Development of refractory metal powders for application in additive manufacturing processes

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I.FAST online presentation, 05. May 2022

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TANIOBIS at a glance

TANIOBIS is a **leading global producer** with over **60 years of experience** in processing of a broad range **of high-quality tantalum and niobium-based materials**

Since July 1st 2018, **TANIOBIS GmbH has been a part of the JX Nippon Mining & Metals Group**

*As of December 31st, 2019

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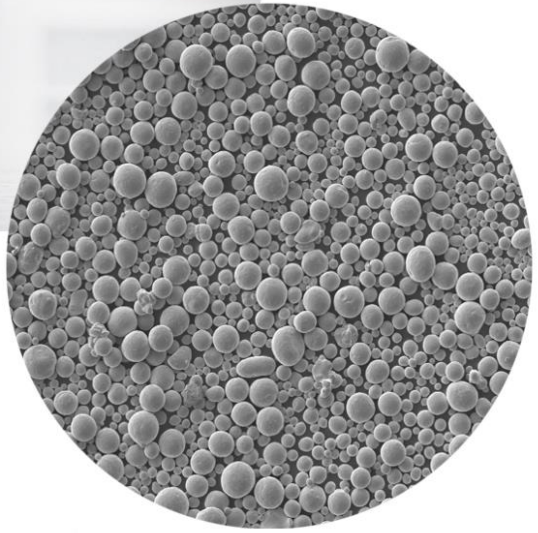

AM

= Additive Manufacturing

→ Laser Powder Bed Fusion (L-PBF)
→ Electron Beam Fusion (EBM)
→ Direct Metal Deposition (DMD)
→ Laser Cladding (LC)

trinsic®

= intrinsic

→ Intrinsic material properties
→ Pre-alloyed refractory alloy powders
→ Customized solutions
→ Excellent processability

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AMtrinsic® spherical powders

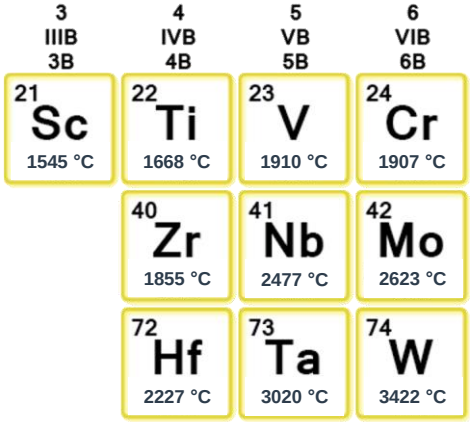
Historical

- 2015 Nb, Ta general
- 2016 Ti/Nb biomedical
- 2017 Ti/Nb/Ta biomedical improved
- 2019 C-103 HT
- 2020 FS-85 HT improved
- 2020 RM HEAs academic
- 2021 Metal/Ceramic Composites

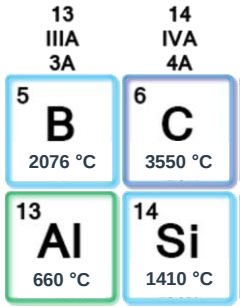
- Since 2017 various customer-specific alloys (compositions shall not be disclosed)

Elements in AMtrinsic alloys (MP)

