OAK RIDGE National Laboratory

WANDA 2024

Development of Spherical Metal Powder Targets

Mike Zach

Sr. Materials Processing Researcher

Isotope Science and Engineering Directorate

Oak Ridge National Laboratory

ORNL is managed by UT-Battelle LLC for the US Department of Energy

This work is supported by the U.S. Department of Energy Isotope Program, managed by the Office of Science for Isotope R&D and Production

U.S. DEPARTMENT OF ENERGY

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Sr. Materials Processing Researcher

- 10+ years as Jeweler, sculptor, entrepreneur
- 10+ years in academics & postdocs: UWSP, UCI, Berkeley, Argonne
- Tenured Professor, NSF CAREER Award, 9 years
- ORNL, Stable Isotopes, 9 years

Mike Zach

Overview

- Advantages of spherical powders
- Overview of spheroidized powder – How it's made
- How it can benefit the nuclear data community
  - Dispensing
  - Novel porous targets
  - 3D printing
  - Inverted target design

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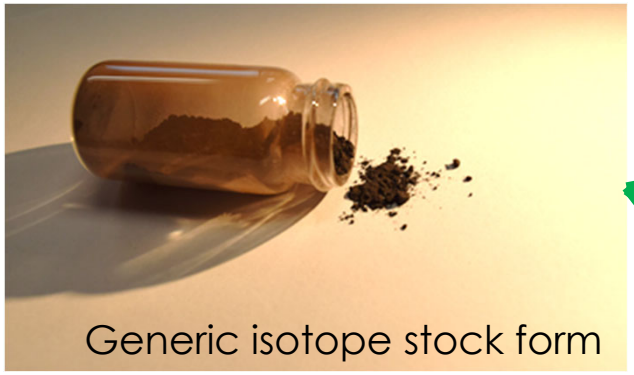
Our Technical Services Enables Science While Conserving The DOE Isotope Program's Inventory



We apply our expertise, tools, and creativity to transform isotopes into unique forms required by the research community

Transformations at very small scale

- We have the materials, tools and skills
- Strive for zero loss
- Take all needed precautions to ensure safety

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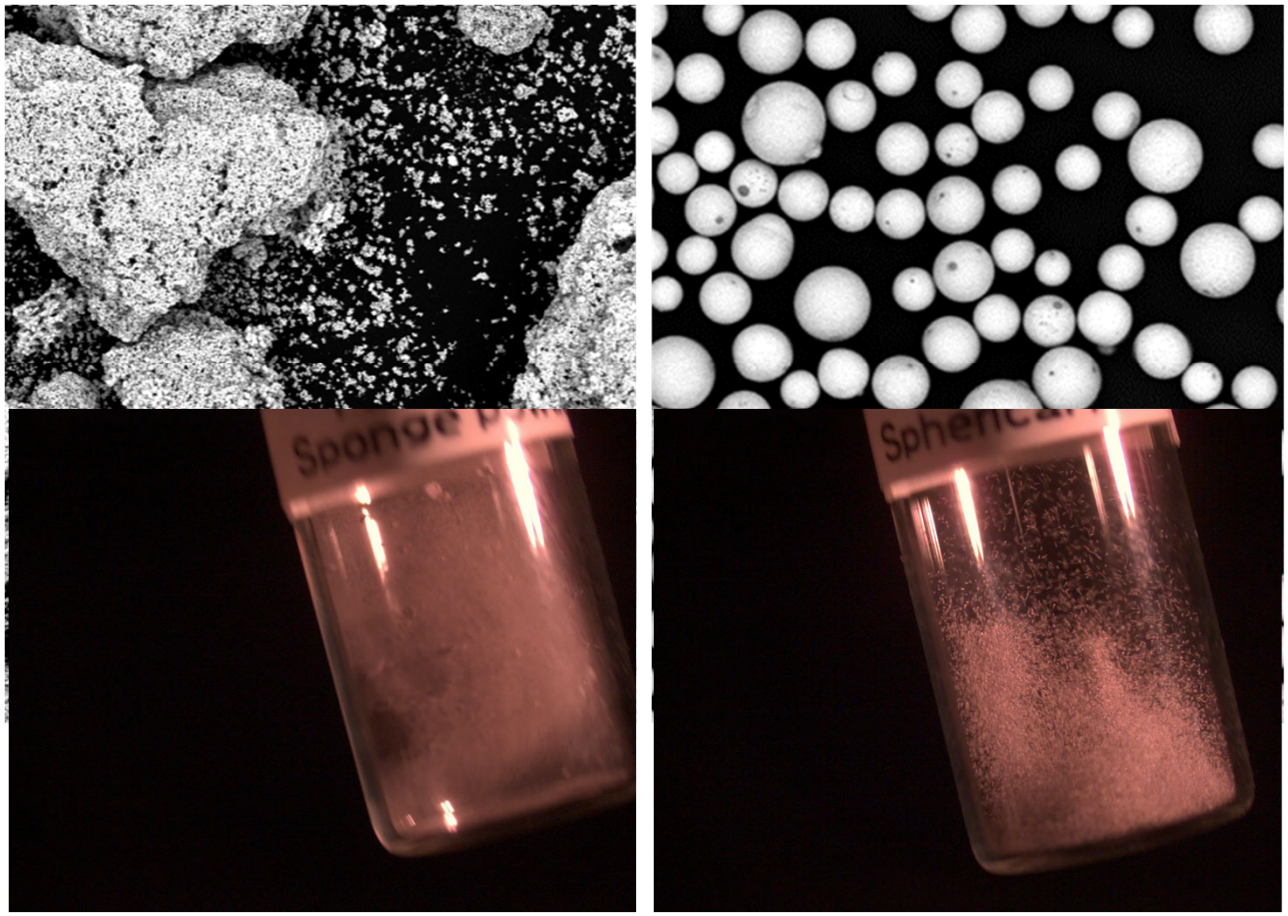
Controlled Powder = Controlled Syntheses



Drastic different properties

- Clumping
- Surface area
- Chemistry
- Flow

Another reason for why we care

Ultimate failure of 3D printing if flow & clumping cannot be controlled!
(H. Holden, Si printer photos)

