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An Ion Beam Platform for Screening Materials for Nuclear Reactors

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Sandia National Laboratories
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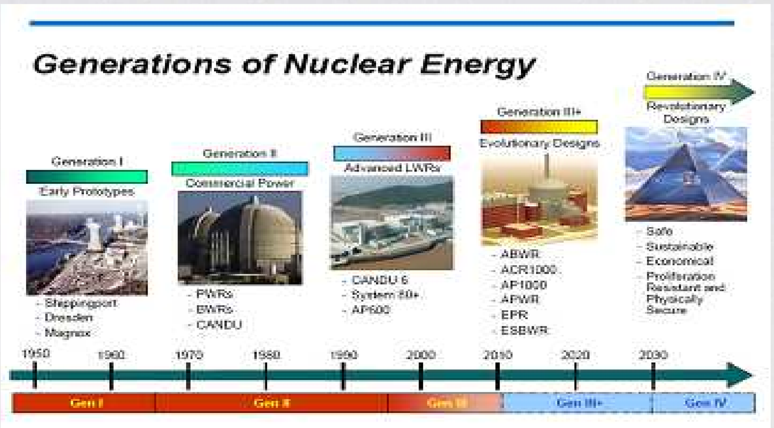
Problem



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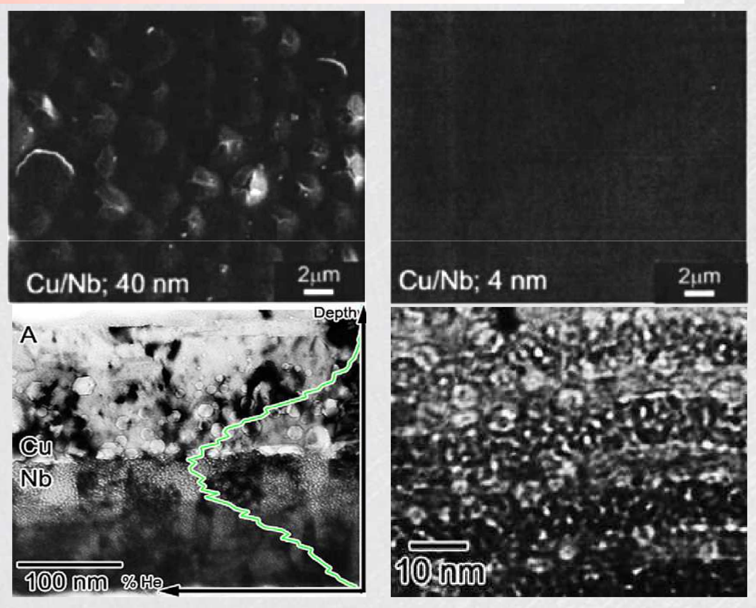
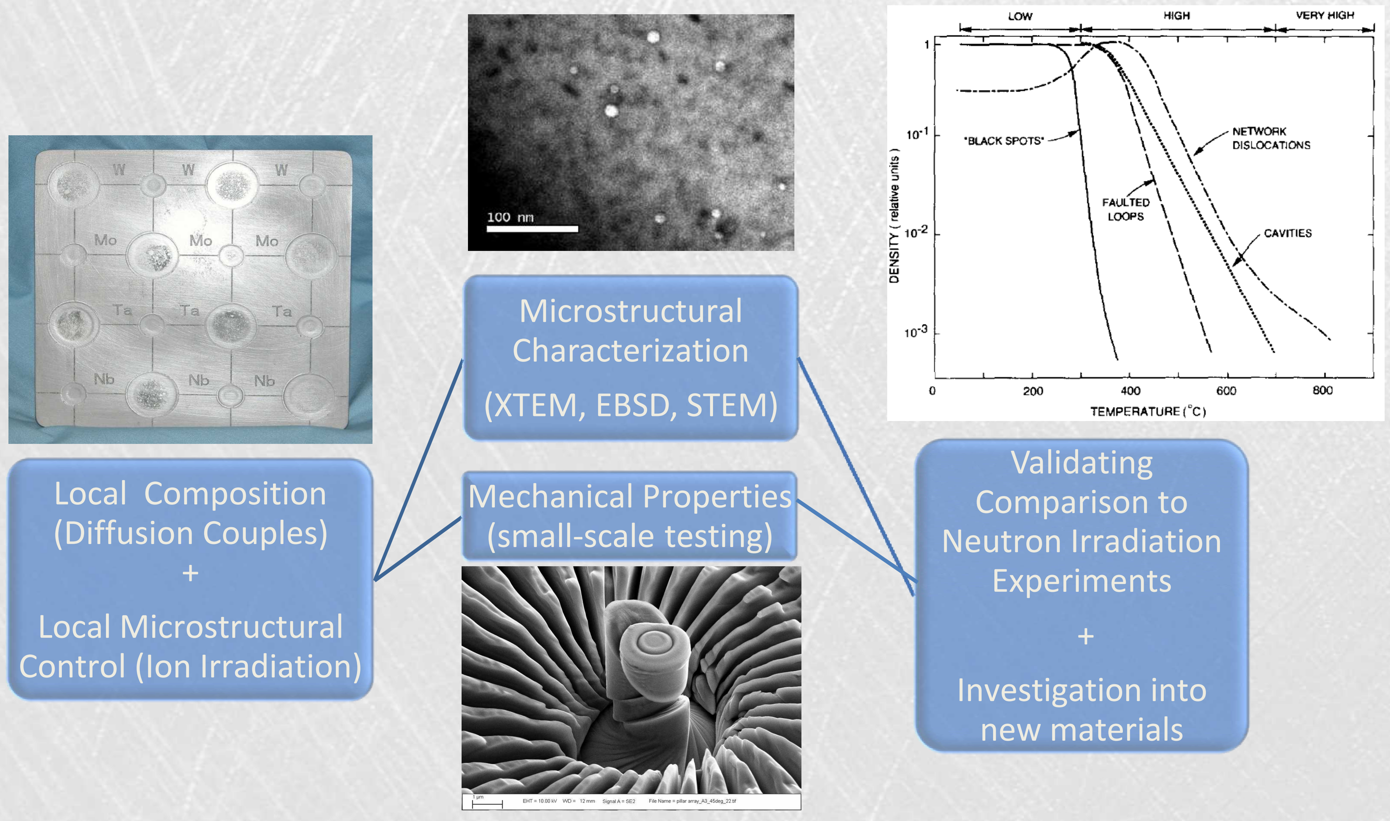