Refractory



Main group



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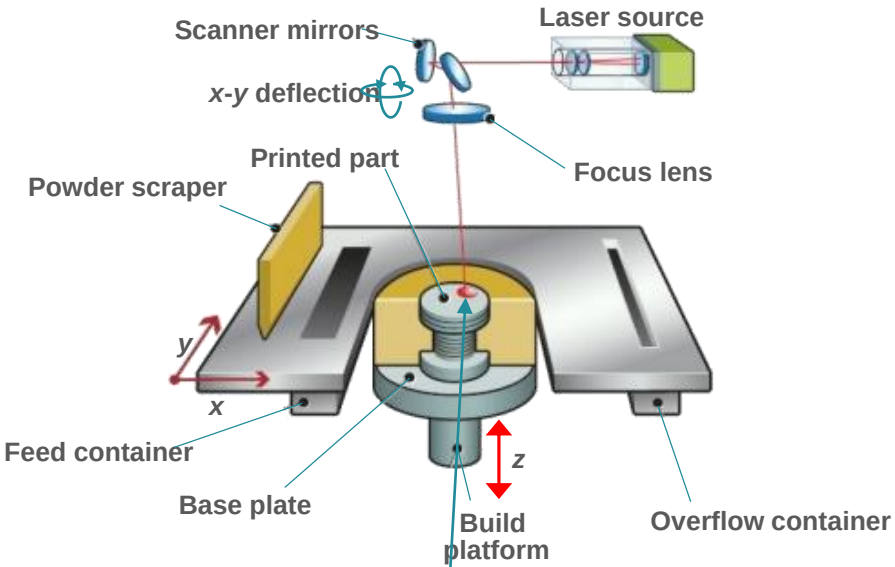
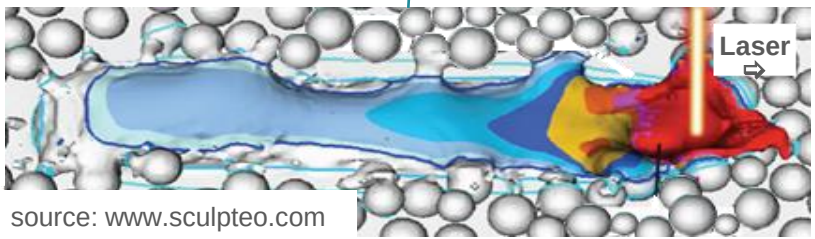
Printing AMtrinsic® spherical powders

Laser powder bed fusion - principles





source: www.sculpteo.com

Principle: layer-wise formation of bulk parts

- substrate plate is coated with powder
- consolidation of selected areas by laser melting
- Lowering build platform

- removal of loose powder
- finishing treatments

Requirements

- pre-alloyed powder (no mixtures)
- narrow PSD with d90 < 60 µm
- excellent powder flow
  → spherical particles

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AMtrinsic® spherical powder production

Challenges

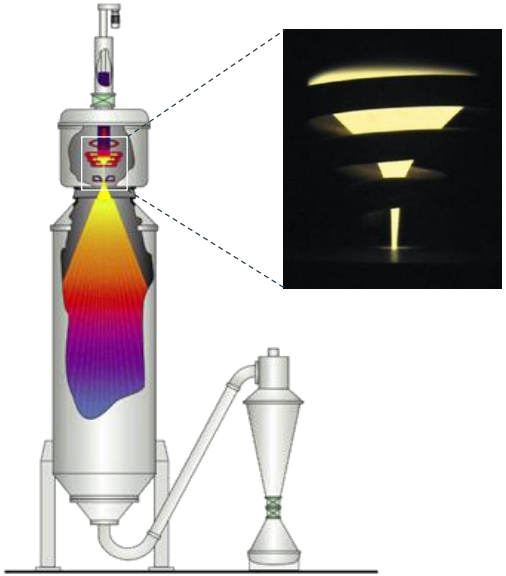
- Atomization using conventional crucible-based processes almost impossible
  - → lack of crucible materials for UH temperature
  - → contamination of target material with crucible material
  - → oxidation
- Atomization using wire limited to very simple and ductile systems
- Spheroidization requires pre-alloyed powders

Solution

- Electrode induction-melting gas atomization (EIGA)
  - → contact-free inductive melting of pre-alloyed or PM rods
    - → in-situ alloying of PM rods during inductive melting
  - → almost no limitation in material composition: from elemental to multinary (e.g. HEA)
  - → adjustable particle size distribution
  - → dense, spherical particles with good processability

