ppm wt.	70 ppm wt.	70 ppm wt.
B	Not Measured	<2 ppm wt.	<2 ppm wt.	—
Co	Not Measured	<10 ppm wt.	<10 ppm wt.	—
Be	Not Measured	<10 ppm wt.	<10 ppm wt.	—
Mg	Not Measured	<10 ppm wt.	<10 ppm wt.	—

*Method: ICP-AES (Tungsten due to cross-contamination during atomization)

Only Few contamination during atomization is observed
→Still better than ASTM type5 grade

Chemical components 2 & RRR

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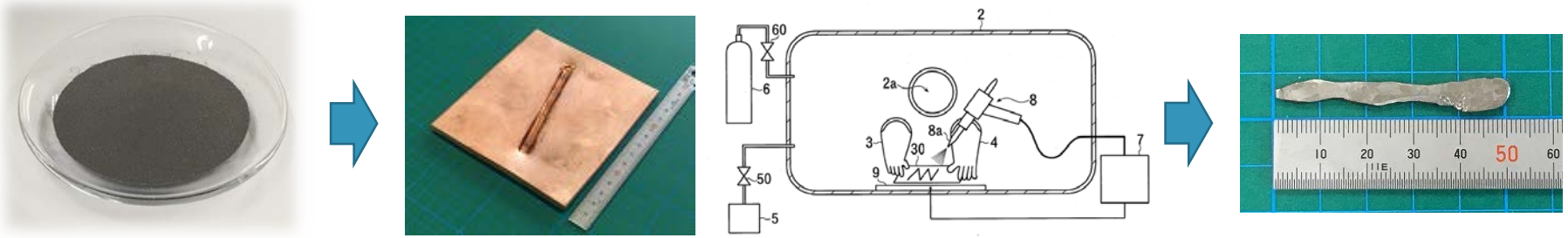
	Ingot	Feedstock	Powder (< 53 µm)	Powder (53 - 100 µm)	Powder (106 - 180 µm)	Ref. ASTM type5
Oxygen	< 10 ppm wt.	< 10 ppm wt.	920 ppm wt.	490 ppm wt.	360 ppm wt.	40 ppm wt.
Nitrogen	< 10 ppm wt.	< 10 ppm wt.	350 ppm wt.	220 ppm wt.	180 ppm wt.	30 ppm wt.

Chemical components (Oxygen & Nitrogen) (*Method: IGF-IRA)



RRR sample production

Shape	RRR
Ingot	**348**
Feedstock	**306**
Bar	**8.4**

- **Oxygen and Nitrogen contents increase during atomization.**
- **RRR of bar is much worse than original material**

- **Need enough degassing of chamber for atomization**
- **Produce RRR sample by EBW**

Future plan

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Collaboration scheme

- Powder production, powder analysis (chemical components, RRR, etc.) :ULVAC
- 3D printing: under consideration
- Characteristic evaluation (RF characteristic): KEK

Target

Parts for HOM coupler

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