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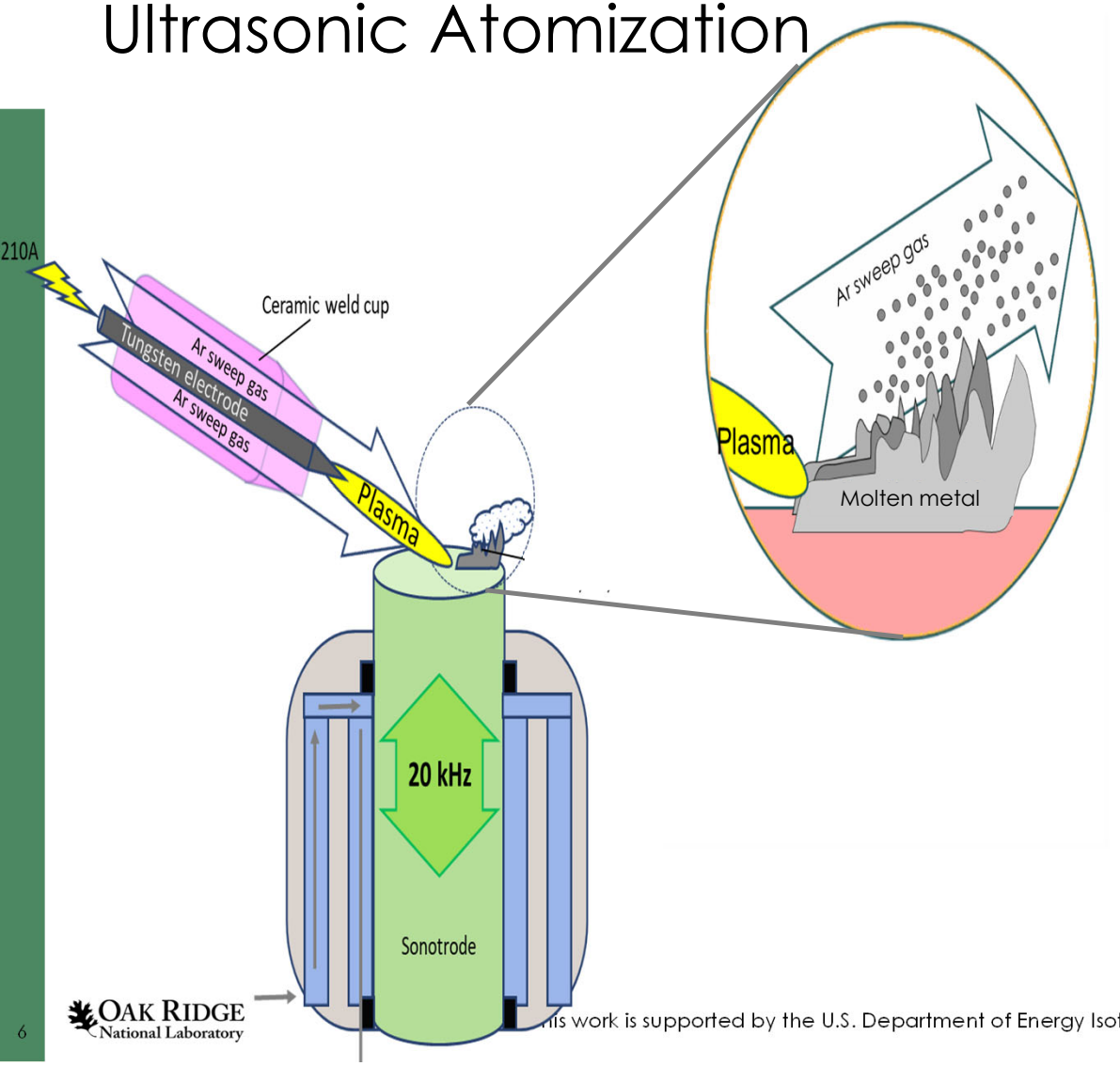
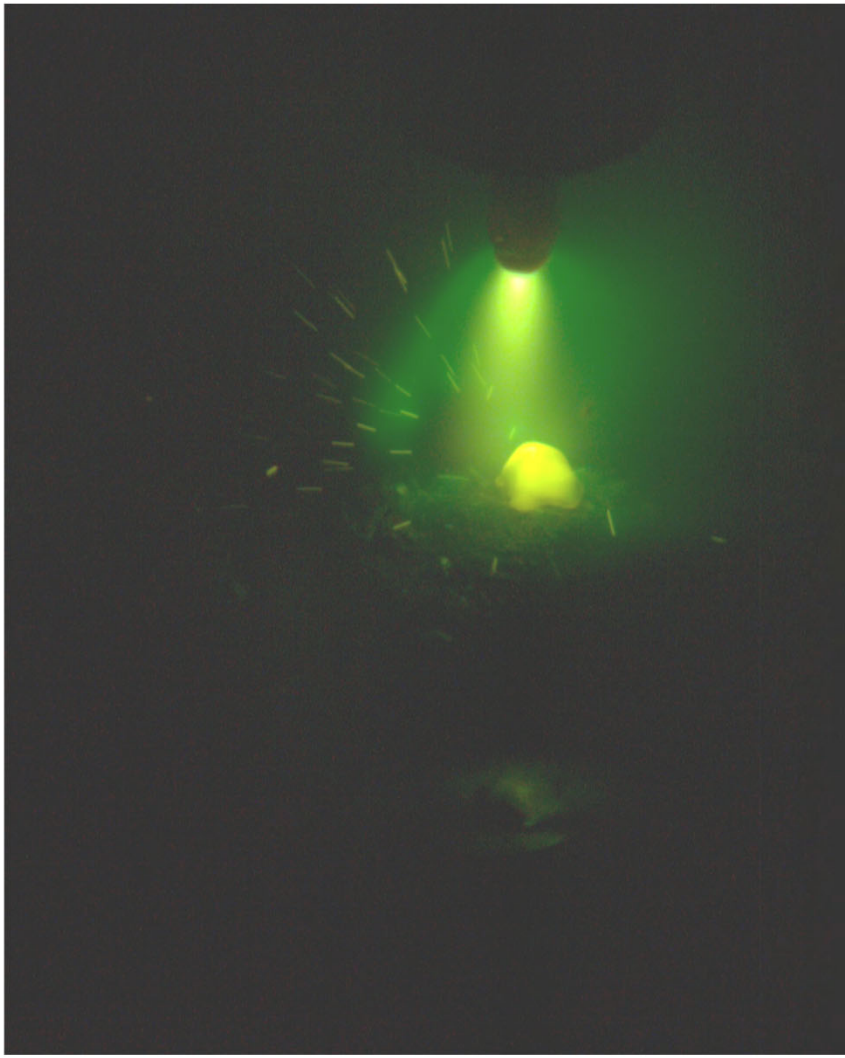
Ultrasonic Atomization





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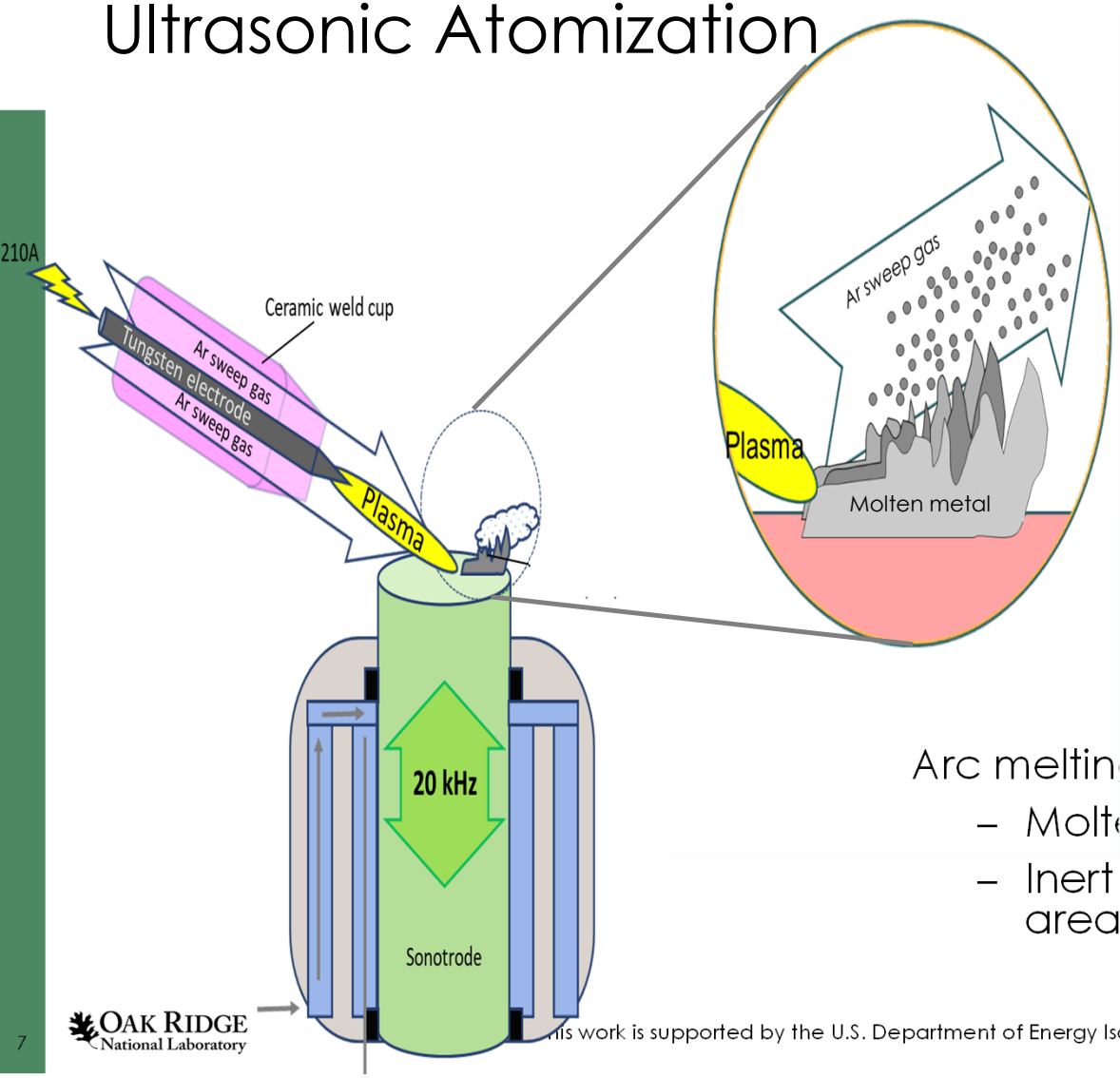

