Refractory Porous Thin Film Targets for Medical Isotope Production

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Sponsor: Office of Nuclear Physics, DOE
Program Officer: Dr. Manouchehr Farkhondeh
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Small Business
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Presentation Overview

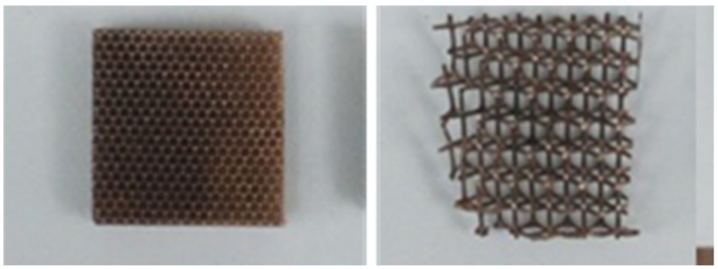
- About InnoSense LLC
- Commercialization Status
- Motivation
- Relevance to Nuclear Physics Programs
- Work in Progress
  - Refractory Oxide Porous Catchers
  - **Thin Film Porous Bismuth Oxide Targets**
- Summary
- Acknowledgments

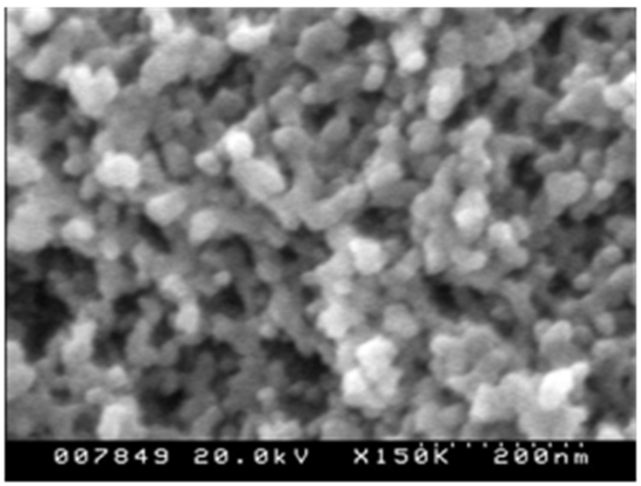
About InnoSense LLC

- Established in 2002 by private investment, R&D operations in 2004, housed in a 9,000 square feet laboratory facility located in Torrance, California. Core Capabilities – Nanotechnology, Chemical and BioSensing
  - Added 1400 sq. ft of space for testing and production capabilities – chemical sensors division
  - Planned expansion (~3000 sq. ft) for dedicated biotechnology/bioassay development
- Seven "wet" chemical facilities equipped with fume hoods, a clean room, a spectroscopy facility, optics and chemical and biosensor testing laboratories, and two machine shops.
- Growth Phase - currently 28 employees, expanding to 30 soon
  - 7 PhD, 7 MS and 2 MBA degree holders.
  - Dedicated business development team added in 2017.
  - Negotiating a large contract with MDA for production of 24/7 monitoring leak detectors
  - Gearing to spin-off divisions
  - Two Army funded efforts in preproduction/licensing activities

Commercialization – Building from ONP Funding

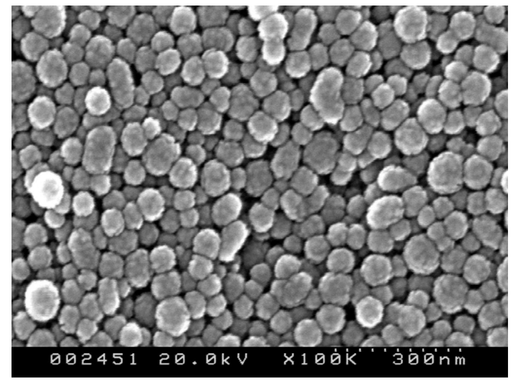
Silica aerogel coatings on metal lattices – $8,500 July 2015

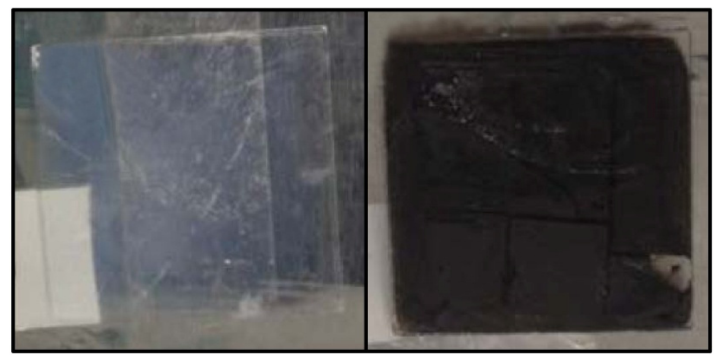




Porous Scaffolds for Refractory Solar Selective Coatings – SuNLaMP

$200 K (2016-2017)