Electrode Induction-melting Gas Atomization

Production setup



Source: ALD

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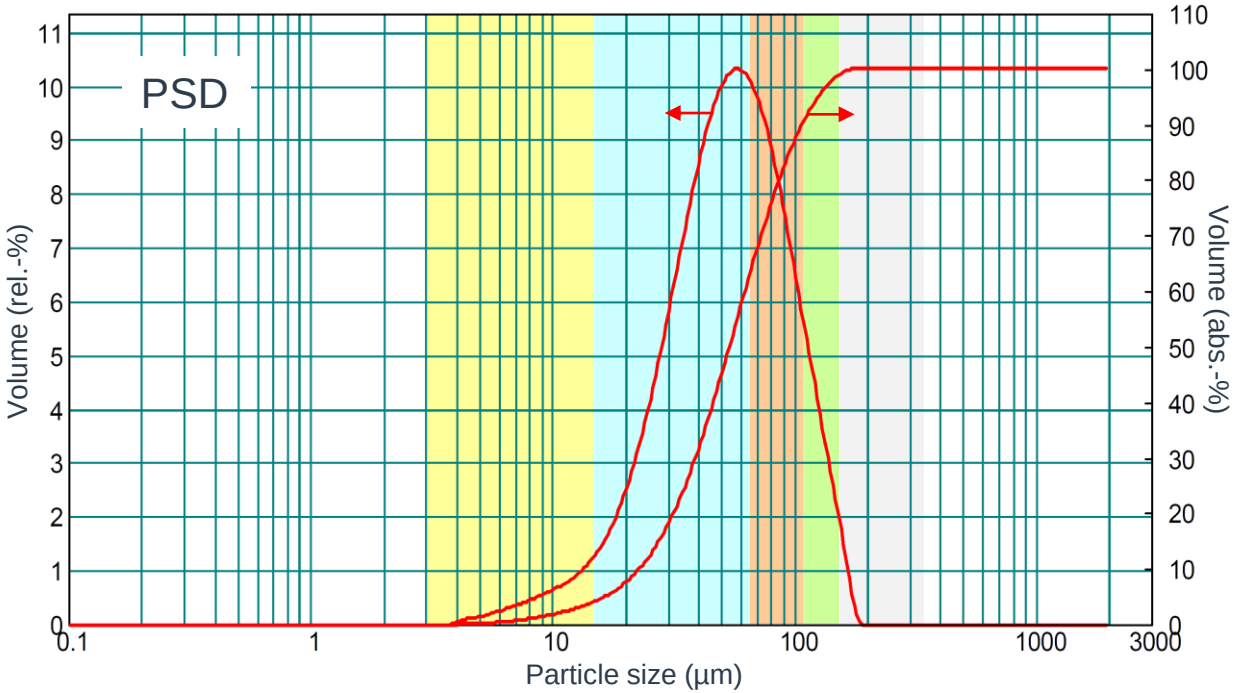
Post-atomization processing: classification required



< 15 µm:	dispose
15 – 63 µm:	L-PBF
63 – 105 µm:	SEBM
105 – 150 µm:	LC, LMD
> 150 µm:	dispose

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M. Weinmann et al., Int. J. Refractory Met. Hard Mater. 75(2018) 126

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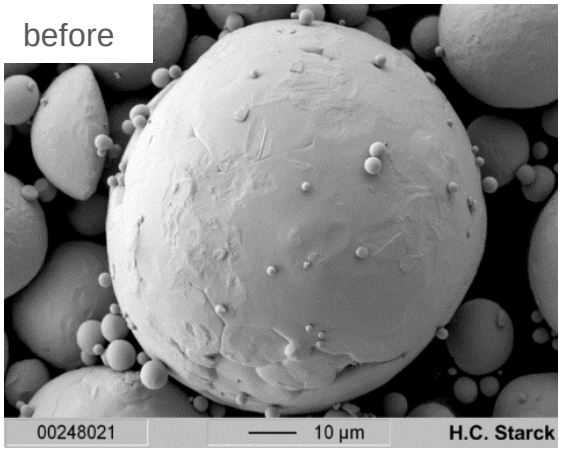
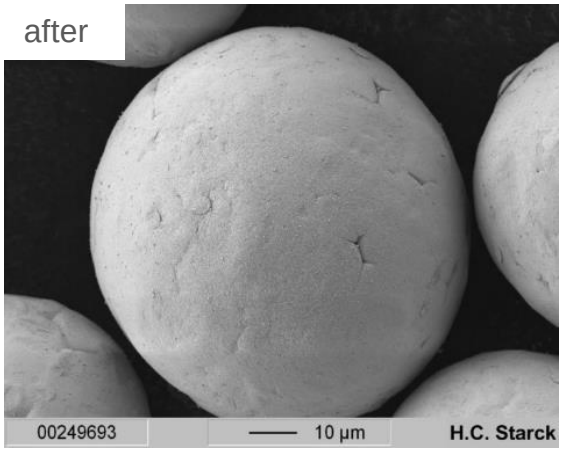
Post-atomization processing: de-oxidation by metal vapor reduction