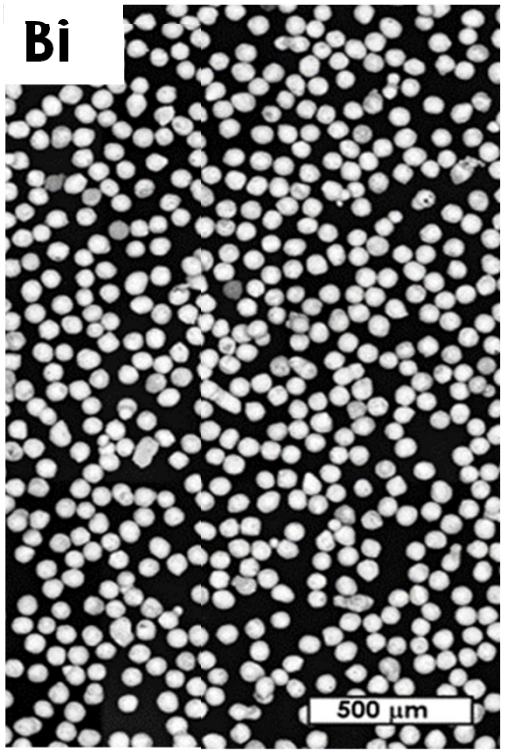

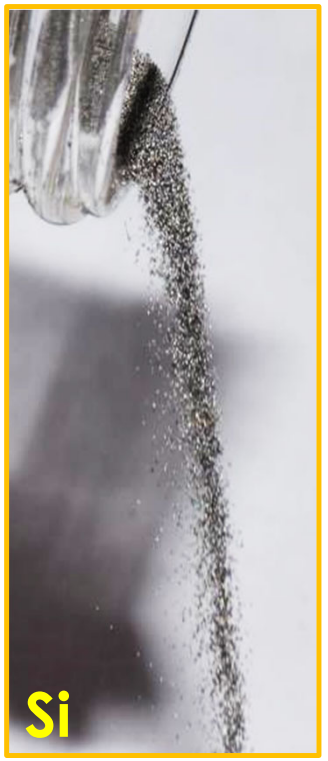

Arc melting and ultrasonic vibration

- Molten metal mist solidifies before hitting wall
- Inert argon atmosphere & minimal surface area minimizes surface chemistry issues

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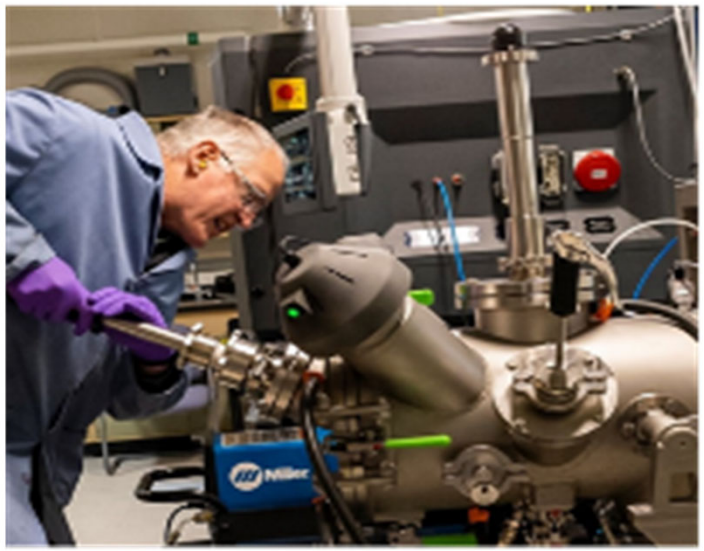
Spherical Powders Produced to Date at ORNL



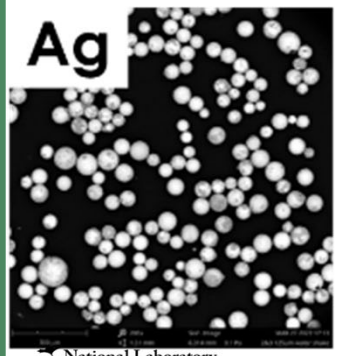
ORNL Made Spherical Powders

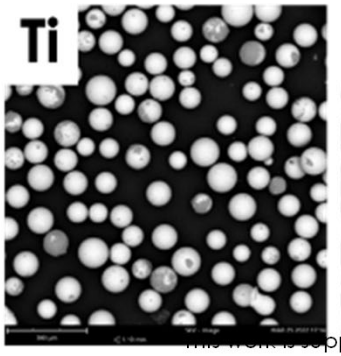
(21 elements and 5 alloys)

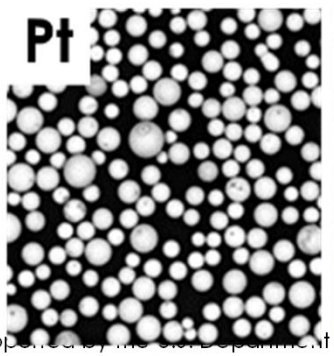
Group IA												IIIA	IVA	VA	VIA	VIIA	Inert Gases
H	IIA																He
Li	Be	IIIB	IVB	VB	VIB	VIIB		VIII		IB	IIB	B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La†	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac‡	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

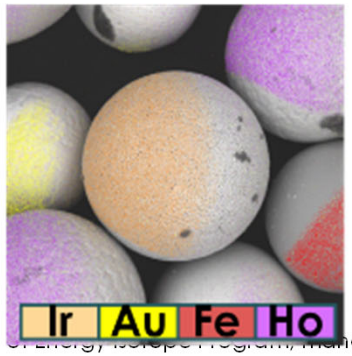
†	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
‡	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

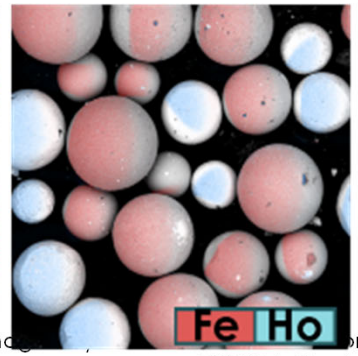
Proven Planned Requires dedicated equipment

