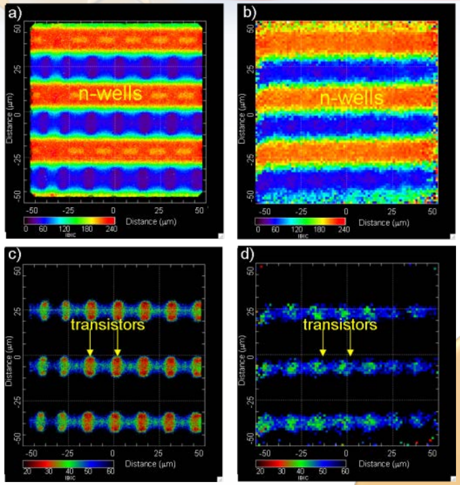
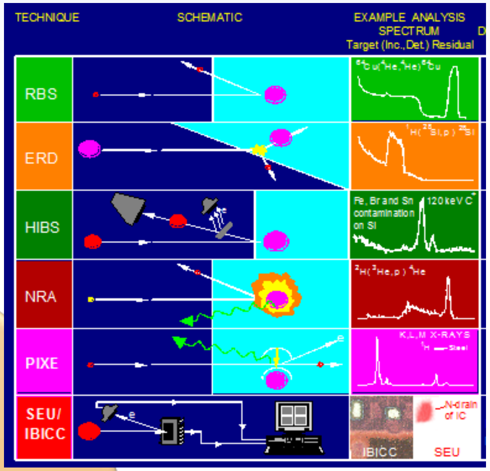
Sandia's Ion Beam Laboratory



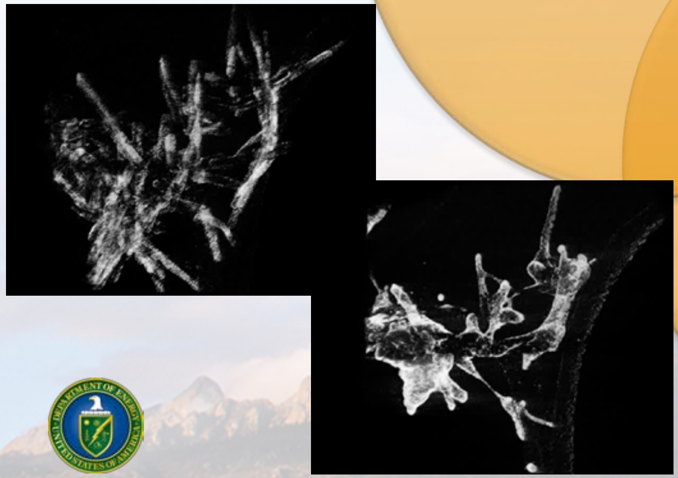


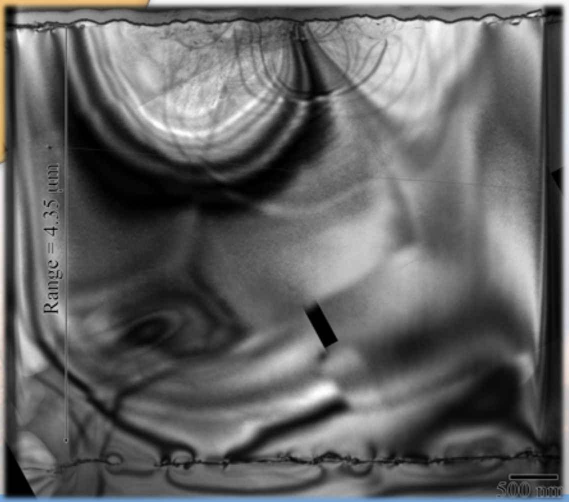
Ion Beam Analysis (IBA)

Radiation Effects Microscopy (REM)