- Example: Nb de-oxidation by Mg vapor

before



after



Fraction (µm)	O as obtained (ppm)	O after Deox (ppm)
105-150	1512	171
63-105	1716	268
<63	2038	247

- Extremely low O content in AMtrinsic® Nb → unique capabilities @TANIOBIS
- Removal of fine fraction after leaching
- No satellites, no agglomeration → very good flow
- Deoxidation of Ti-containing alloys under investigation

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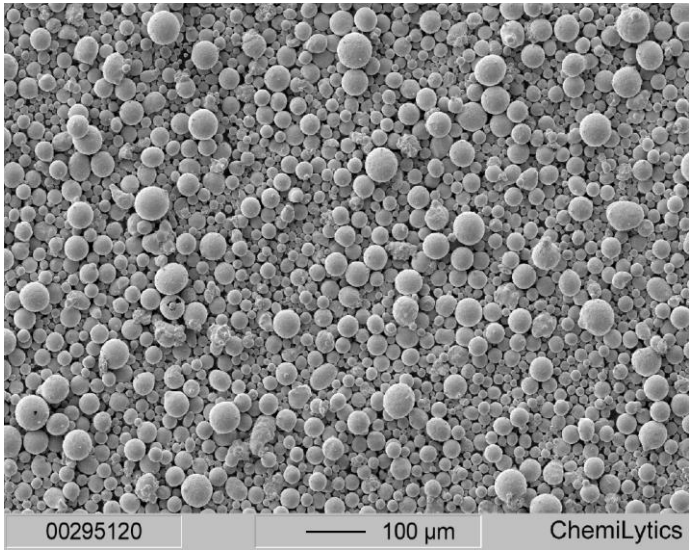
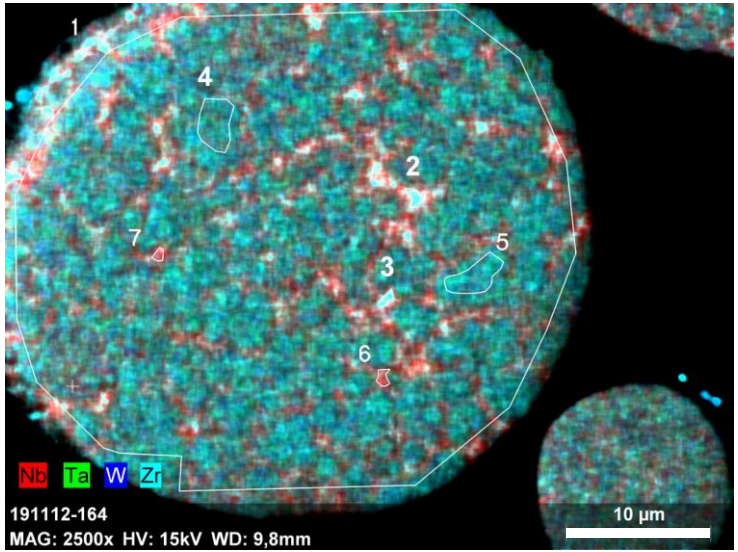
FS-85 powder morphology: alloys for HT application (Nb-28Ta-10W-1Zr)





wt-%	1 (average)	5	6 (inter-dendrite)
Nb	63,3	54,6	66,5
Ta	26,1	31,3	22,6
W	9,2	13,7	9,3
Zr	1,3	0,4	1,6

dendrite

SEM: spherical, no satellites or agglomerates
EDX: dendrite-type, though less pronounced.
- Ta/W-enriched dendrite vs. Nb/Zr-enriched inter-dendrite phase

