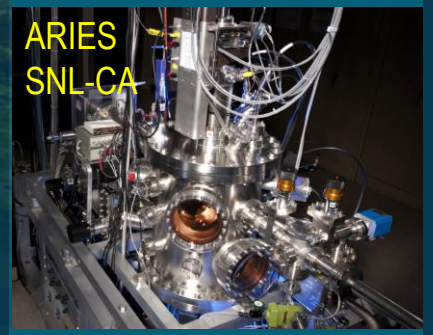
Capabilities for Fusion Materials and Technology R&D at Sandia National Laboratories



PRESENTED BY

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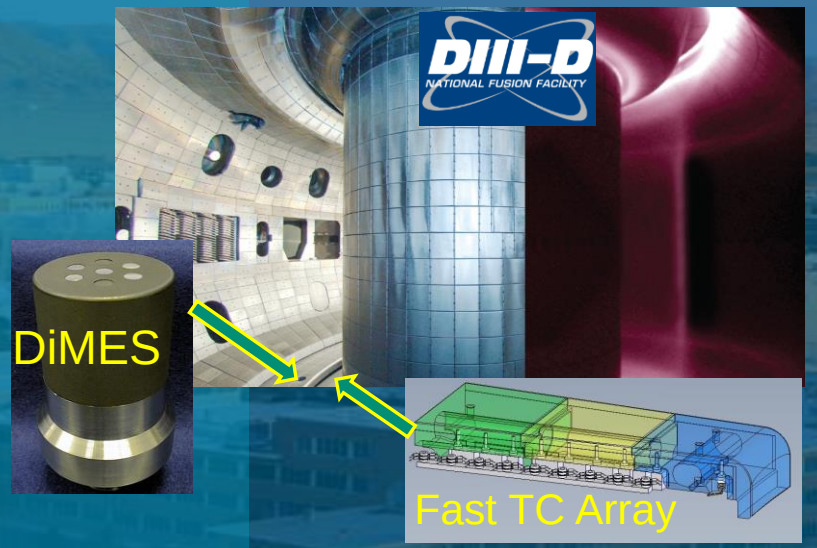
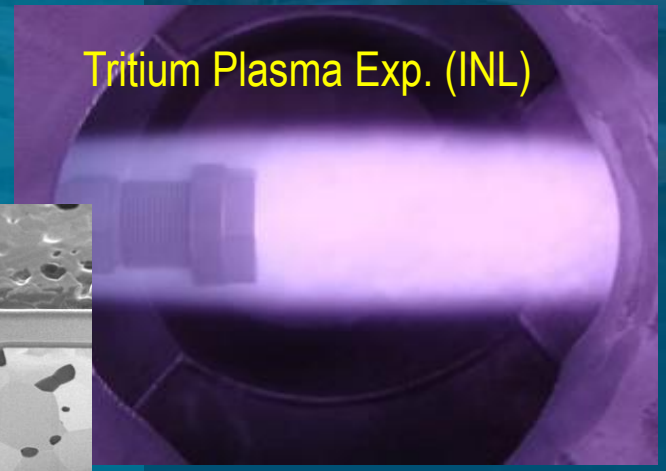
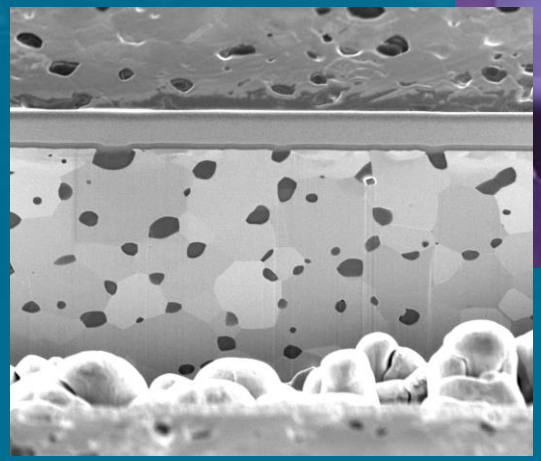
Fusion Energy Sciences R&D at Sandia