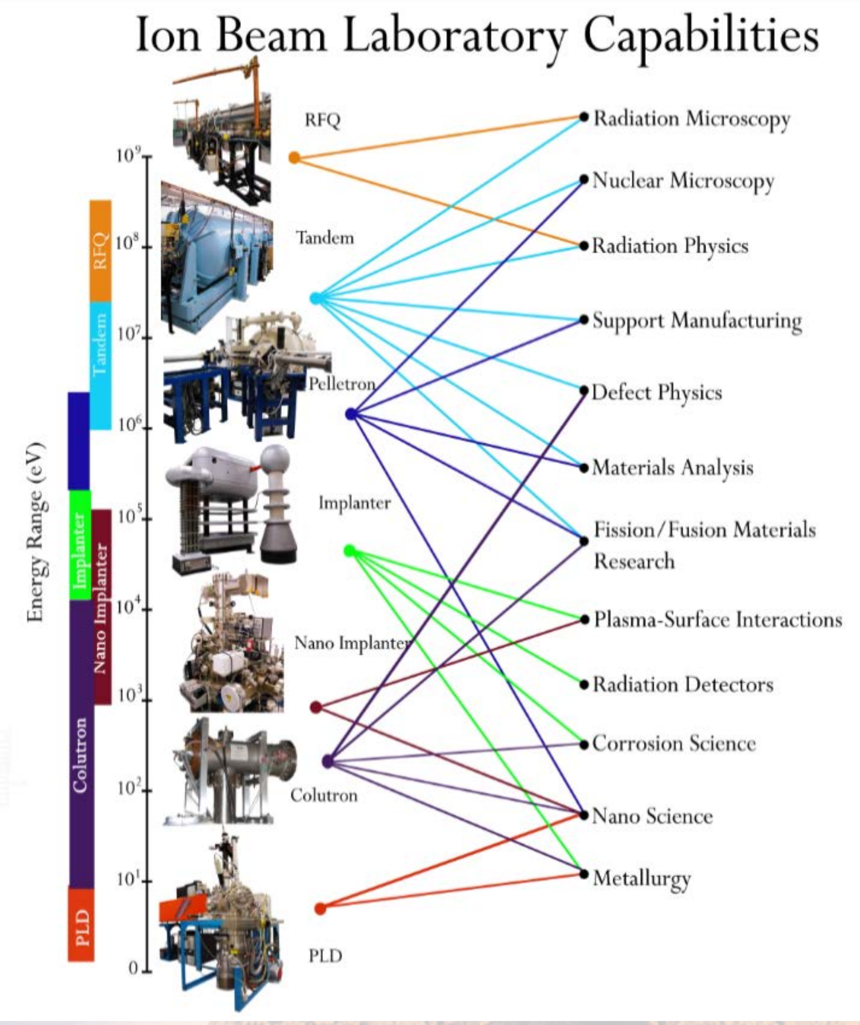
Ion Beam Modificaiton (IBM)

In situ Ion Irradiation Transmission Electron Microscopy (I^{3}TEM)

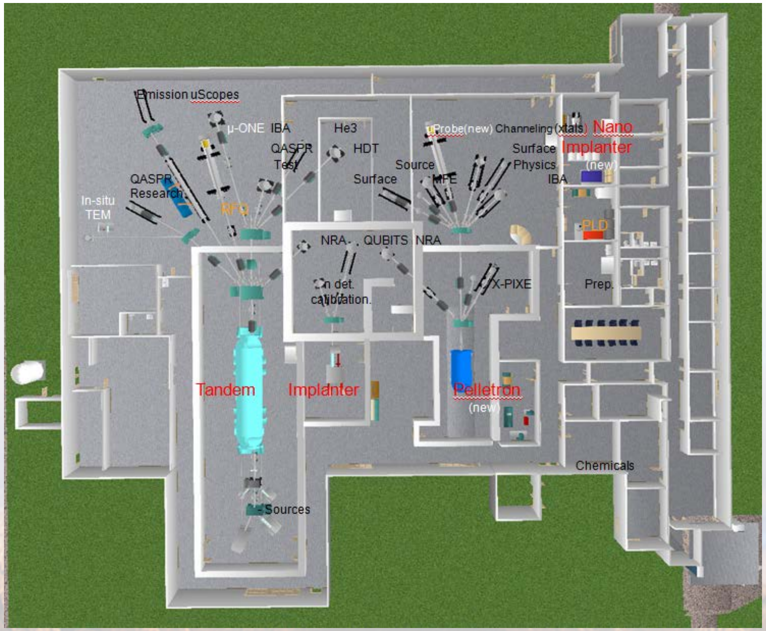




Overview


Ion Beam Laboratory Capabilities
RFQ
Tandem
Pelletron
Implanter
Nano Implanter
Colutron
PLD
Energy Range (eV)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
0
Radiation Microscopy
Nuclear Microscopy
Radiation Physics
Support Manufacturing
Defect Physics
Materials Analysis
Fission/Fusion Materials Research
Plasma-Surface Interactions
Radiation Detectors
Corrosion Science
Nano Science
Metallurgy


