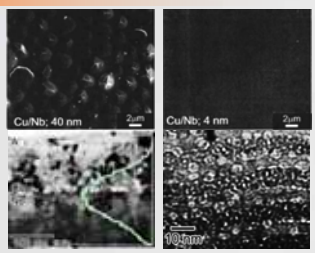
An Ion Beam Platform for Screening Materials for Nuclear Reactors

Sandia National Laboratories

K. Hattar, L.N. Brewer*, B.L. Boyce, T. Buchheit,
J. Puskar, P. Kotula, P. Lu, B.L. Doyle
*Naval Postgraduate Reseach Institute

Problem

www.inlportal.inl.gov

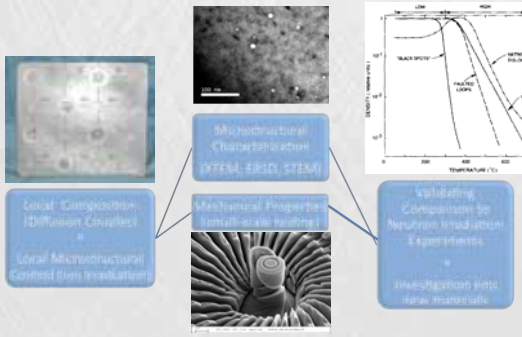


Hattar et al. Scripta Mat. 2007

- 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

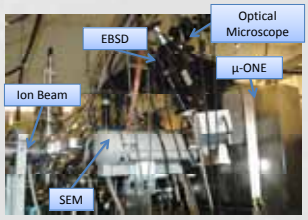
Advanced materials and the need for rapid testing often requires new experimental testing techniques

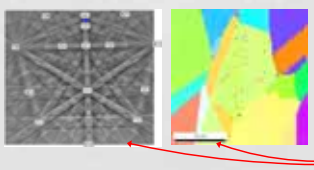
Approach

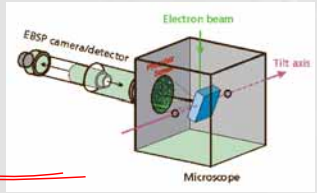


Micrometer Resolution Optical, Nuclear, and Electron Microscope

- 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



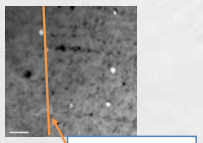




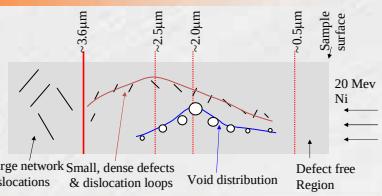
First EBSD Pattern and Map obtained with the Micro-ONE EBSD system

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

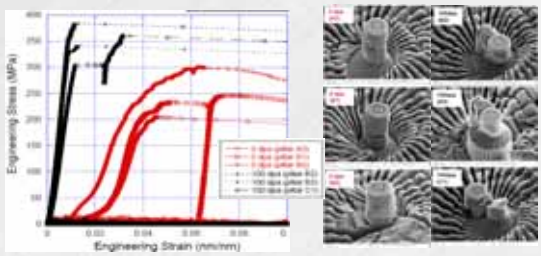
Results



~ 2.5 µm into sample

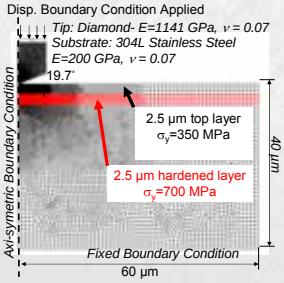


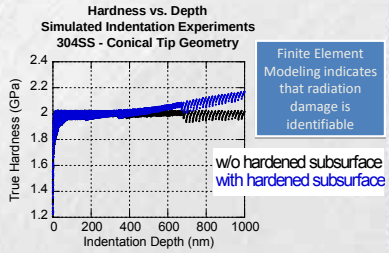
316 SS samples were irradiated at 400°, 500° and 600 °C by 20 MeV Ni ions to a maximum peak dpa of ~100 at about 3.5 µm. The FIB was used for TEM sample preparation.



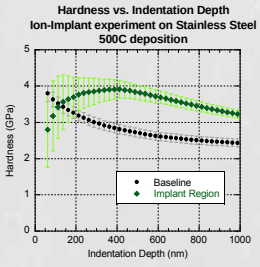
Results from ion irradiated and FIB prepared Cu micropillars indicates that ion-beam irradiation can be used to determine the mechanical properties of ion-irradiated volumes.

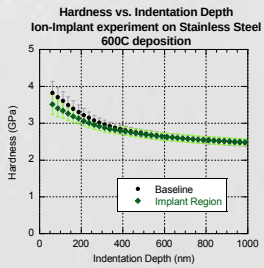
Disp. Boundary Condition Applied





Finite Element Modeling indicates that radiation damage is identifiable



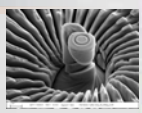


Implantation at 600 °C is dominated by diffusion of defects not seen in the 400 °C and 500 °C dominated by a high density of point defects.

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.



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

SAND 2010-2783C

Sandia National Laboratories