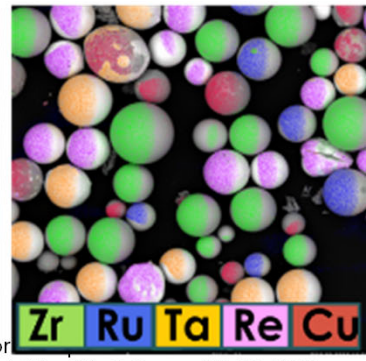












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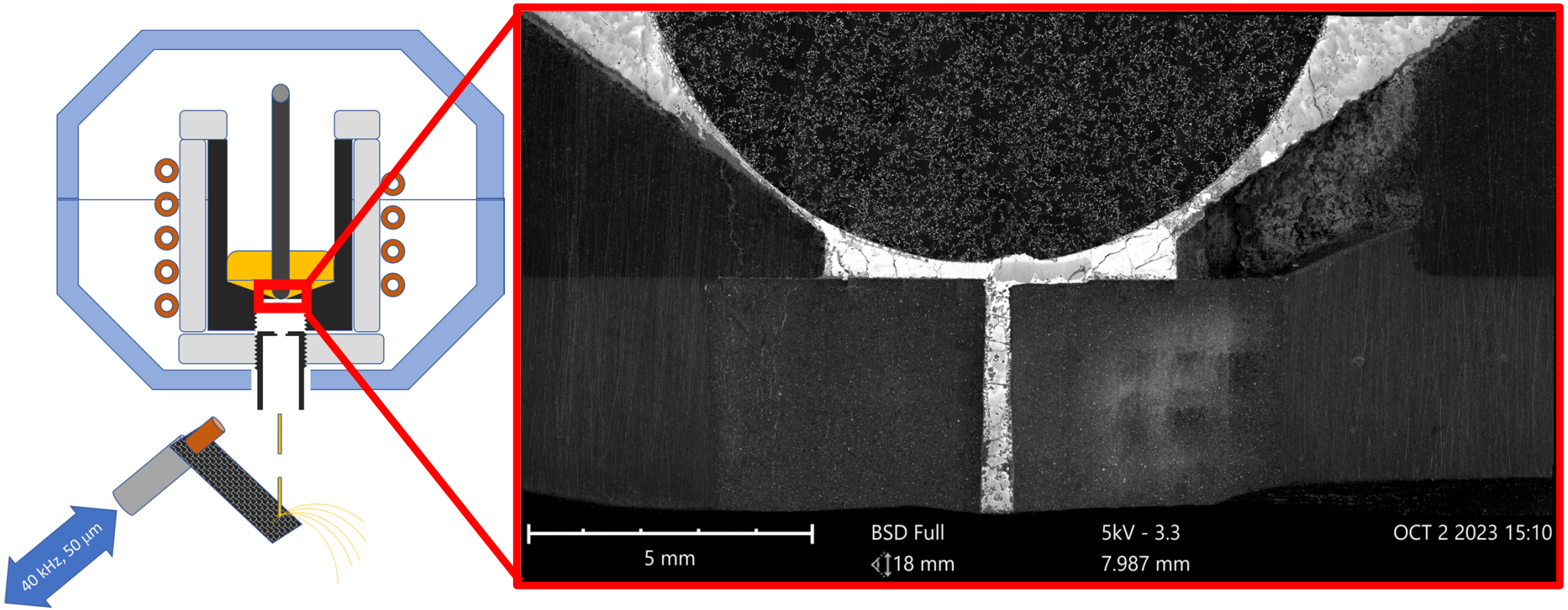
Second Ultrasonic Atomization Method: Induction Melting



Cleaner, Higher Throughput, Amenable for Large Quantities

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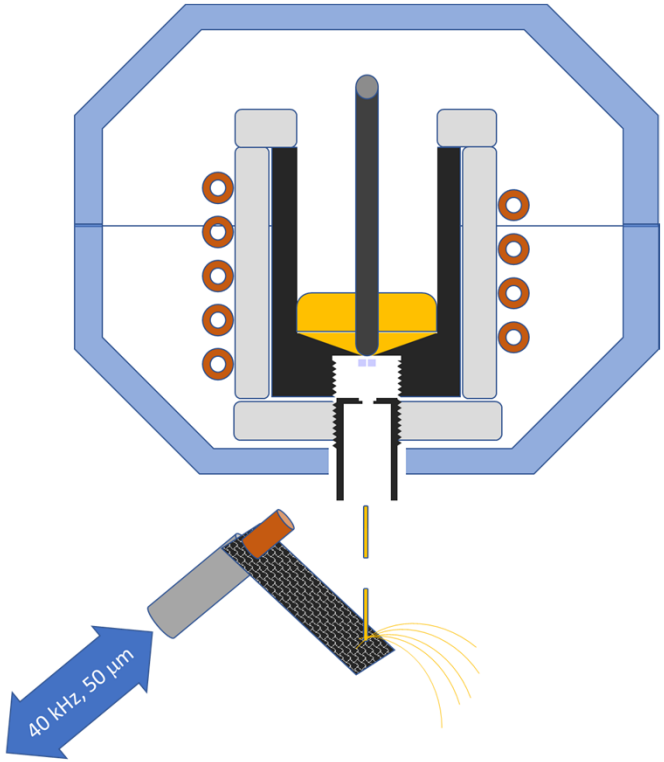

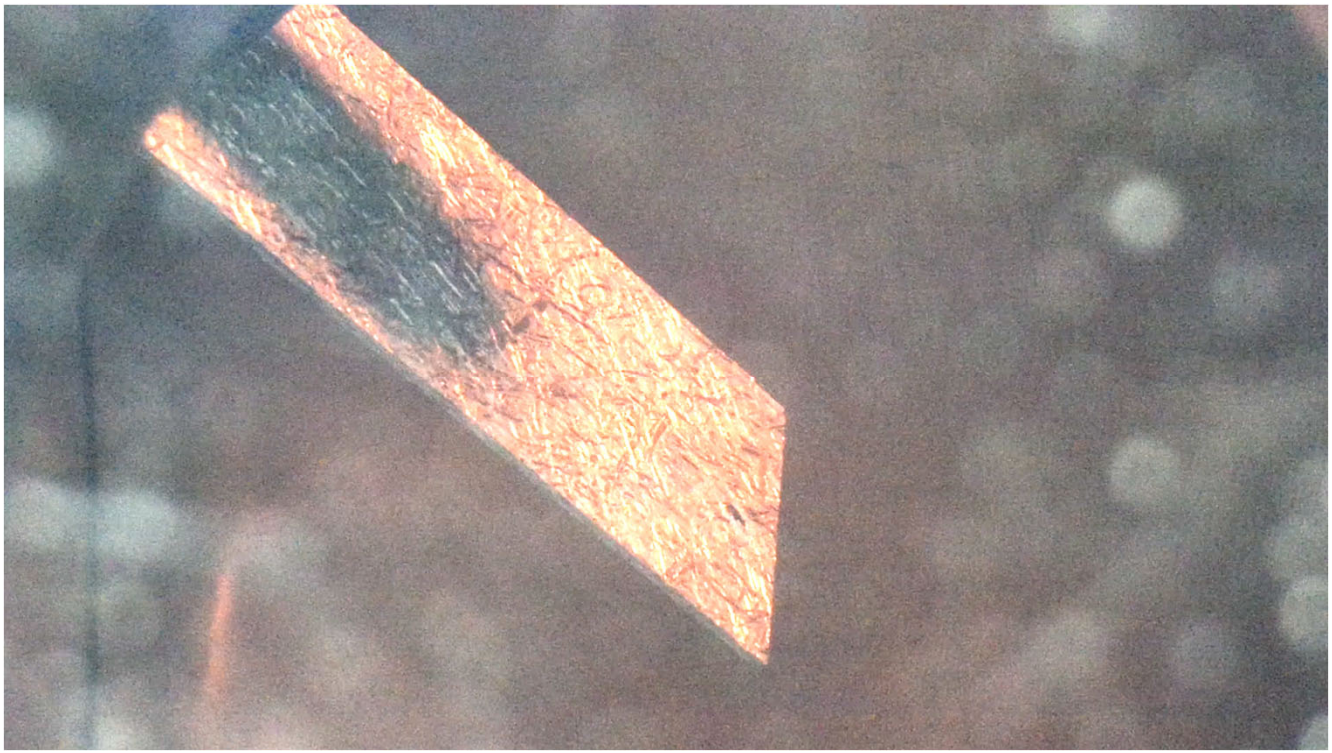

Video complements of Bartosz Kalicki (Amazemet & Warsaw University of Technology)