720

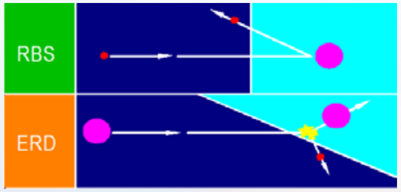

Emission uScopes
μ-ONE
IBA
He3
QASPR Test
HDT
uProbe(new)
Channeling (xtals)
Nano Implanter (new)
Surface Physics
Source
Surface
IBA
QASPR Research
In-situ TEM
RFQ
PLD
NRA
QUBITS
NRA
In det. calibration.
X-PIXE
Prep.
Tandem
Implanter
Pelletron (new)
Chemicals
Sources

Overview

Ion Beam Analysis

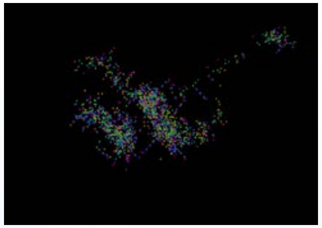
- *The basic concept:*

  A charged particle interacts with a material and one of a variety of signals produced gives information on the local chemistry and structure
- Each beam has associated benefits and limitations



Radiation Effects Testing

- Space and other nuclear environments demand radiation hardness
- Can simulate radiation damage from a single ion strike to up to 500 dpa

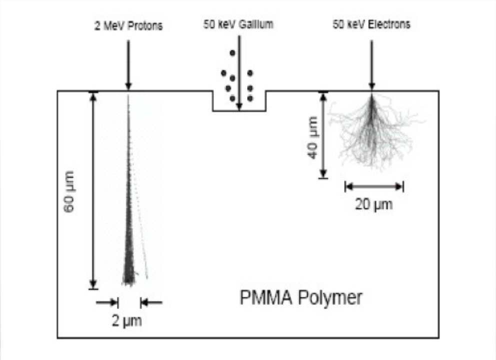


Blistering in CuNb multilayers

Ion Beam Modification

- *The basic concept:*

  Alteration of the structure through ion beam interactions
  - Implantation of dopants
  - Sputtering of material
  - Decomposition of gasses



http://www.pbeam.com

In-situ Ion Irradiation Transmission Electron Microscopy

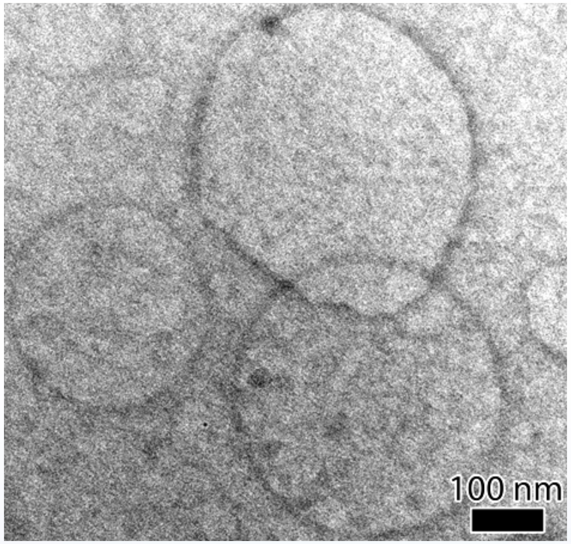
- *The basic concept:* Characterization of materials exposed to various types of particle bombardment in real time, at the nanoscale.
- Current capabilities include
  - Heating
  - Straining
  - Tomography

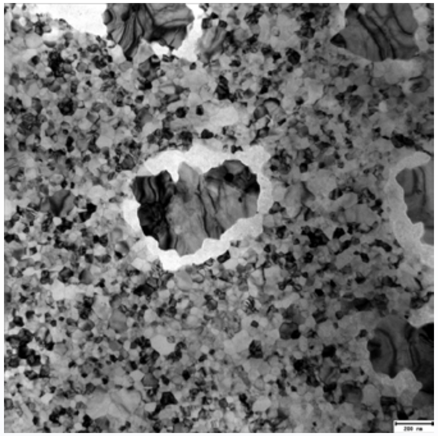
IBA, radiation effect testing, and ion beam modification are all widely used in research and industry