Hattar et al. Scripta Mat. 2007

- All future reactor designs require advancements in radiation tolerant materials
- Many materials systems are being considered
- Interface engineering is providing a potential solution
- One example: CuNb nanolamellars (immiscible system with a weak interface) provides a plethora of interfaces that distribute He bubble and associated damage in films irradiated at 10^{17} cm^2 of 33 keV $^4He^+$ at 763 K

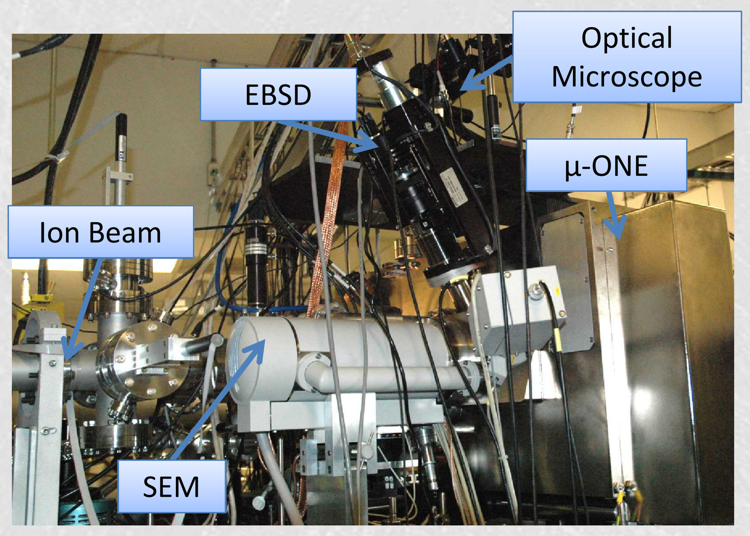
Advanced materials and the need for rapid testing often requires new experimental testing techniques