- 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, Sony Brook Univ., UCSD-PISCES

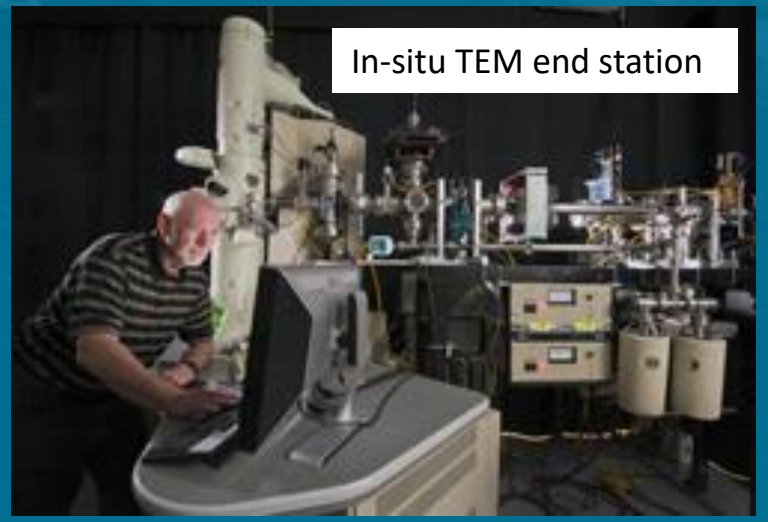
Sandia's Ion Beam Laboratory (IBL) has unique facilities and instrumentation for radiation damage studies and materials characterization

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



In-situ TEM end station

Sandia's Ion Beam Laboratory (IBL) has unique facilities and instrumentation for radiation damage studies and materials characterization

Radiation effects on materials:

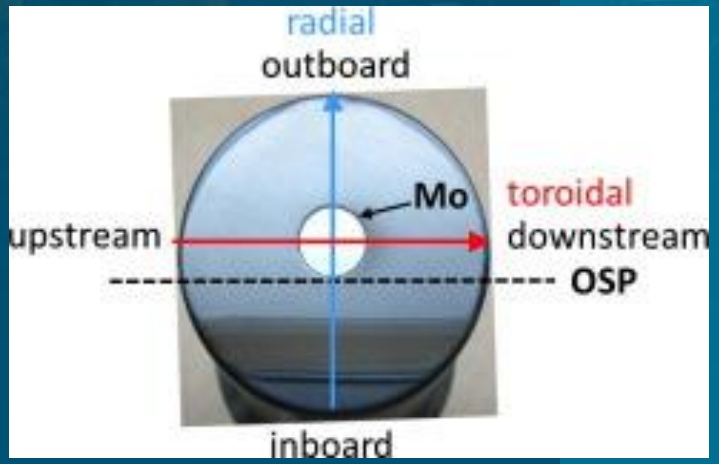
- Ion beam energy / species tailored for desired dpa level, minimizing conc. of implanted species
- Simulation of n damage in plasma-facing & structural materials, electronic components

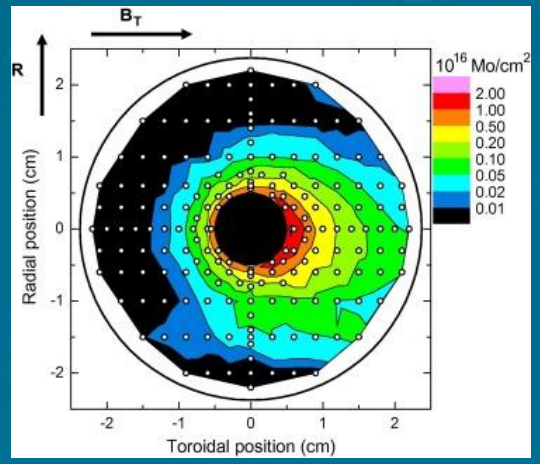
Nuclear Reaction Analysis (NRA):