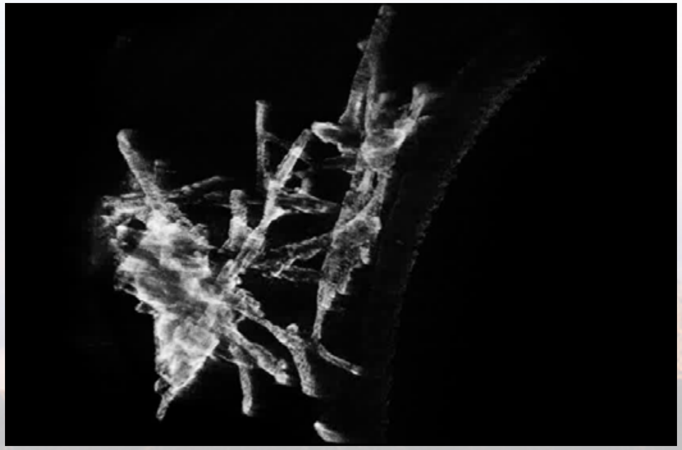
Sandia National Laboratories

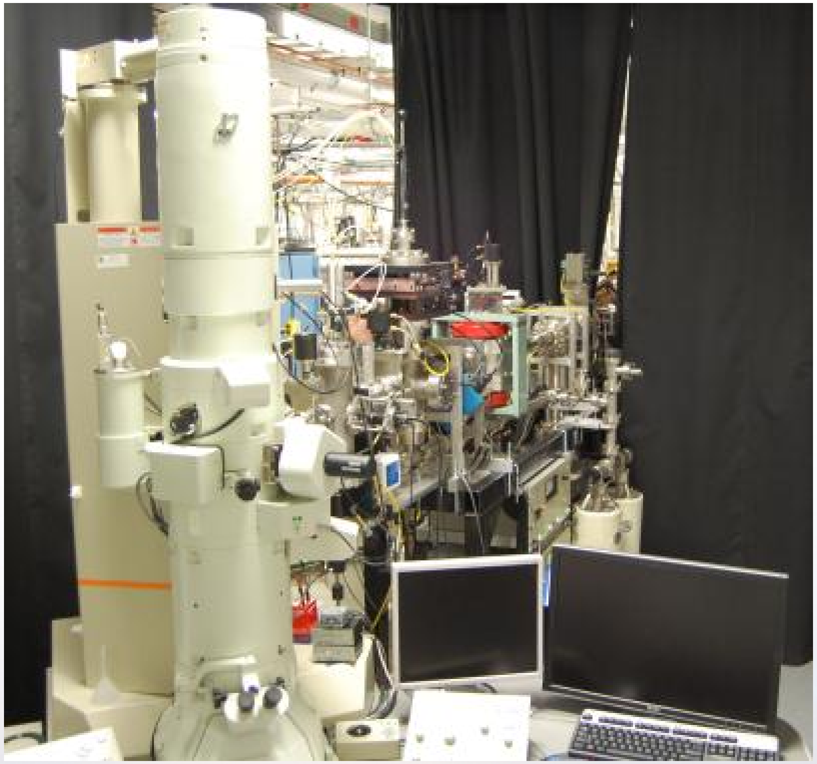
In Situ Transmission Electron Microscopy (I[3]TEM)

Characterization of materials exposed to various types of particle bombardment in real time, at the nano scale







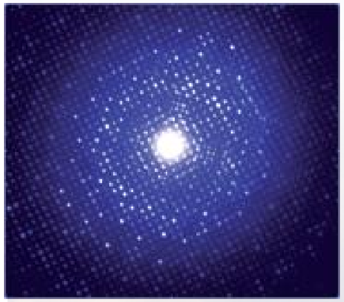


The IBL is one of only 11 facilities *worldwide* with this capability

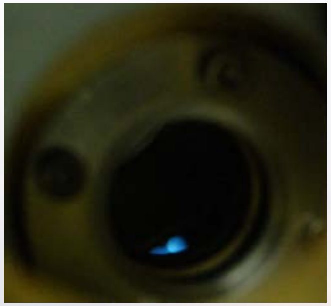
In situ Ion Irradiation TEM (I³TEM)