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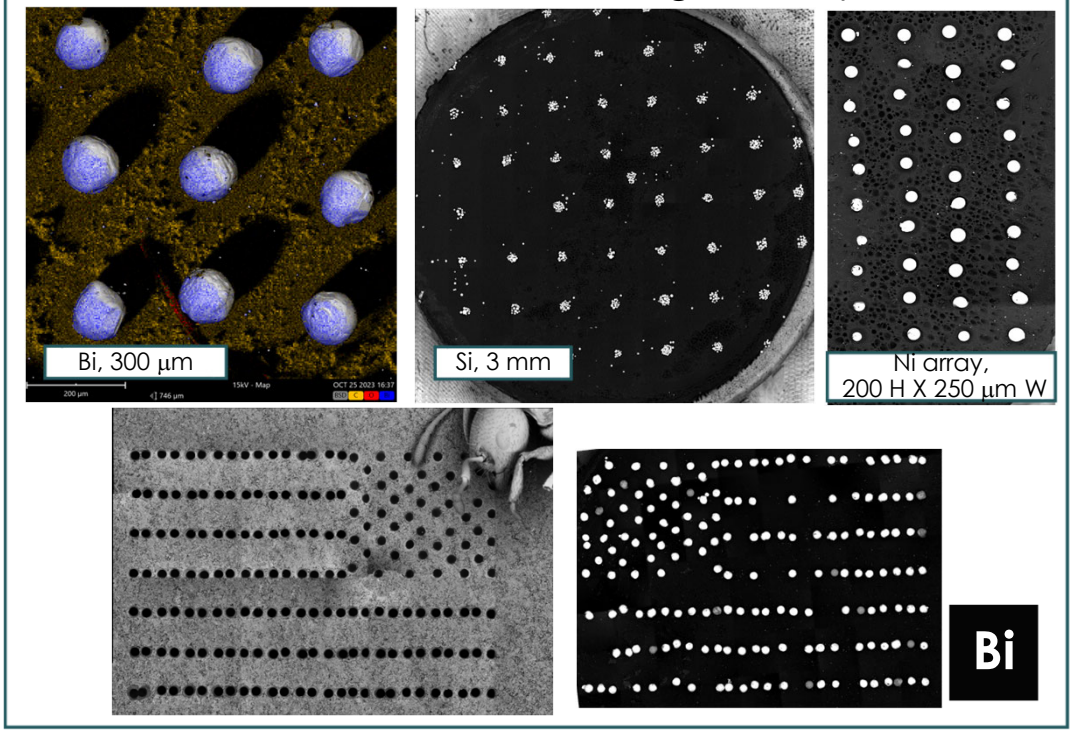
New Options for Dispensing and Targets

- Spherical powders are entirely new tools important to the DOE Isotope Program
- Emergent properties allow solids to be handled as liquids or gases
  - Discrete handling of particles
  - Measured to ± 1 microgram
  - Minimal surface area (minimal other atoms)
  - Requires change in modeling theory (spherical)

Precision Placement of individual grains of powder



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Simple Powders as Targets

- Not airborne powder
- Fast dissolution up to 1000X based on geometry
- Near zero target fabrication labor
- Hot cell capacity utilization
  - Irradiations seldom space limited
  - Short and long half-life
- Co-generation of isotopes
  - Post irradiation sorting
    - –size separation
    - –magnetic separation
    - –density separation

Demonstration of magnetic separation

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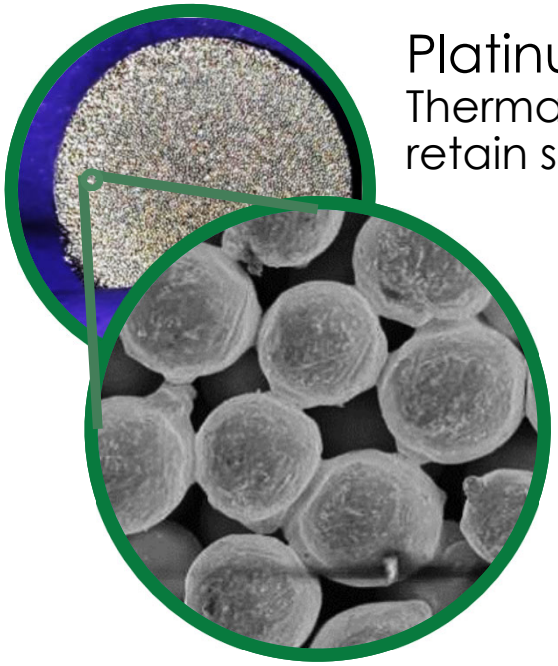
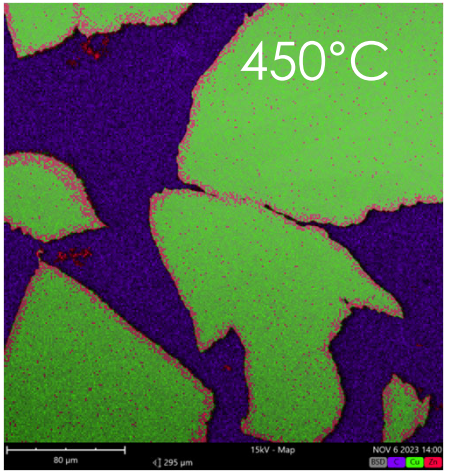
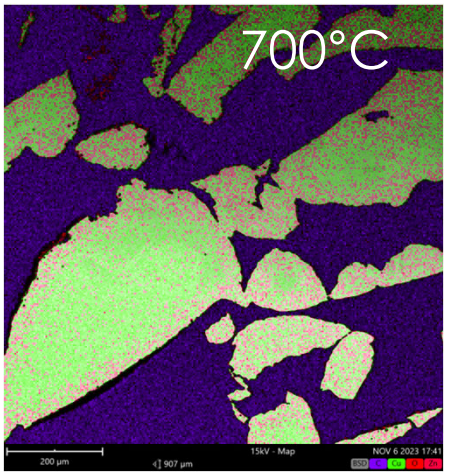
Powders Enable New 3D Options – Open Scaffold Structures



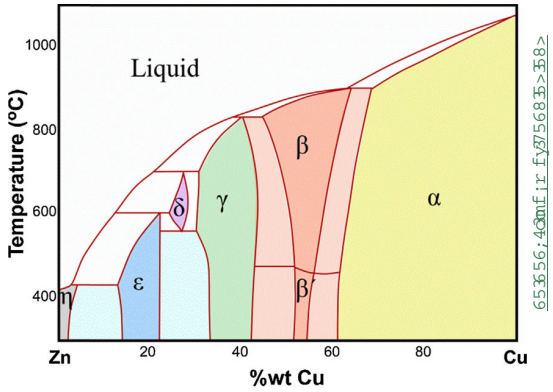
Platinum filter frit-
Thermally sintered to retain spheres @ 1545°C





Eutectic Aided Sintering

- Cu melts 1084.62°C
- Zn melts 419.53°C
- Brass (Cu+Zn) diffuses and melts intermediate



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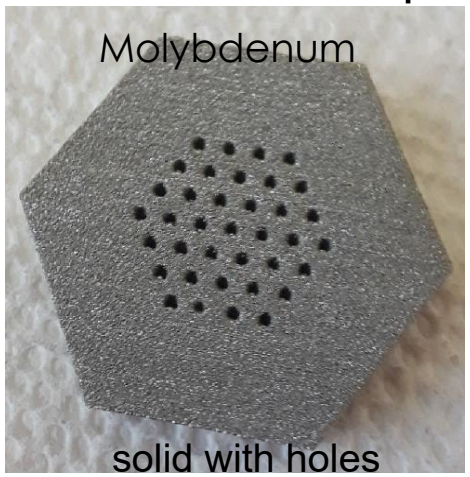
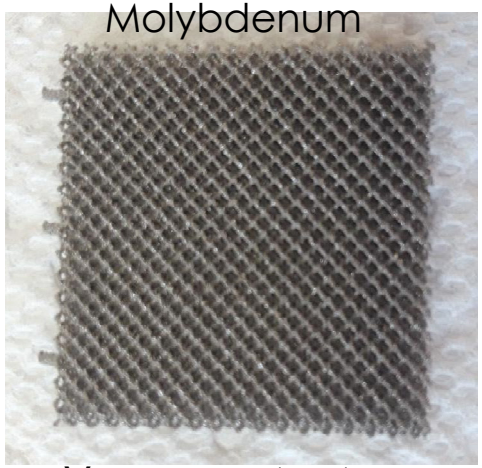
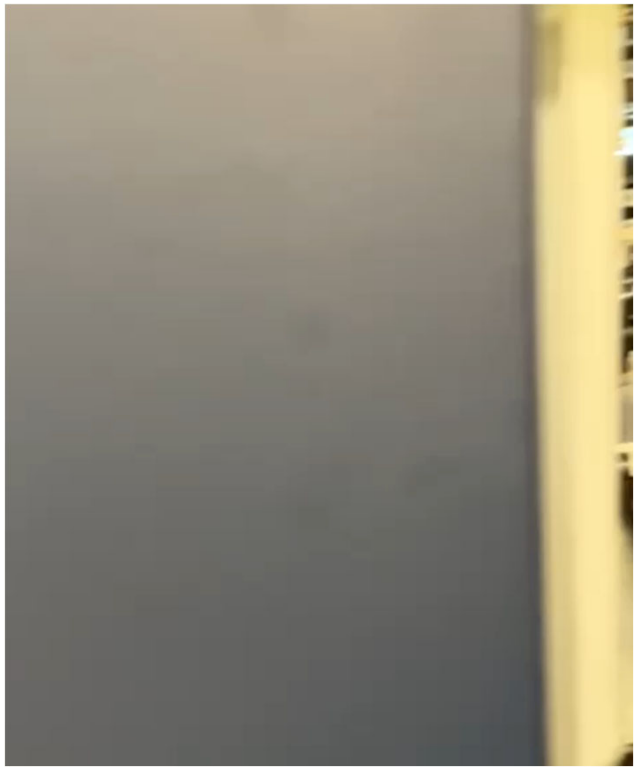