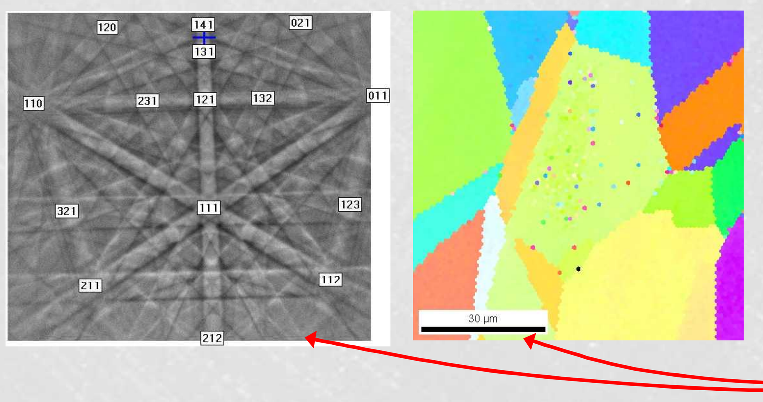
Approach

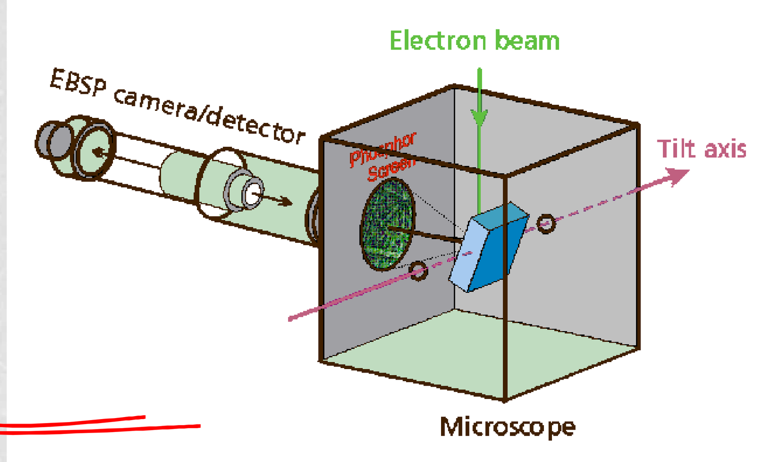


Micrometer Resolution Optical, Nuclear, and Electron Microscope

- Improvements have been made to micro-ONE to permit rapid characterization of ion beam damage during implantation of H, He, or heavy ions at currents up to 10,000 ions/s.
  - Updating and making operations a SEM run in parallel
  - Addition of electron back scattered (EBSD) detector