- Depth profiling of hydrogen isotopes in materials up to (~ 3 μm)

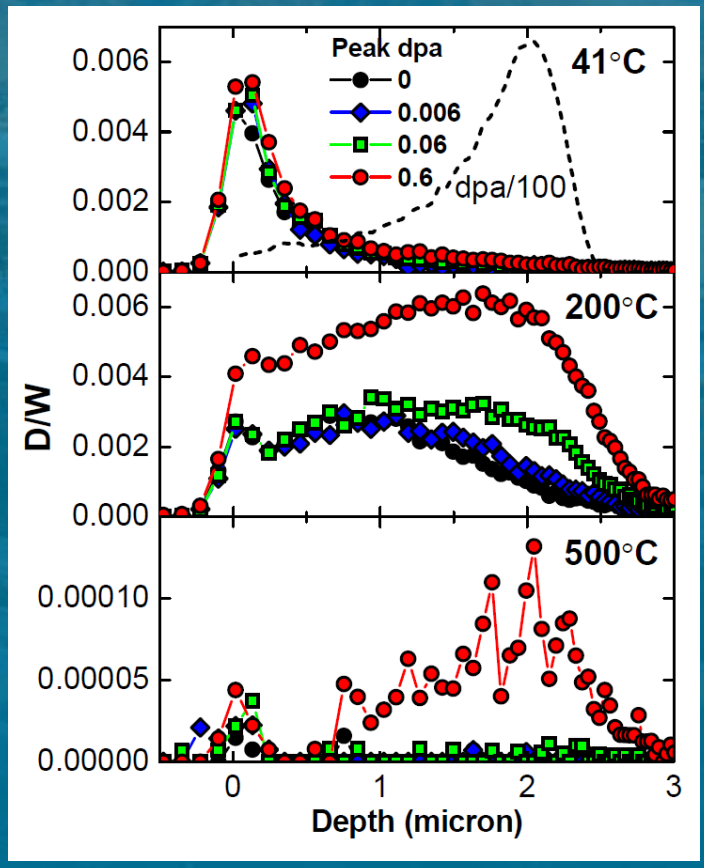
Rutherford Backscattering (RBS) & Elastic Recoil Detection (ERD):

- Composition analysis, sputtering and redeposition studies





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

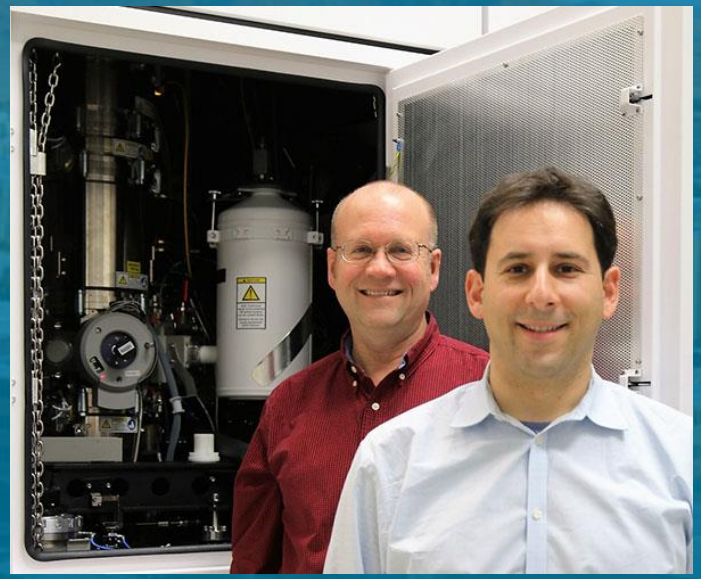


Example: D retention at displacement damage in W [Wampler, Phys. Scr. (2009)]

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:

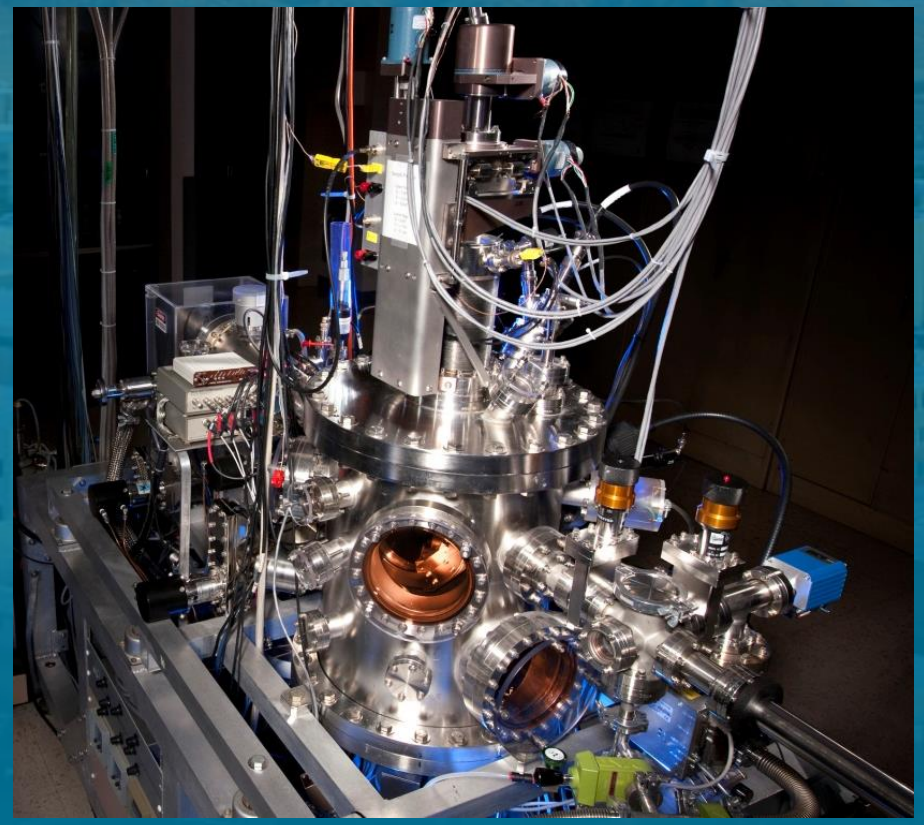
Ion scattering spectrometry
- Composition & atomic structure (sensitive to H)
- Able to probe insulator surfaces