Mo & inconel structures 3D printed with Rick Lowden in Bldg. 3508



New 3D laser powder bed printer
50 mm x 100 mm height build volume
+ lots of new capabilities

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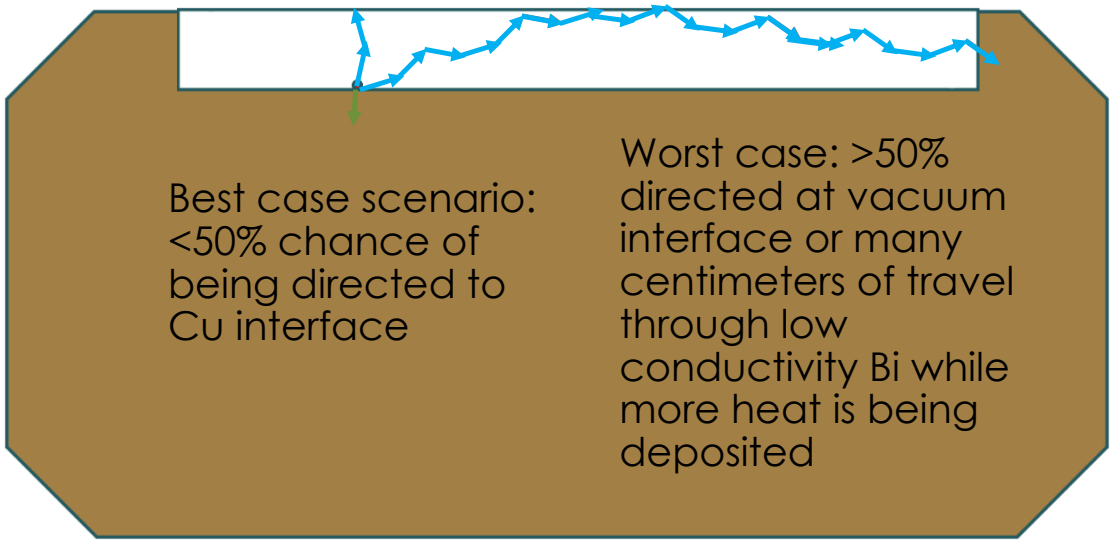
One Reason Why Existing Target Designs Fail

<u>The heat has no where to go!</u>

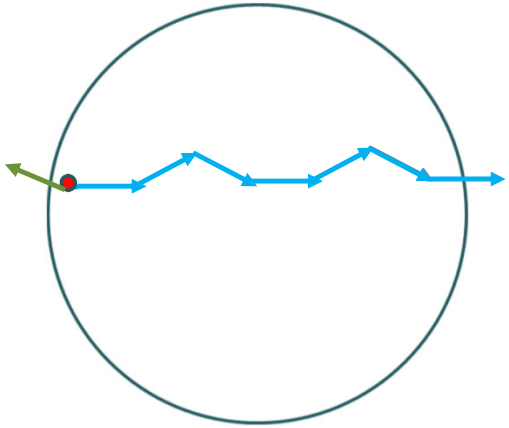
M.R. Zalutsky, Nucl. Med Biol, 100-101 (2021) 12-23

Heat transfer blocked by the vacuum



Best case scenario: <50% chance of being directed to Cu interface

Worst case: >50% directed at vacuum interface or many centimeters of travel through low conductivity Bi while more heat is being deposited



Best case scenario: ~50% chance of being directed to He cooled interface

Worst case scenario: slightly longer than 1 diameter of travel to a He cooled interface

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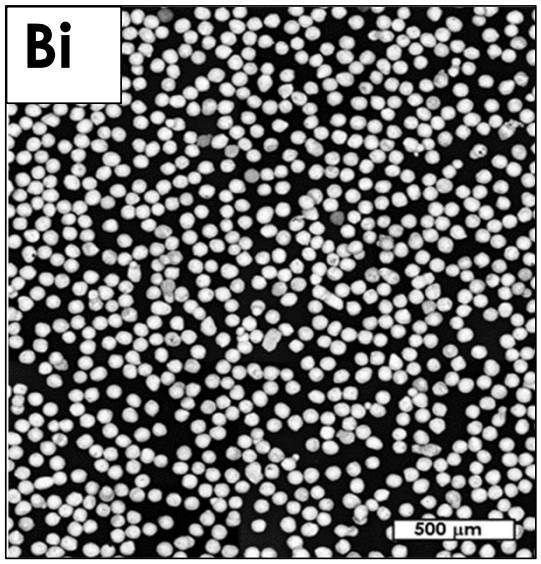
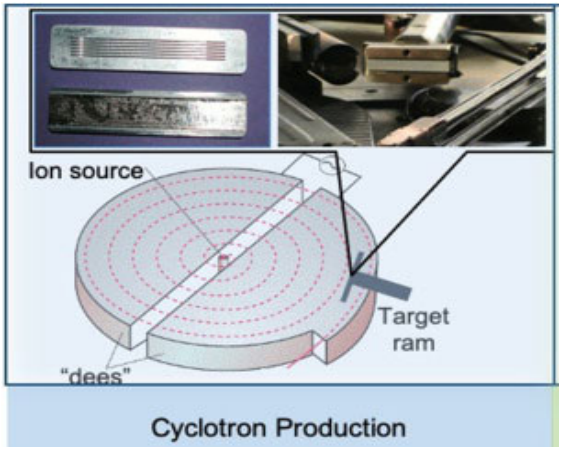
Bi Powder Is Special

- Monoisotopic
- Earth abundant -- $20/kg
- **^{209}Bi (α, 2n) ^{211}At**
- Relatively inexpensive cyclotron
- Key concept: Cycle the powder, not complex percolation of heat





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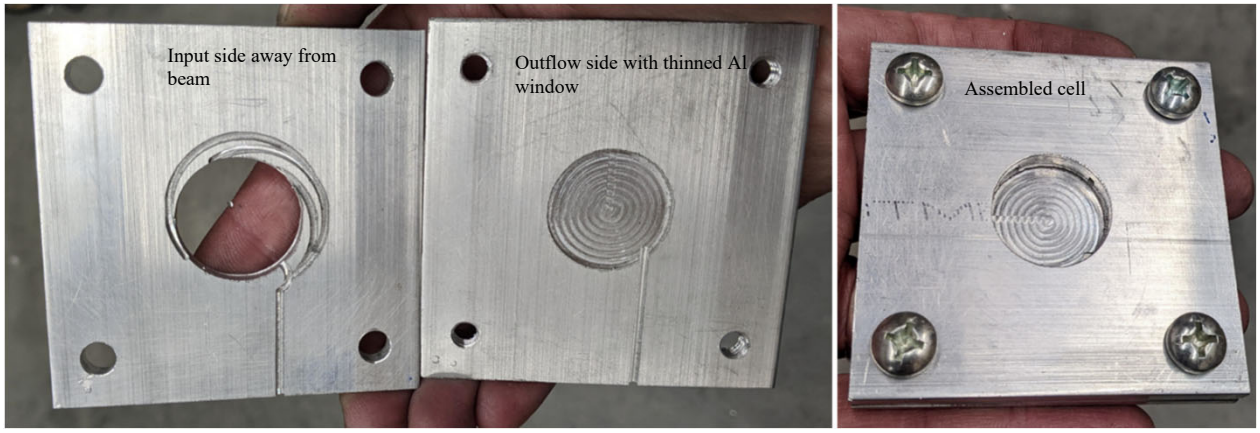
Spherical Powder Inverted Target Design for Isotope Production



