Evaporating W-182 at >6000°C (through #12 welding shield)

Is there a better way?
Mike Zach, Materials Processing Researcher
Stable Isotope Group, Physics Division
Oak Ridge National Laboratory

My job: I work with researchers to find creative ways to solve their research needs.

I do whatever it takes to transform enriched stable isotopes making whatever form the researcher needs to make their experiments successful.
This talk

- Overview
- Project of e-beam W-182
- Is there a better way? (New tool for our lab)
- Invitation
# Isotopes Available To You Through Isotopes.gov

- ~225 isotopes of ~50 elements available
- Custom chemical conversions of these isotopes

See [www.isotopes.gov](http://www.isotopes.gov)
Technical Services Available Through Stable Isotope Group

- Dispensing of isotopes as compounds or metals
- Custom synthesis of enriched isotopes
- Pyrochemical conversion of high-purity metals
- Arc melting and alloying
- Dispensing of enriched isotopic gases
- Hot and cold rolling (mm to μm thicknesses)
- Wire rolling and swaging
- High-vacuum evaporation (resistance, RF, e-beam)
- Inert processing of reactive metals

Small milligram quantities of isotopes provided for tracer studies, analytical standards or sample spikes
Ni-62 pellets for production of Ni-63
Sr-88 metal strips to create ions used for trapped-ion quantum computation
Shipment can be made in 10^4 Torr environment
High-purity distillation of 144Sr after lanthanum reduction
Electron beam evaporation of 152W

Arc melting
Inert atmosphere processing
Hot pressing
Rolling
Induction heating
Evaporating
W-182 Coating Used as a Fusion Research Tool

E-beam Evaporator

With plenty of challenges
Two runs for 72 tiles
Donovan, et. al.; Review of Scientific Instruments (Vol.89, Issue 10)
UT Graduate Student Working at ORNL Is Using LAMS

- Microdestructive
- LAMS avoids
  - multistep dissolution
  - hazardous chemical HF
- Gives isotopic fingerprint with spatial resolution
- Addition to solution based ICP-MS and Rutherford backscattering spectroscopy
Analytical isotopic mapping

- Laser ablation / inductively coupled plasma – mass spectroscopy gives spatial distribution of elements and isotopes
- This experiment: tracks erosion and redeposition

Donovan, et. al.; Review of Scientific Instruments (Vol.89, Issue 10)
Problems with Thin Films of Isotopic Enriched Materials

• Isotopes are very limited availability and high value ($1-$20K/mg and could require multimillion $ campaign to make more)

• Most semiconductor coating instruments use low value materials (Au = 3.8¢/mg, Pt = 2.6¢/mg, Rh =8.3¢/mg)

• Golden era of nuclear physics fundamentals
  – Expertise
  – High demand specialized equipment
  – Lax environmental standards

• Modern capital equipment budgets purchase semiconductor instruments for thin films
Options for Thin Films

- Rolling foils
- Thermal evaporation
- Electron beam evaporation
- CVD, ALD, MBE
- Laser ablation deposition, laser induced forward deposition
- Electrochemical deposition
- Sputtering
Concept for Ion Beam Sputter Deposition Tool

- Ion beam
- Small isotope source
- Confined plume of isotope
- 30 cm
Ion Beam Sputter Deposition

- Kaufman & Robinson, Inc. KDC 10 Ion Source
- 100-1200eV
- 0.5-4 sccm Ar or Xe
- Under 1 cm focused beam
- 10mA @ 600eV continuous
Diamond coated graphite dish w/ isotope
Graphite Source Holder

- Graphite sputtering threshold = 323 eV
  - Xe$^+$ ions, -30° to ⊥ incidence, 1 mA/cm$^2$

- Metals are 9eV-92eV range

- Sub-threshold sputtering range will allow absence of C into sputtered films.

<table>
<thead>
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<th>Material</th>
<th>Threshold (eV)</th>
<th>Etch rate at 300 eV ion energy (Å/min)</th>
<th>Etch rate at 1200 eV ion energy (Å/min)</th>
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<td>Si</td>
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<tr>
<td>C</td>
<td>323</td>
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Energy and Angular Dependent Plume of Sputtered Atoms

- Two contributions to sputtered plume
  - Isotropic (randomization by multiple scattering)
  - Non-isotropic (carries more of the ion momentum)
- High energy causes random scatter to beam
- Keeping target close to source and rastering should be high efficient, localized and captured by target or capture substrate

Study on polycrystalline Ti


Fig. 1. Sketch of the experimental setup.
New tool to allow:
Nanometer to 10 micron films

Air sensitive
• Li
• Ca
• Ba
• Sr

Refractory metals
• W
• Ti
• Ta
• Mo

Most any other enriched isotopic material
(excluded for now are As, Se, Te, Cd, Zn and naturally occurring radioactive materials)

• Low loss (50-95% efficient vs. 1-5% using thermal, CVD or e-beam)
Transfer in <1ppm O₂ / H₂O
Evacuate to 10⁻⁷ Torr for indefinite storage
Going forward: How Can I Help?
What is the Next Project?

Solve challenging problems Isotopes.gov

New ion beam sputter tool for efficient deposition

Our new laser ablation tool for mapping isotopic abundance

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