Capabilities for Fusion Materials and Technology R&D at Sandia National Laboratories

PRESENTED BY

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Fusion Energy Sciences R&D at Sandia

- **Fusion Materials Program** R&D reveals the effects of plasma exposure on materials, hydrogen transport & trapping, recrystallization effects
- **Ion Beam Lab** provides critical support for both DIII-D and the fusion materials program
  - DiMES sample preparation and analysis
  - Material migration studies
- **SciDAC** program couples computational materials science with machine learning and uncertainty quantification to enhance our understanding of plasma-surface interactions
- **Blanket and Tritium Fuel Cycle** focus on H isotope permeation, interactions with blanket structural materials
- **SNL Boundary Physics Program** supports DIII-D collaboration, Langmuir probe arrays (critical diagnostic)
- **Low-temperature plasma science** collaborative user facility

Advanced W materials
Collaborators: Penn State, Utah, Stony Brook Univ., UCSD-PISCES
Sandia’s Ion Beam Laboratory (IBL) has unique facilities and instrumentation for radiation damage studies and materials characterization.

The IBL supports a wide range of programs at Sandia ($4.5 M/yr budget)

Accelerators:
- **HVE 6 MV Tandem:** Accelerates most elements from H to Au (1 μm spot size), ideal for simulating radiation damage in materials
- **NEC 3 MV Pelletron:** Accelerates most gases, (150 nm spot) Rutherford backscattering and Nuclear Reaction Analysis
- **HVEE Implanter:** 350 kV beam (1 μm spot), can produce 14 MeV n
- **Other surface coating, deposition techniques available**

![3 MV Pelletron Accelerator](image1)

![In-situ TEM end station](image2)
Sandia’s Ion Beam Laboratory (IBL) has unique facilities and instrumentation for radiation damage studies and materials characterization.

Radiation effects on materials:
- Ion beam energy / species tailored for desired dpa level, minimizing conc. of implanted species
- Simulation of n damage in plasma-facing & structural materials, electronic components

Nuclear Reaction Analysis (NRA):
- Depth profiling of hydrogen isotopes in materials up to (~ 3 μm)

Rutherford Backscattering (RBS) & Elastic Recoil Detection (ERD):
- Composition analysis, sputtering and redeposition studies

Example: Erosion and redeposition of Mo exposed to DIII-D plasma Wampler, JNM (2013).

Example: D retention at displacement damage in W [Wampler, Phys. Scr. (2009)]
Cutting-edge microscopy capabilities are available throughout the Sandia site

DOE-funded facility: **Center for Integrated Nanotechnologies**
- Focus on nano technology synthesis, characterization and modelling
- Contains numerous world-class microscopy capabilities

**Aberration corrected transmission electron microscopy**
- Near-atomic resolution imaging of materials / interfaces

**Focused ion beam profiling, field emission SEM**
- Surface patterning and cross-sectioning of materials
- High resolution imaging

**In-situ Ion Irradiation Transmission Electron Microscopy (I^3TEM)**
- Enables direct imaging of ion effects on surfaces
Sandia’s Livermore site has unique capabilities for surface characterization and hydrogen science studies

**Surface Characterization:**

**Ion scattering spectrometry**
- Composition & atomic structure (sensitive to H)
- Able to probe insulator surfaces

**Scanning Auger spectroscopy**
- Chemical composition mapping, depth profiling

**X-ray photoelectron spectroscopy**
- Local chemical environment
- Near-ambient pressure instrument available

**Atomic force microscopy**
- nm-scale surface roughness

**Hydrogen Science:**
- Hydrogen permeation
- Thermal desorption spectroscopy

Angle-resolved ion energy spectrometer at Sandia/CA
Sandia expertise in radiation-hardened electronics can be used to support reactor-relevant instrumentation.

Sandia core mission: design, fabricate and qualify electronics for use in radiation environments for US national defense programs.

- Experimental facilities for testing
- Modeling and simulation of devices and effects of displacement damage and ionization
- MESA facility for fabrication of rad-hard electronic components.
A wide range of capabilities and expertise are broadly available laboratory-wide

Lab-wide areas of expertise

- Heat, radiation & particle fluxes
- Corrosion, stress
- Compatibility
- Waste disposal
- Balance of Plant, remote handling, safety systems
- Automation
- Structural/functional materials