Prior DOE ONP funding enabled us to develop the technology for porous monoliths and expand the application base for these materials

Company Commercialization Status

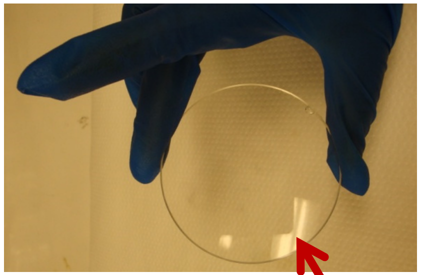
Army: W15QKN-09-C-0153

Passive Temperature Dosimeter

- **Ongoing Phase III Funding ~$1M**
- **Correlation Testing completed at Yuma Proving Grounds 2018**
- **Expanding customers in the Army to ramp up production**

Army: W911NF-11-C-0056

Permanent anti-fog coating



PC lens and PU visor

- **DOD DTRA RIF award – 2015**
- **Nanomaterials in coating**
- **Negotiations with DOD and Commercial vendor for licensing**

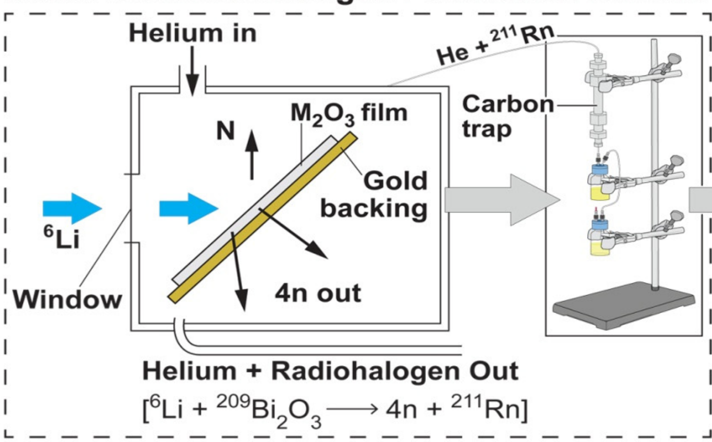
MDA: HQ0147-14-C-7012

Hypergolic Leak Detector for THAAD

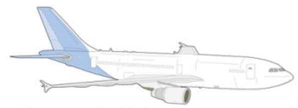
- **Drop-in Replacement Leak Detector for MDA THAAD missiles**
- **$200K Production order from Lockheed**
- **New contract under negotiation.**

Medical Isotope Production Target Development (must be stable with beam power)

Noble Gas/Radiohalogen Production Scheme

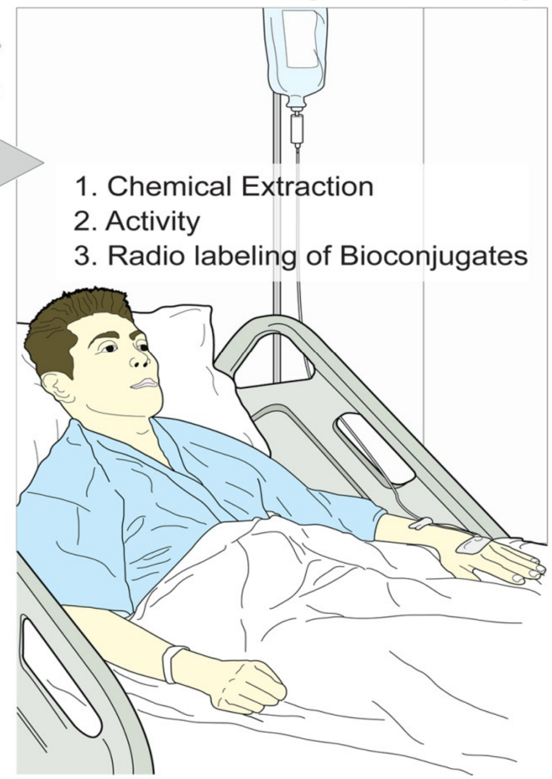


Helium gas transports radioactive noble gas to carbon trap



Overnight Transport within Continental US

Extraction and Chemical Preparation of Radioactive Halogen for Therapy



$$M_2O_{3(s)} + {}^{6}Li \longrightarrow N_{(g)} + 4n$$

where, $M_{(s)} = {}^{209}Bi$, ^{75}As or ^{121}Sb

and $N_{(g)} = {}^{211}Rn$, ^{77}Kr or ^{123}Xe (Noble gases)

that decay to Radiohalogens

^{211}At ($t_{1/2}$ = 7.2 h), ^{77}Br ($t_{1/2}$ = 2.78 d), ^{123}I ($t_{1/2}$ = 13.4 h)

- Efficient production and release of radioactive noble gas precursors at low and room temperature – **Higher production rates of ^{211}At, ^{77}Br and ^{123}I**
- ^{6}Li induced reaction for parent/daughter production system, concept for a dedicated linac or cyclotron for radio-halogen production – **Overnight delivery to users from single national facility.**