Proposed Capabilities

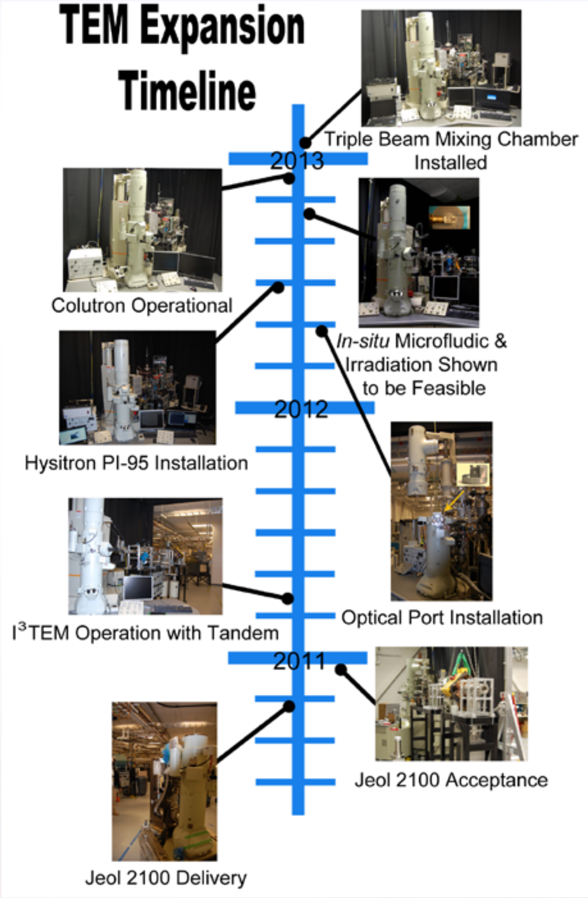
- 200 kV LaB_6 TEM
- Ion beams considered:
    - 1 MeV H^{1+}
    - 3 MeV He^{1+} Si^{3+} Cu^{3+} $Au^{3+}$$W^{3+}$
    - 14 MeV Si^{3+}
    - 10 keV D^{2+}
    - 10 keV He^{+}
    - All beams hit the same location
- Electron tomography
- Nanosecond time resolution (DTEM)
- Precession scanning (EBSD in TEM)
- *In situ* PL, CL, and IBIL
- *In situ* heating and cooling stages
- *In situ* electrical measurement stage
- *In situ* quantitative mechanical testing
- *In situ* vapor phase stage
- *In situ* liquid mixing stage