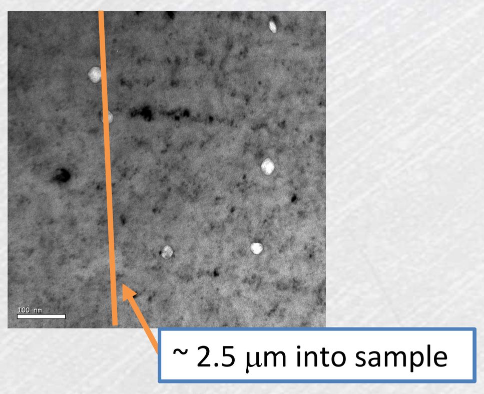


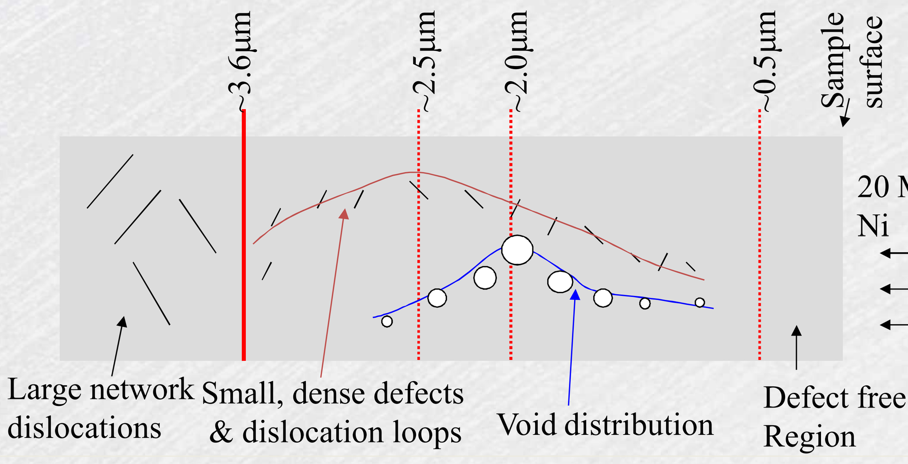


First EBSD Pattern and Map obtained with the Micro-ONE EBSD system

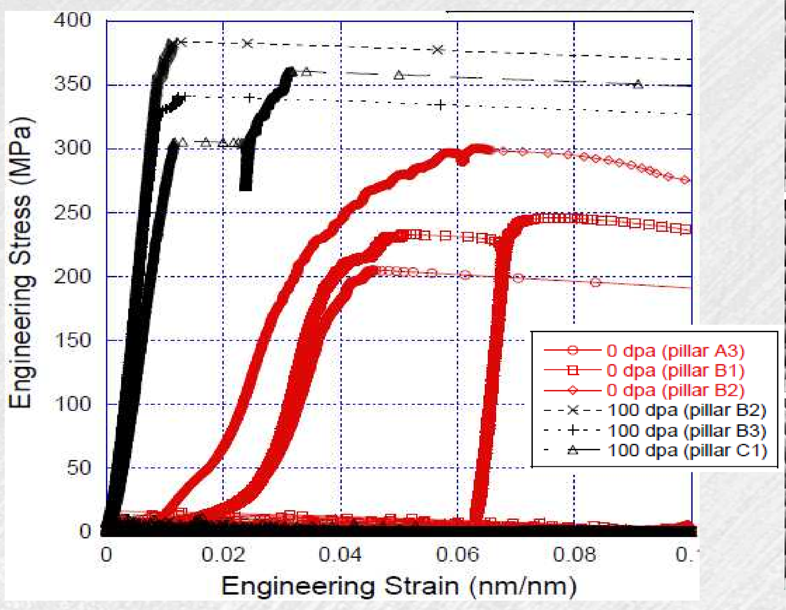
Micro-ONE now permits parallel imaging of changes in microstructure: grain size, phase transformations