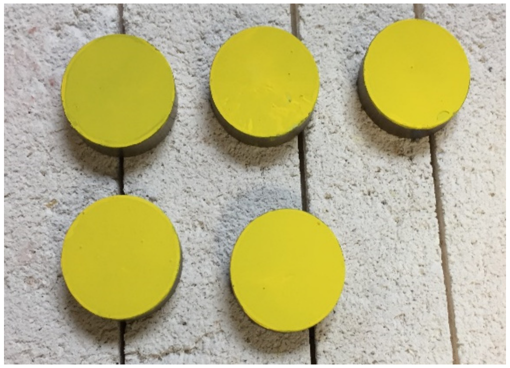
Catchers/Targets Being Studied at ISL and ANL

Refractory Catcher/Target	Production beam	Collected Isotopes
Tungsten-coated SiO_2 Aerogel	^{18}O (typical)	^{8-11}Li $^{6,8}He$
Carbon Aerogel	^{16}O, ^{48}Ca, etc.	$^{12}C^{14}O$–$^{12}C^{24}O$ $^{12}C^{14}O_2$–$^{12}C^{24}O_2$
Yttria-Stabilized Zirconia (YSZ) and Hafnia (HfO_2) Porous Monolith	^{12}C, ^{48}Ca, etc.	$^{9}C^{16}O$–$^{22}C^{16}O$ $^{9}C^{16}O_2$–$^{22}C^{16}O_2$
Sintering-inhibited Disks of Tungsten, Tungsten + ALD-Hafnia and Tungsten Carbide	^{18}O, ^{48}Ca, etc.	"All of the above"
Nanoporous CaO Monolith	^{40}Ca	$^{31-35}$ Ar
Nanoporous Metal Oxide (M_2O_3) Thin Films* (M = ^{209}Bi, ^{75}As, ^{121}Ab)	^{4}He, $^{6,7}Li$	$^{211}Rn/^{211}At$, $^{77}Kr/^{77}Br$, $^{123}Xe/^{123}I$ $t_{½}$ [14 h/7.4 h]; [1.24 h/2.78 d]; [2.08 h/13.4 h]