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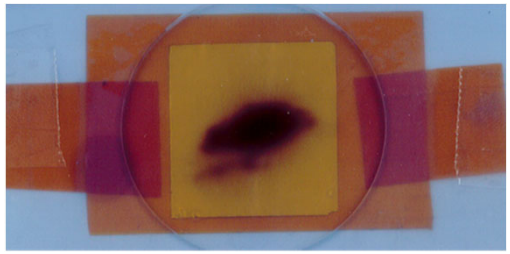
Spherical Powder Inverted Target Design for Isotope Production (SPITDIP Concept)

- Brings coolant to the points of heat generation instead of percolating heat through a solid
- Irregular beam spot homogenized
- Cooling time is independent of beam power
- Direct interaction of helium coolant with entire surface area

- **Enables "Isotopes on Tap"**!
- Fluidic based handling vs. complex transport of film & coolant block



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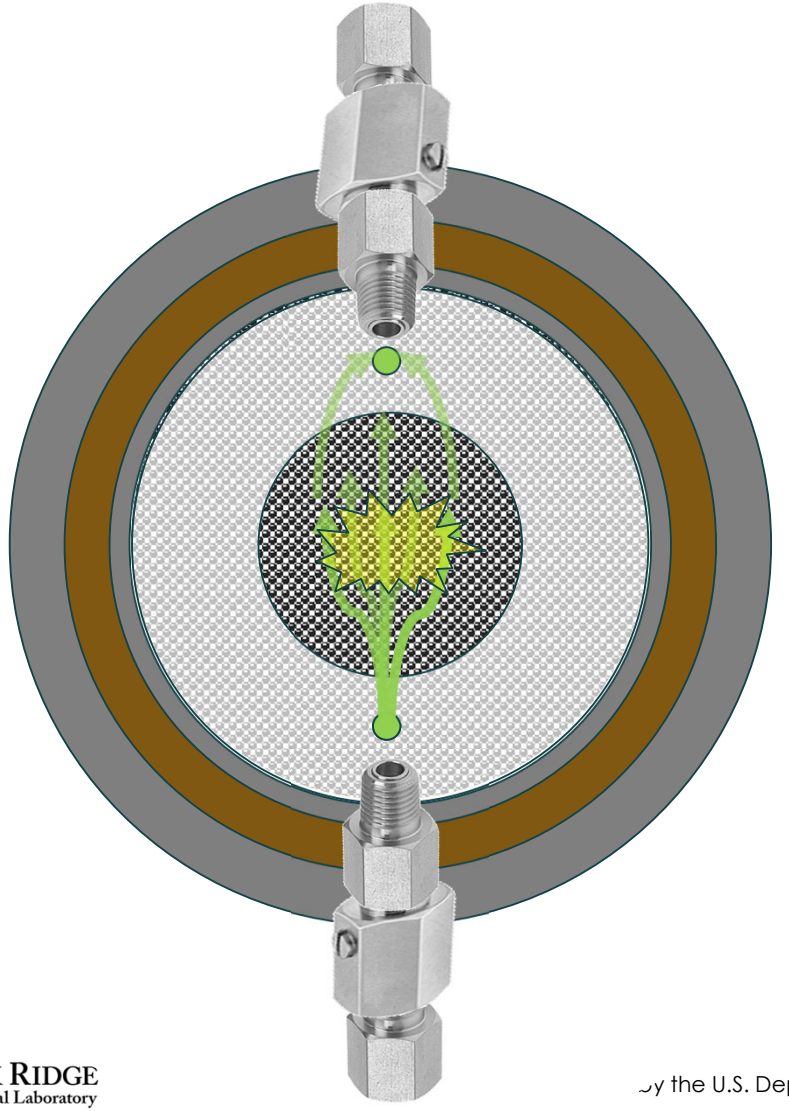

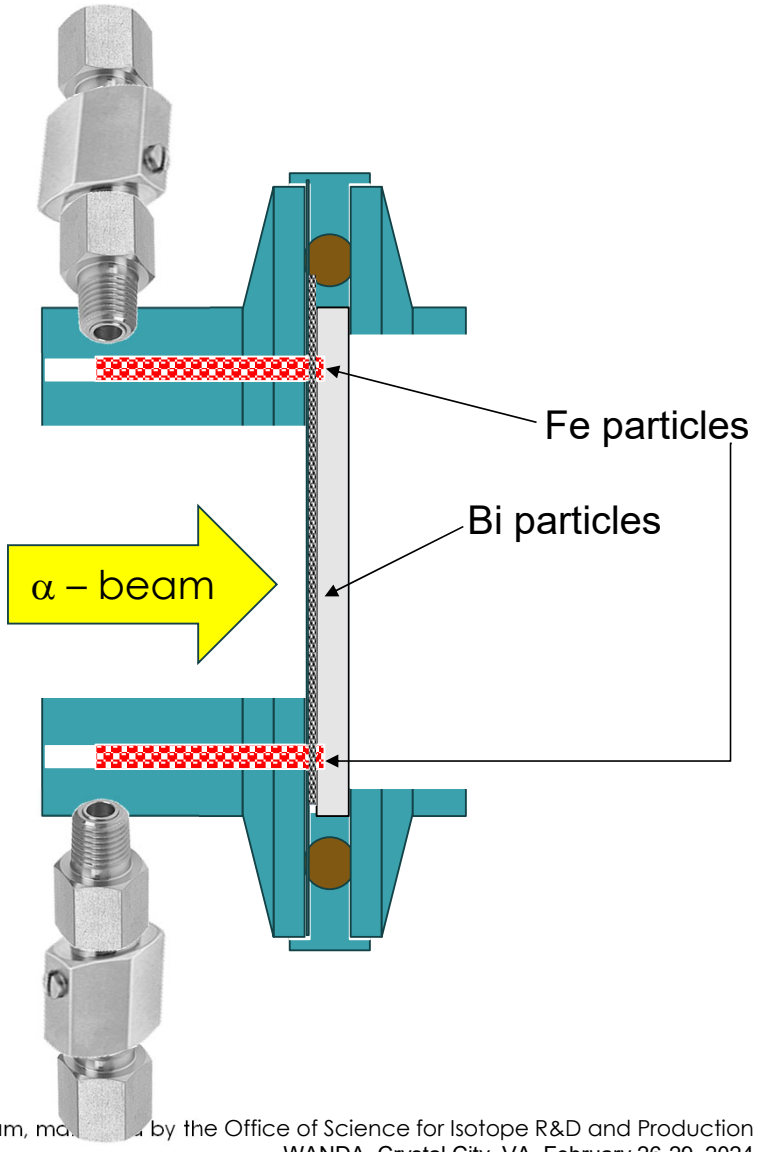

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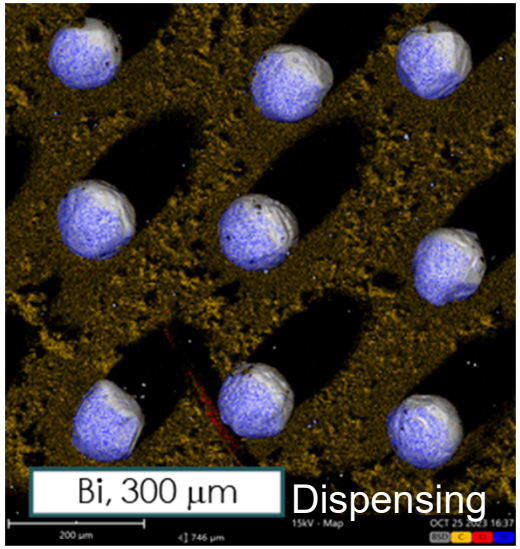
Conclusion:

We're seeking new ways to help solve your toughest target problems.