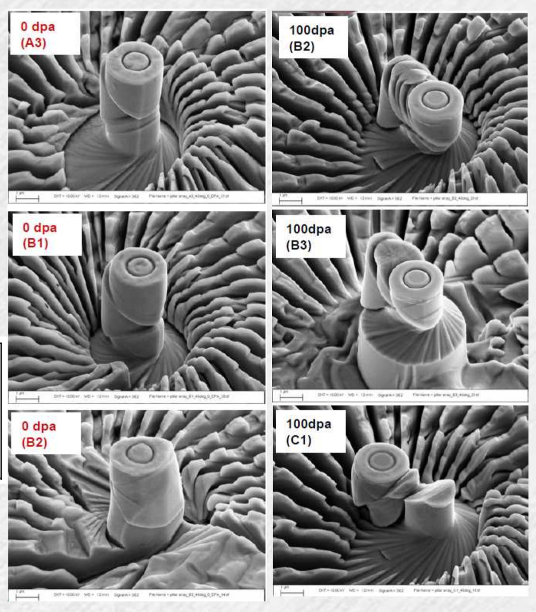
Results



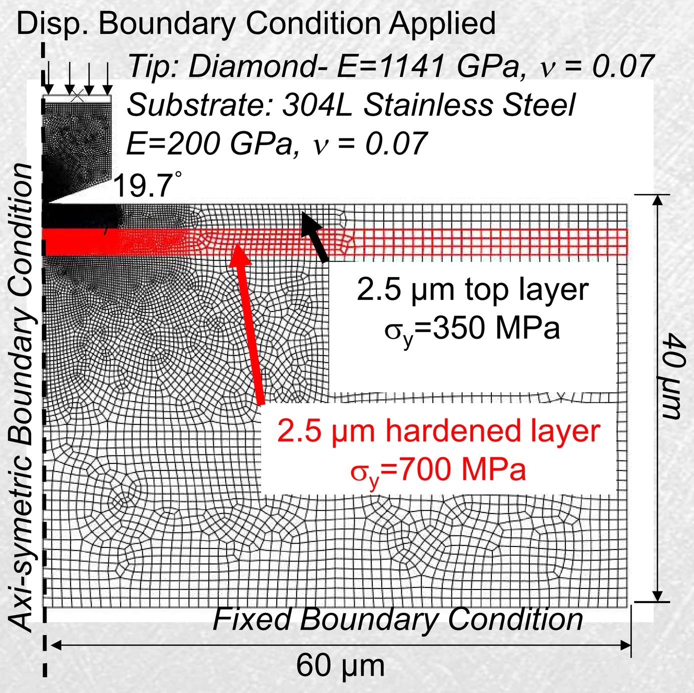


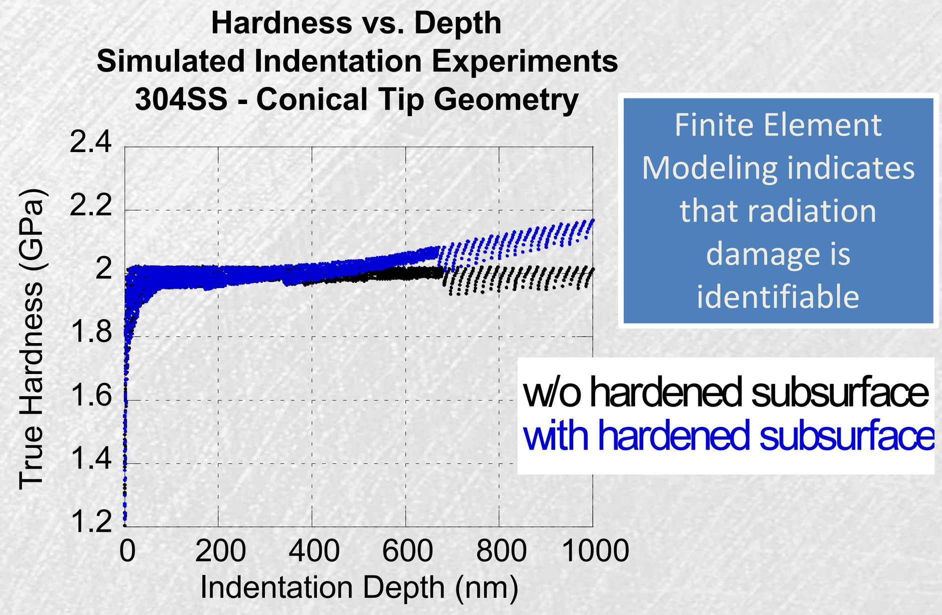
316 SS samples were irradiated at 400°, 500° and 600°C by 20 MeV Ni ions to a maximum peak dpa of ~100 at about 3.5 µm. The FIB was used for TEM sample preparation.