* Thin film targetry for medical isotope production

Refining Bismuth Oxide Thin Film Processing

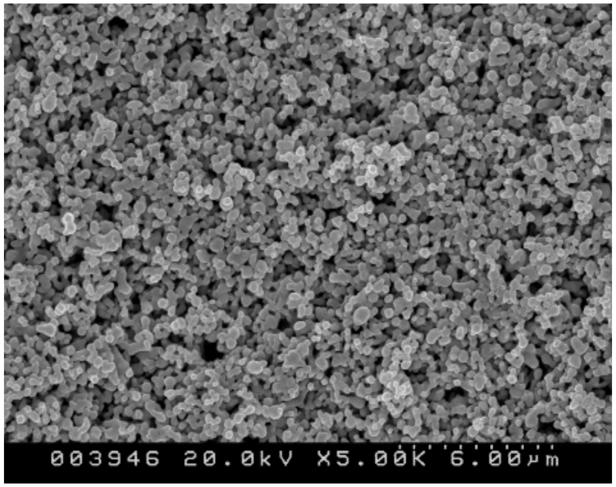
As-Deposited



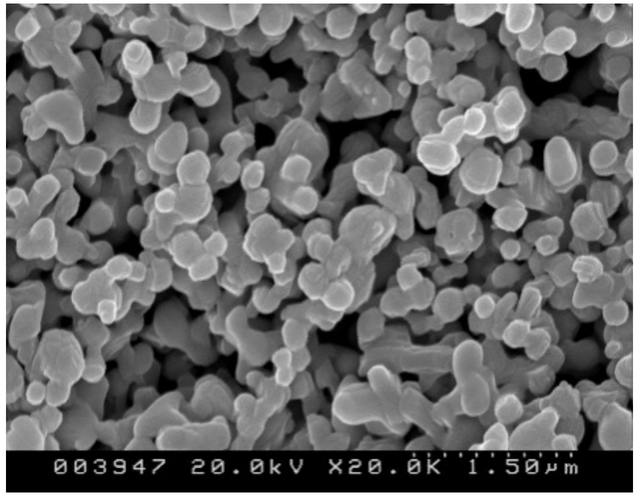
Fired @600 °C; 3x

Nanoporous Bismuth Oxide Thin Films

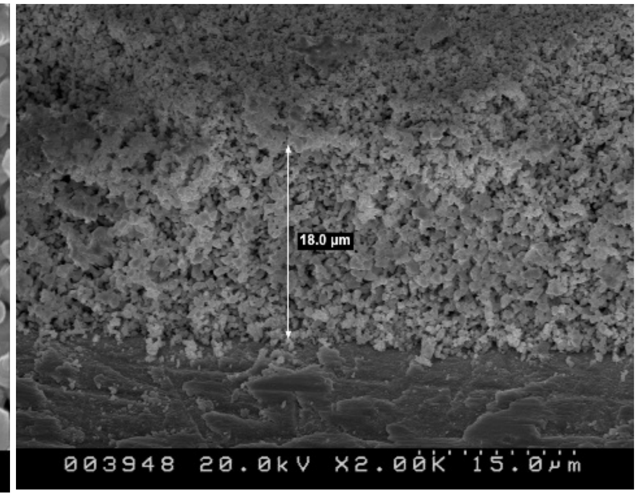
x5K



x20K

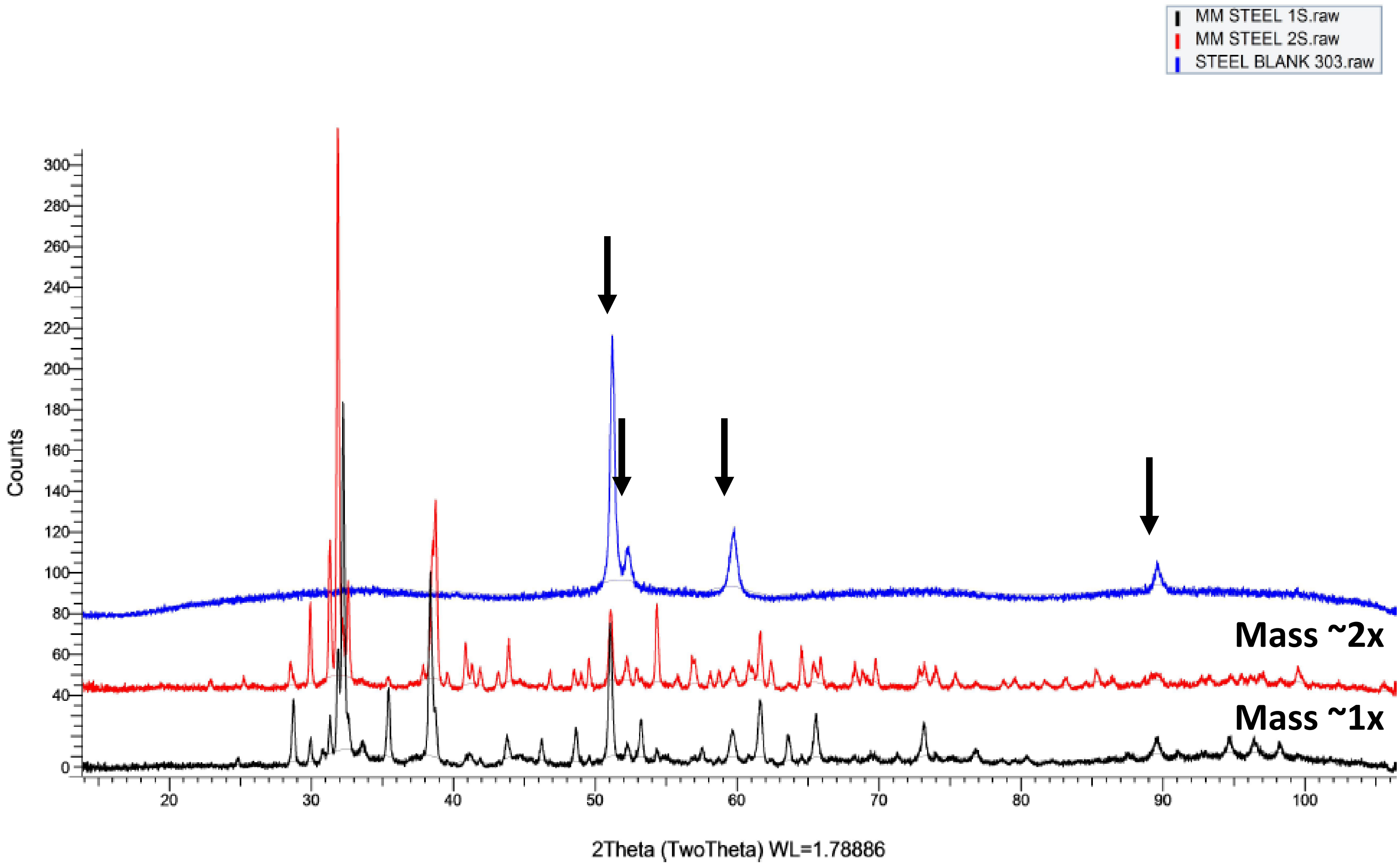


Imaged @ 44.6 degree

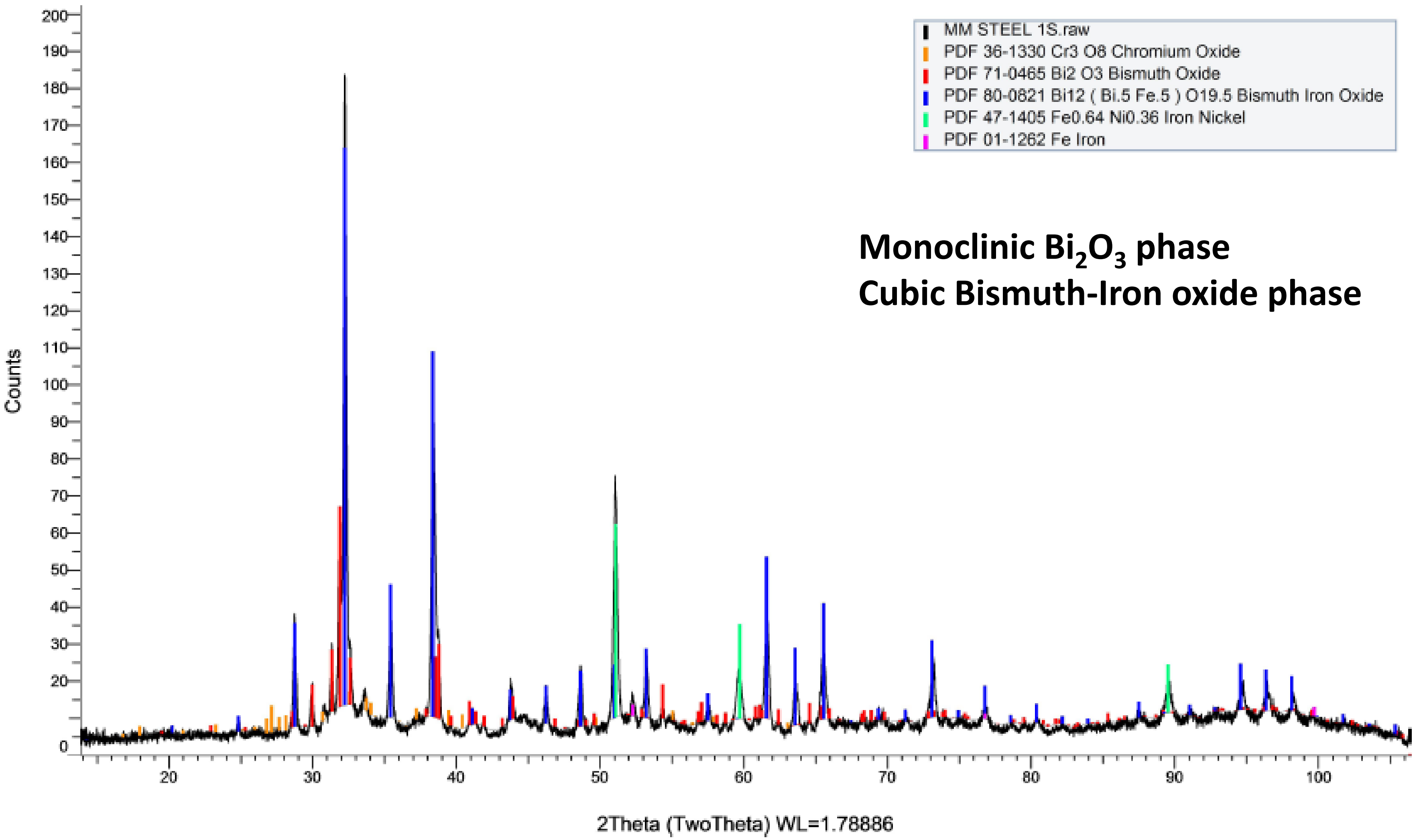


- Processing developed for contiguous nanoporous bismuth oxide films on stainless steel 303 coupons (0.5” thick, 7/8” diameter)
- Film thickness ranged from 9-15 mg/cm^2
- Films remain adhered after 3x in vacuum heating to 600 °C
  - Some mass loss noted - investigating this
- Tested at ATLAS in May 2018 with energetic ^{6}Li beams for formation and release of radiohalogen Radon-211 to decay to Astatine-211.