TVIPS



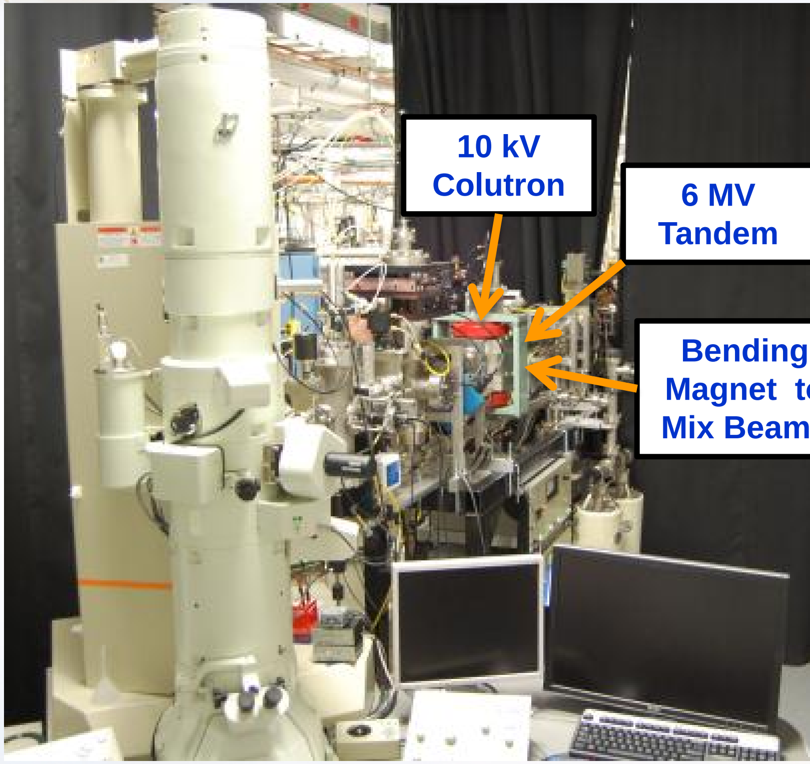
In situ IBIL

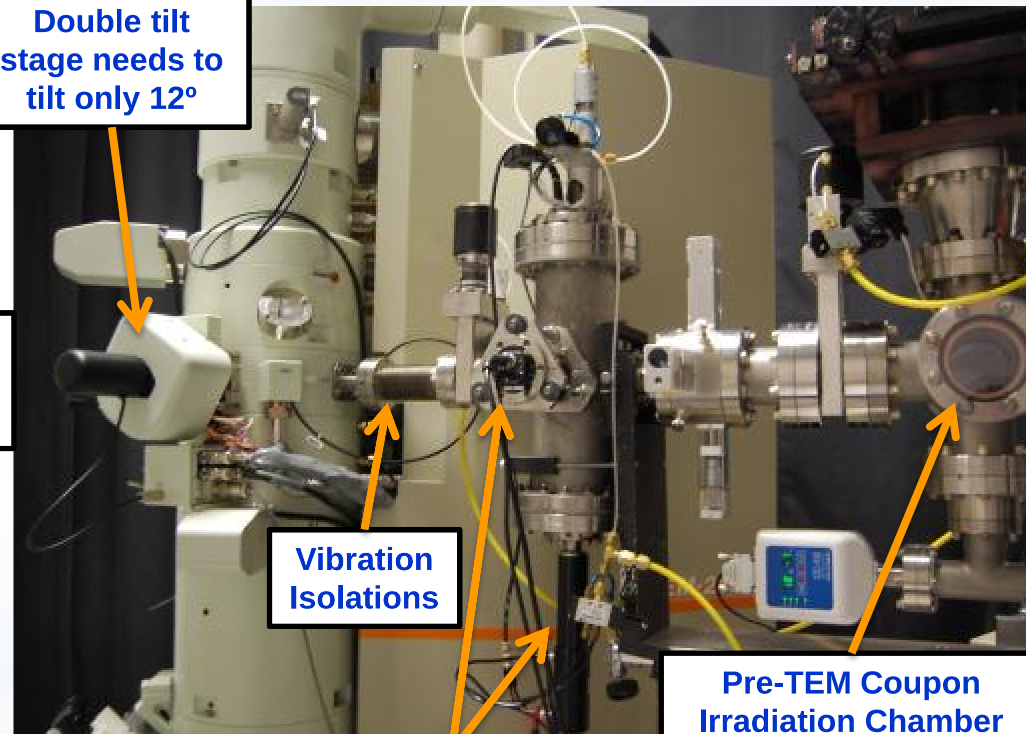


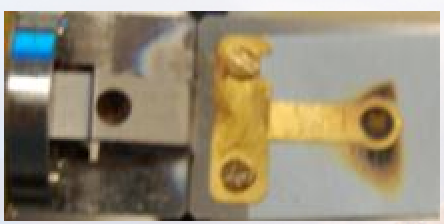
We have completed the Tandem accelerator connection and Colutron accelerator connection.

Many potential additions are being considered

Current Status of the *In situ* TEM Beamline







Beam burn from
14 MeV Si

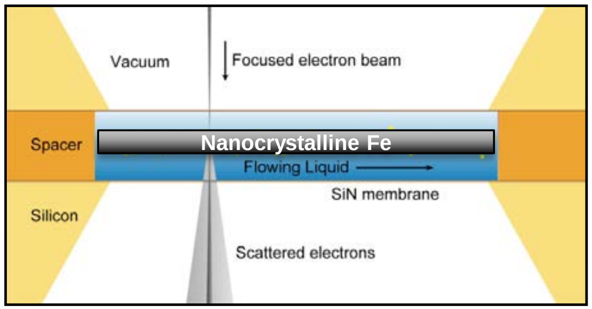
I^{3}TEM is operational,
but also still in development