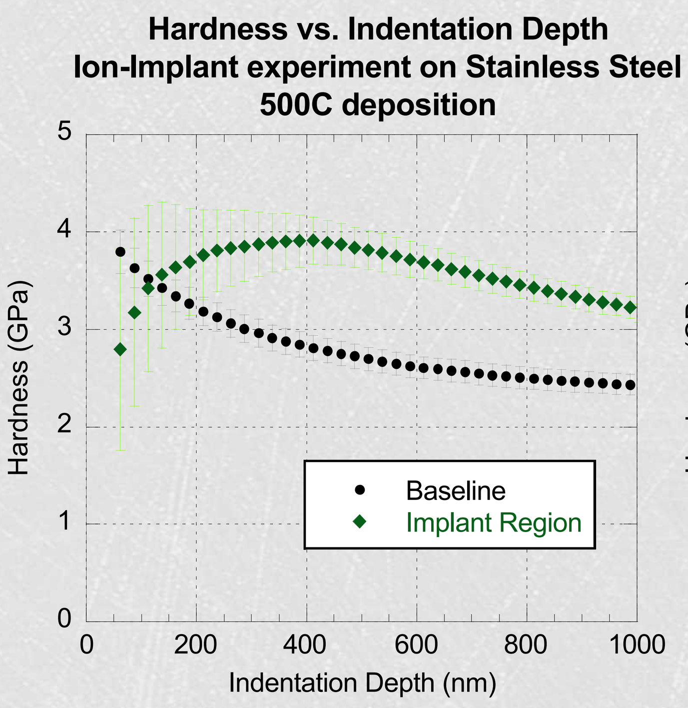


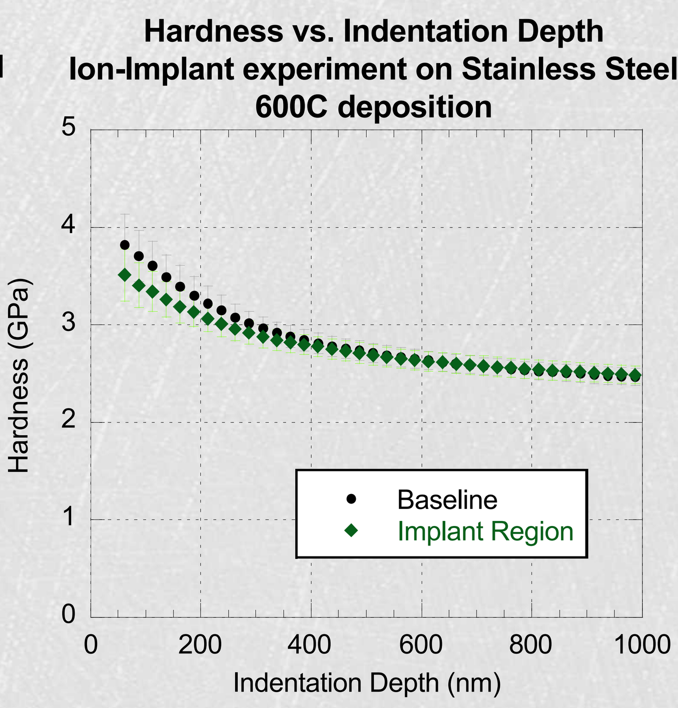
Results from ion irradiated and FIB prepared Cu micropillars indicates that ion beam irradiation can be used to determine the mechanical properties of ion irradiated volumes.





Finite Element Modeling indicates that radiation damage is identifiable



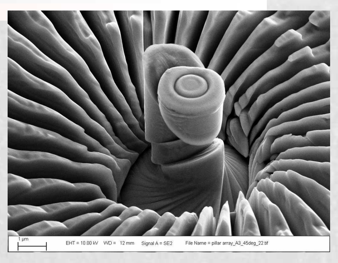


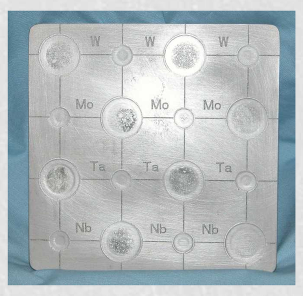
Implantation at 600 C is dominated by diffusion of defects not seen in the 400 C and 500 C dominated by a high density of point defects.

Significance

If a combinatorial approach to rapidly test the radiation damage produced to emulate neutron damage is developed, it will significantly enhance:

- First-order validation method for advanced cladding and structural materials for the next generation nuclear reactors.
- Rapid method to characterize and identify radiation tolerant materials
- Greater fundamental understanding of property-microstructure-processing relationship of materials in the extreme temperature and irradiation environment.
- Emergence of Sandia as a cutting-edge facility for ion-based simulation of radiation damage.





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