X-Ray Powder Diffraction of Bismuth Oxide Films on 303SS Substrates

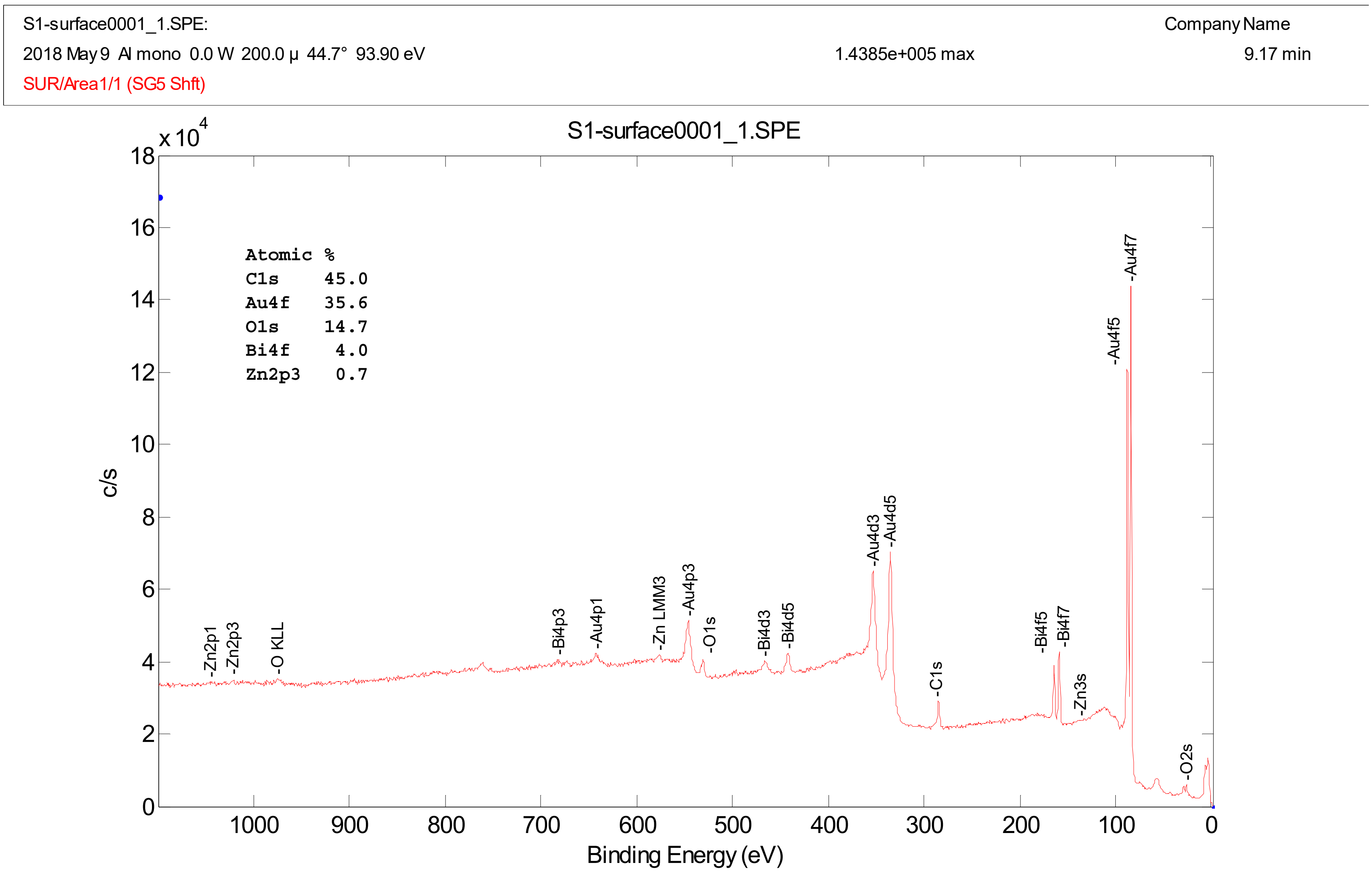


Indexed to JCPDS Files

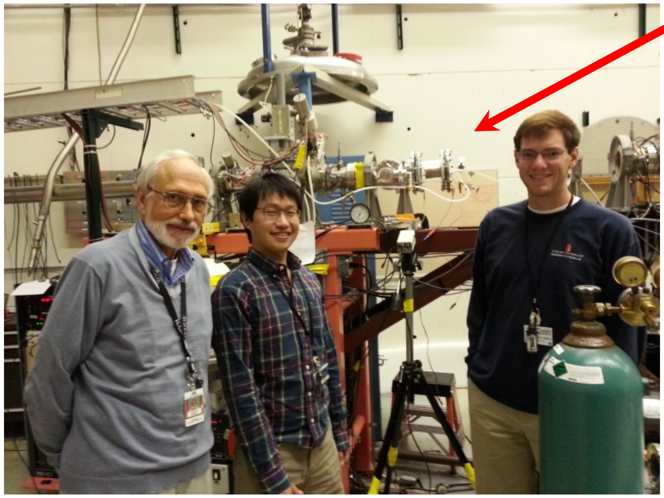


Monoclinic Bi_2O_3 phase
Cubic Bismuth-Iron oxide phase

X-ray Photoelectron Spectroscopy of Bi_2O_3

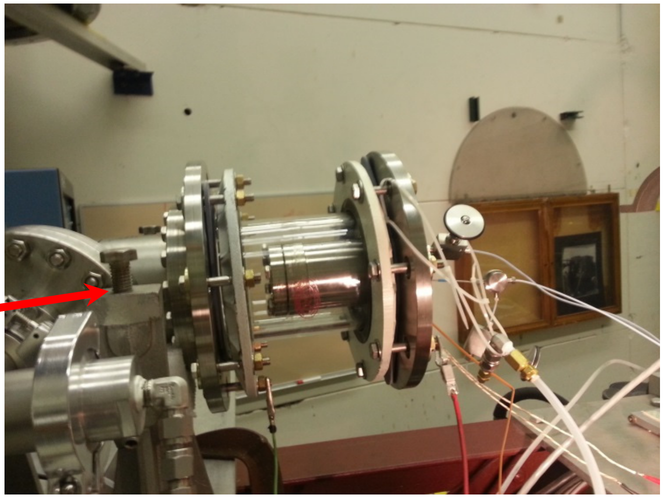


Initial Tests at ATLAS with a Bismuth Metal Target



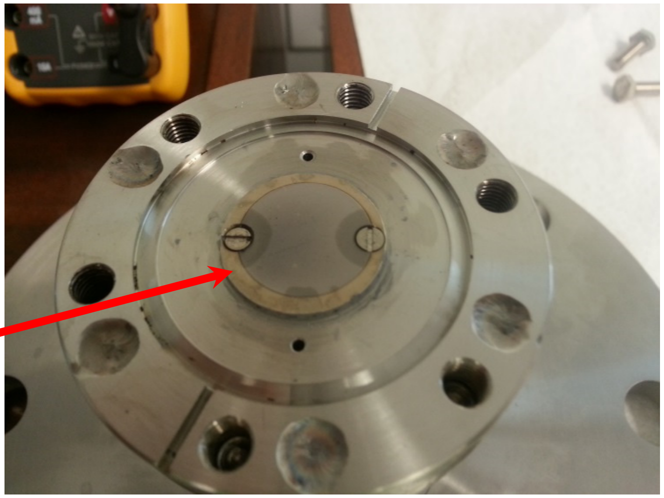
Health physicist,
Post-doc,
Undergraduate