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

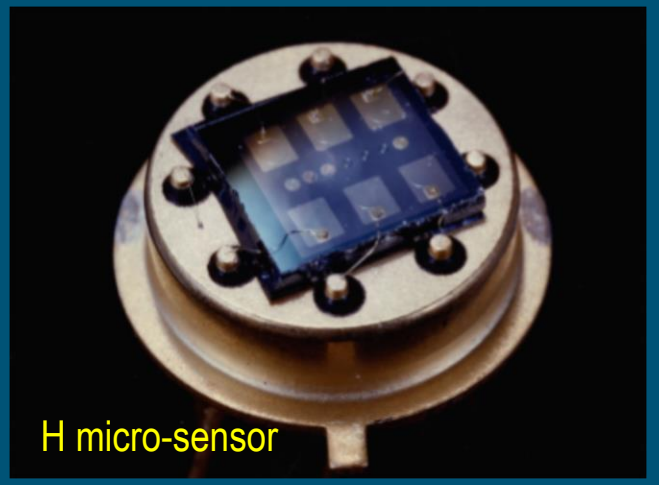


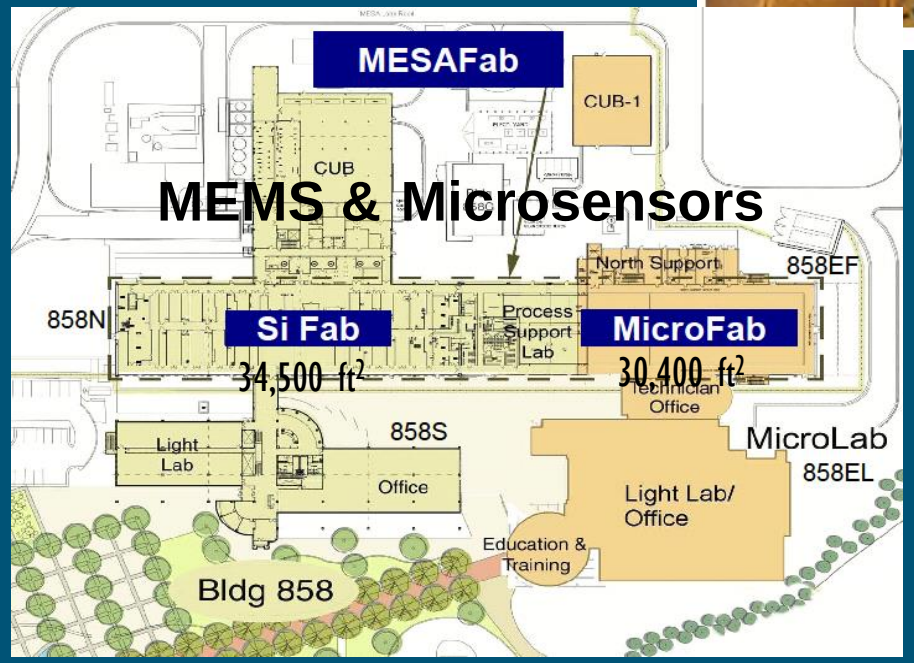
Angle-resolved ion energy spectrometer at Sandia/CA

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.



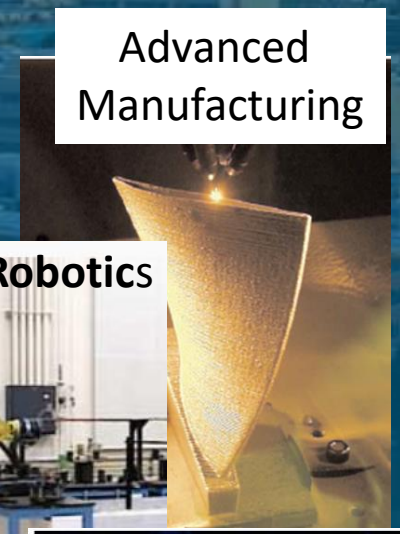


A wide range of capabilities and expertise are broadly available laboratory-wide

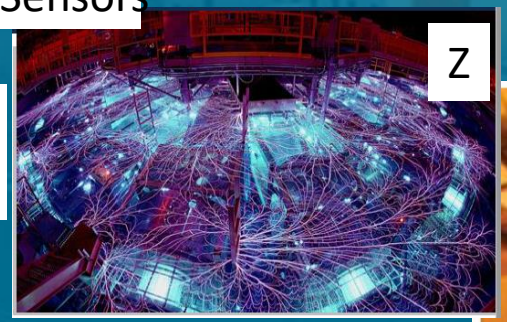
Lab-wide areas of expertise

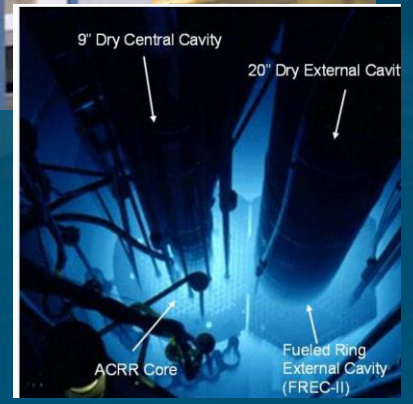
- Heat, radiation & particle fluxes
- Corrosion, stress
- Compatibility
- Waste disposal
- Balance of Plant, remote handling, safety systems
- Automation
- Structural /functional materials

Rad Hard Sensors



Radiation Hardening & Components





MESA – μ–electrons & Fab

Safe Reactor Design and Operation