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Printing AMtrinsic® spherical powders: Niobium

Parts for superconductor application

printed @CERN

HOM coupler Crab cavity DQW printed @CERN

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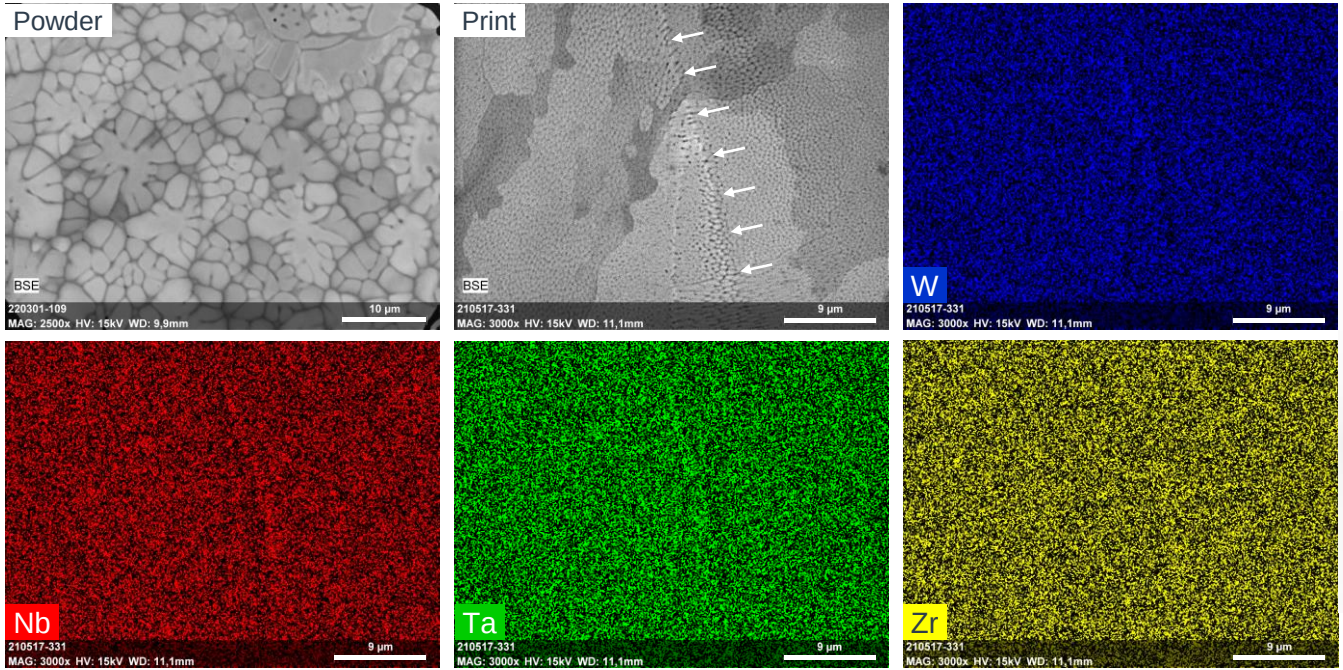
https://indico.cern.ch/event/742082/contributions/3085128/attachments/1735232/2806832/Additive_Manufacturing_For_Crabs_-_HL-LHC_Collaboration_meeting_8th_-_OCT2018_2.pdf

Printing AMtrinsic® spherical powders: FS-85

Parts for high-temperature application (Nb-28Ta-10W-1Zr)



Satellite thruster ©Alloyed

- Crack- and pore-free, homogeneous element distribution without dendrites
- Melt tracks and grain boundaries visible
- Mechanically fully investigated, superior to C-103

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