Target/ helium plumbing/ heater assembly



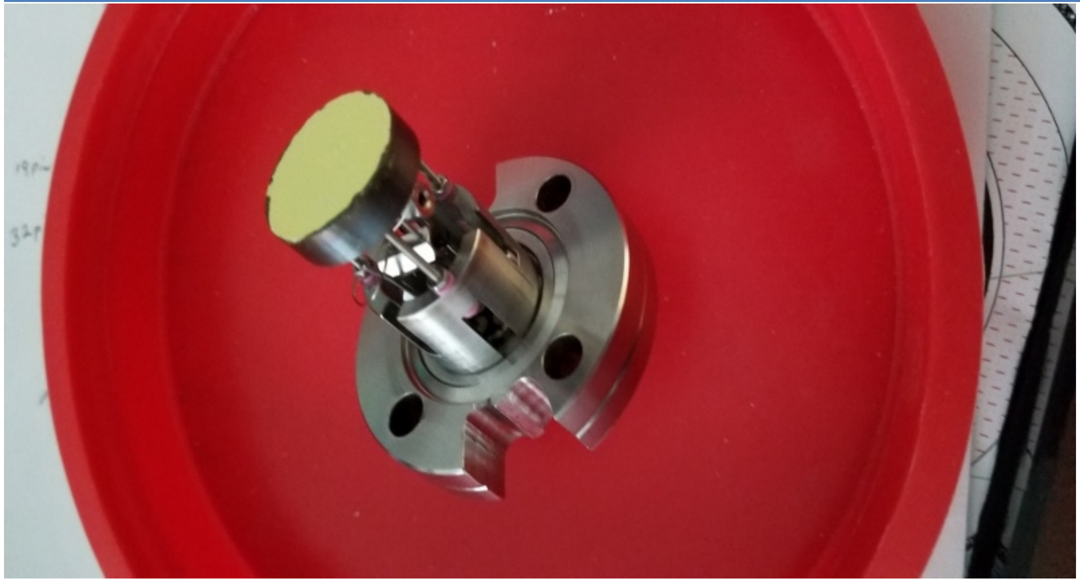
Havar window

32 mg/cm^2 Bi on Ni

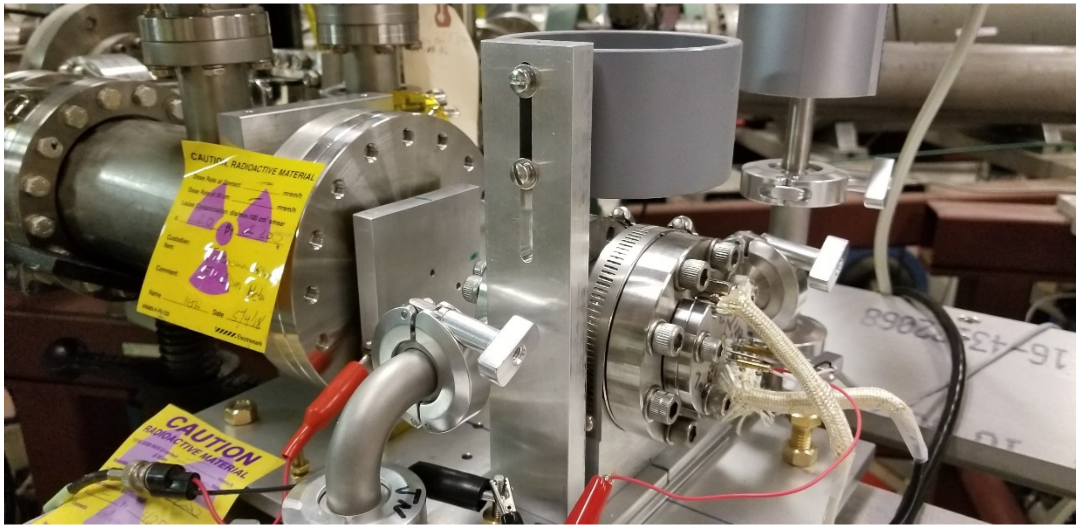


Release and capture efficiency ~1% at ~200 ^{o}C

First Test at ATLAS with Bismuth Oxide Target



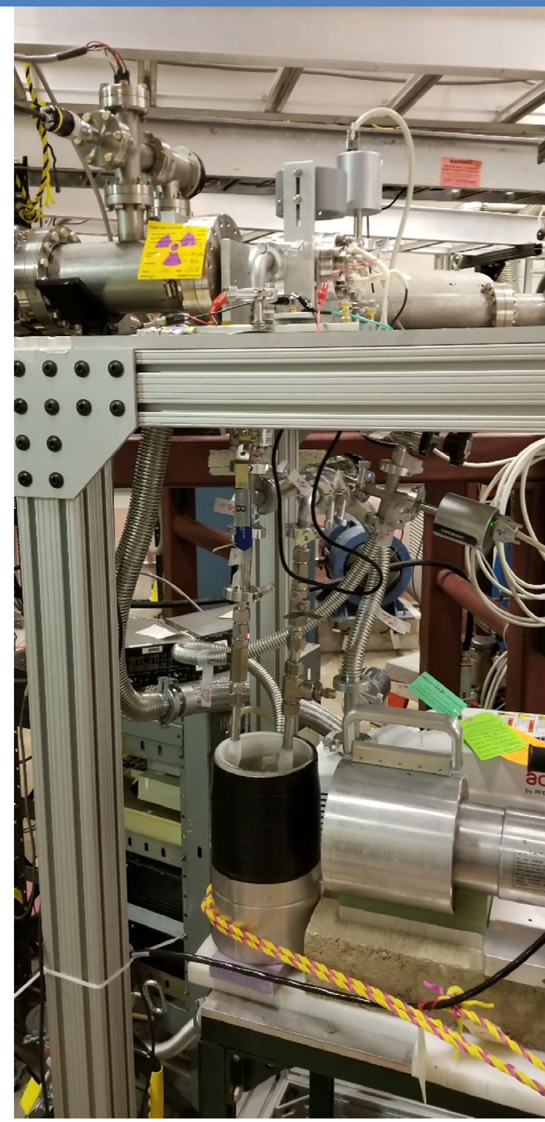
Sample 3 = 15.08 mg/cm2
area density



Sample chamber at
ATLAS beam line

Test Setup at ATLAS

Helium circulation pump and cold trap



Cold trap and Ge gamma detector

Counts gammas from 211Rn transferred to charcoal

Off-line counting of long lived ^{207}Bi

50% of ^{211}Rn (14 hour) decays to ^{207}Bi (32 year), so counting the ^{207}Bi is useful for tracking the final location of the ^{211}Rn/^{211}At

Counting the ^{207}Bi gammas from the cold charcoal trap (1% transferred at 65 ^{o}C)

Counting the ^{207}Bi gammas from the Bi_2O_3 target. Results scale to 64 µCi of ^{211}Rn produced @ 30 puA current, 10 h.

Summary

- Refractory nanoporous bismuth oxide thin films developed on 303 stainless steel substrates
- Retain open porosity and remain adhered through thermal cycling – robust, ceramic-like coating on backing
- Tested 15 mg/cm^2 target on-line at ATLAS to produce ^{211}Rn
- Next steps (at Argonne)
  - Improve sample heater to reach 600 ^{o}C to increase release
  - Add sample chamber neutron shielding to permit higher beam currents (ANL funded) and on-line counting of yields
  - Quantitatively determine $ions/cm^2$ limit of target lifetime
- Ultimate goal is to use large area Bi_2O_3 targets for production and distribution of $^{211}Rn/^{211}At$ radioisotope generator for cancer therapy.

Acknowledgments

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Dr. Michelle Shinn