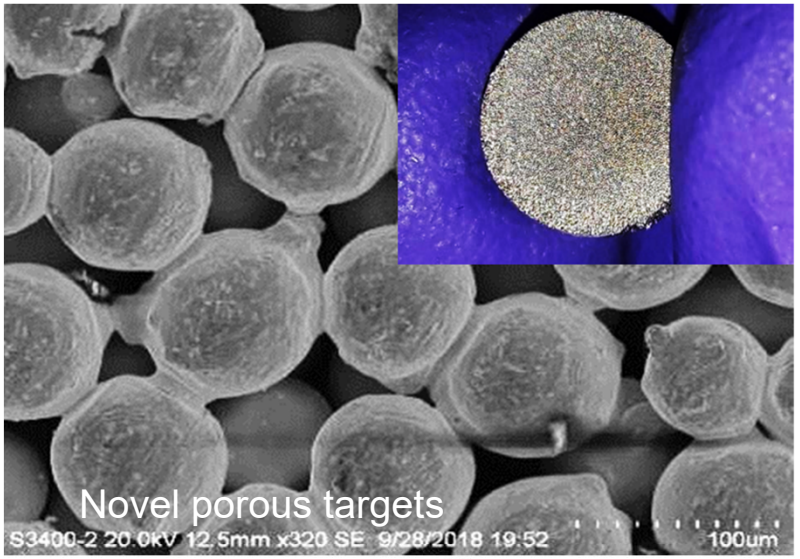
Reach out with new challenges and ideas.

www.isotopes.gov

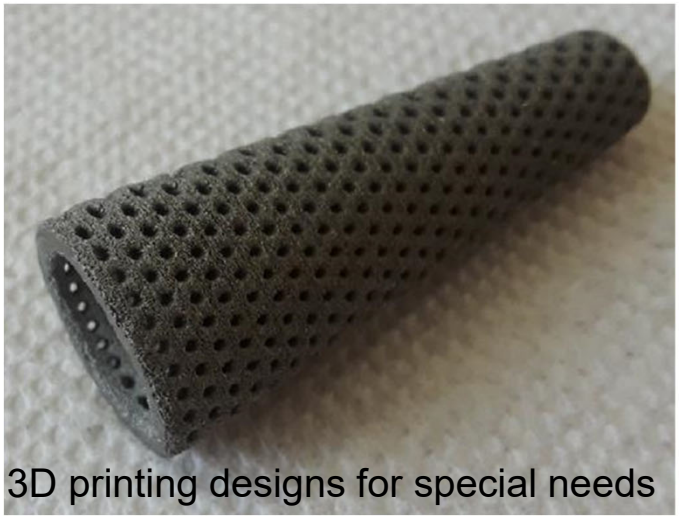
ZachMP@ornl.gov

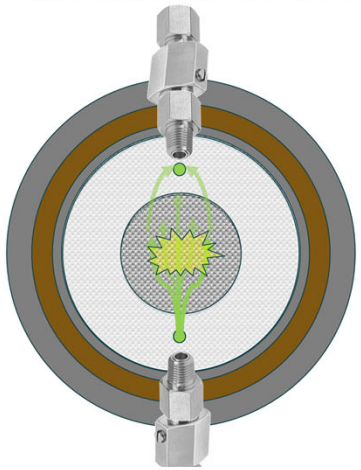


Dispensing



Novel porous targets


3D printing designs for special needs


Inverted target design

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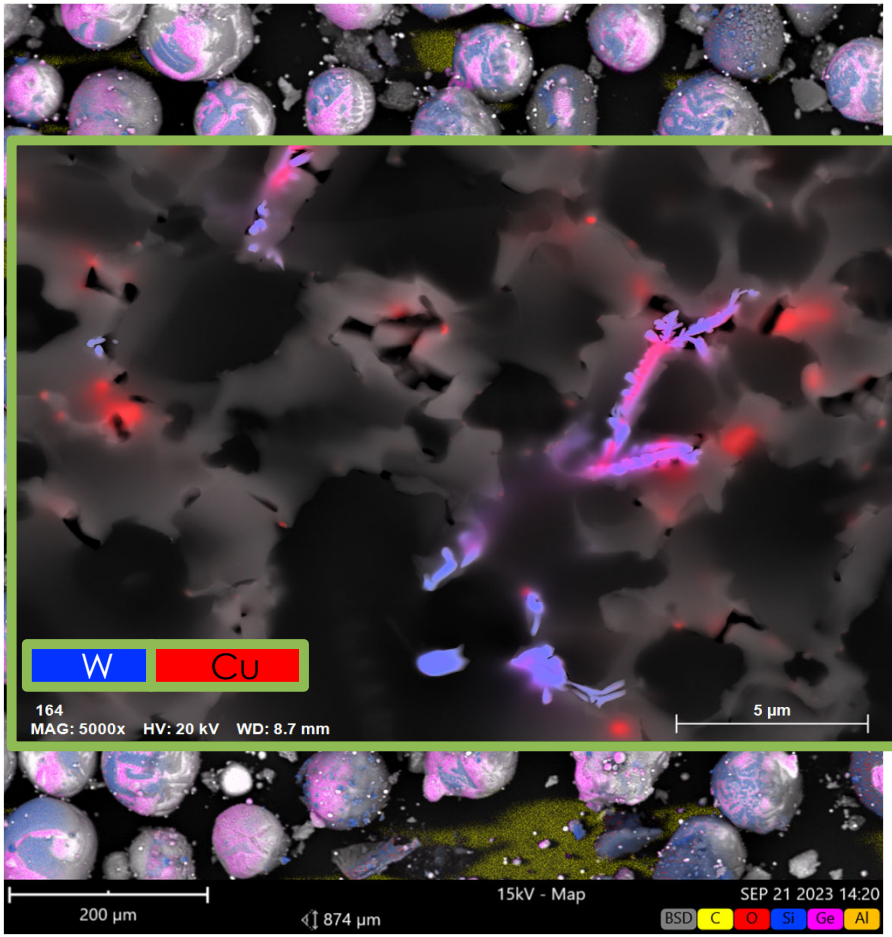
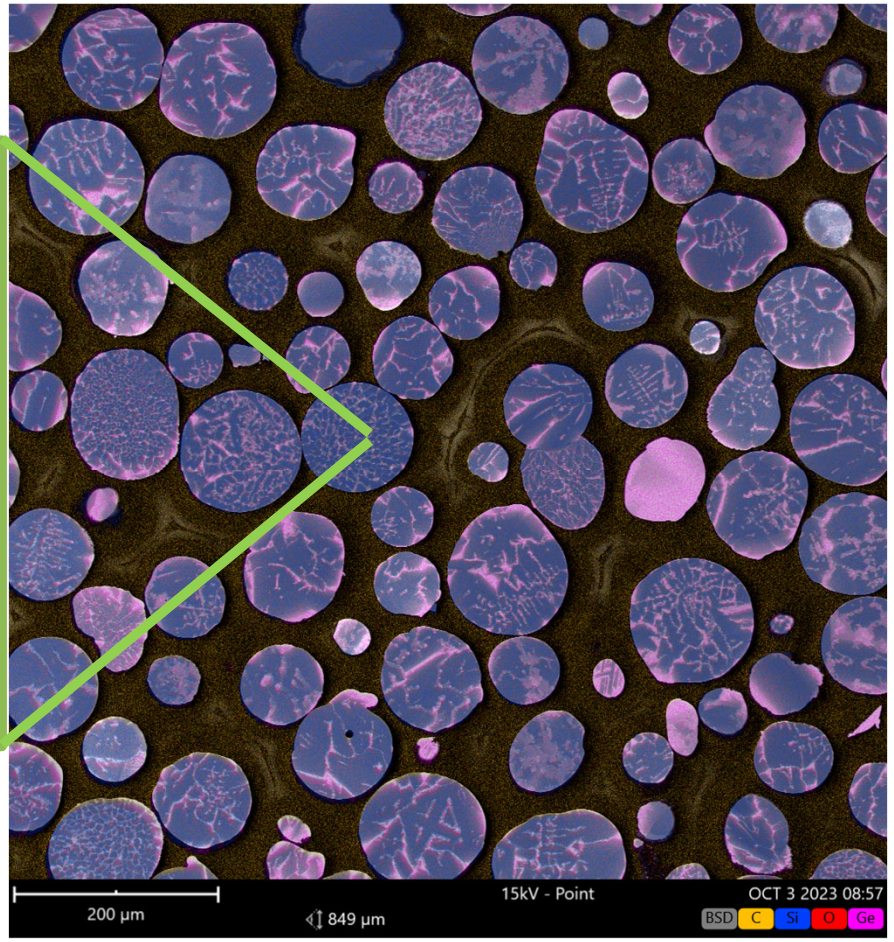
Deep Dive into Mixing & Contamination …(Up to 1% Cu & 1% W)

1





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