Microfluidic Holder Beam Burn

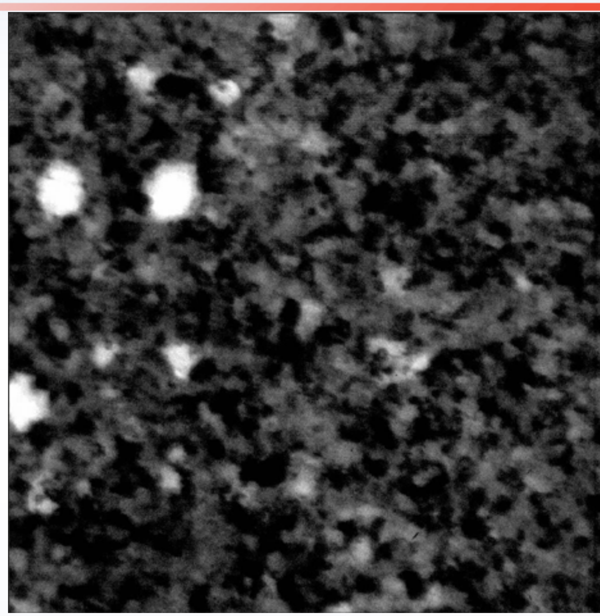
Can We Gain Insight into the Corrosion Process through *In situ* TEM?

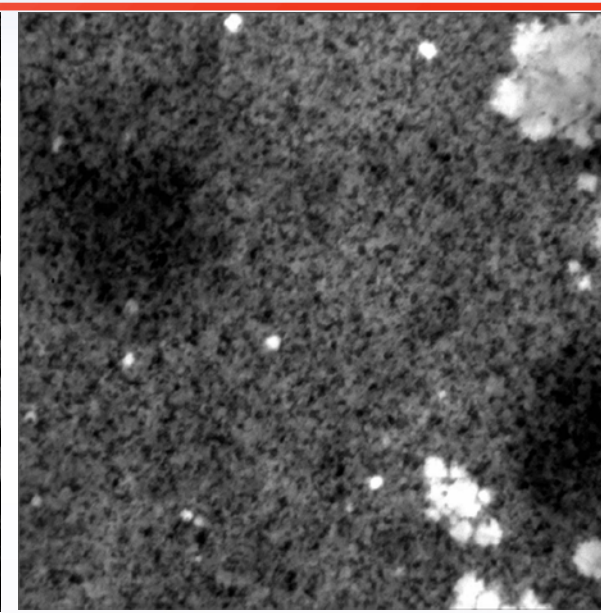
Microfluidic Stage

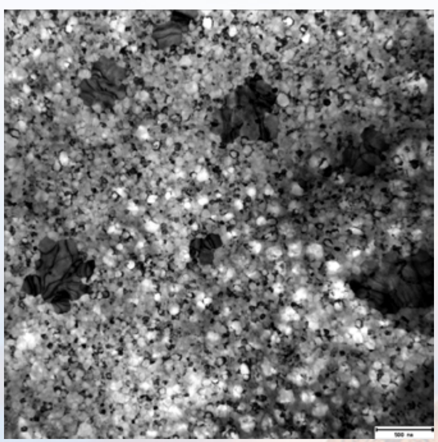
- Mixing of two or more channels
- Continuous observation of the reaction channel
- Chamber dimensions are controllable

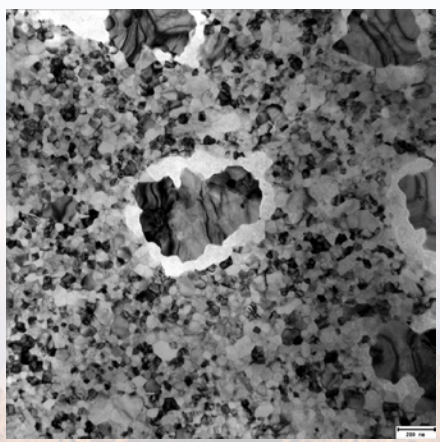


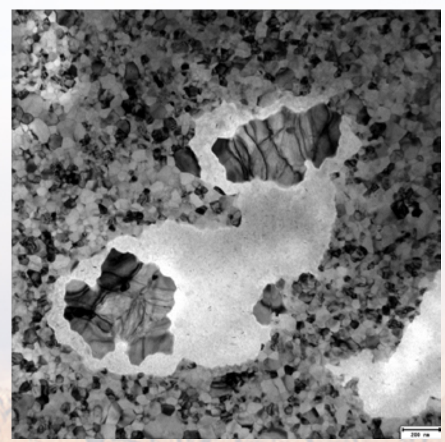
Cross-sectional schematic

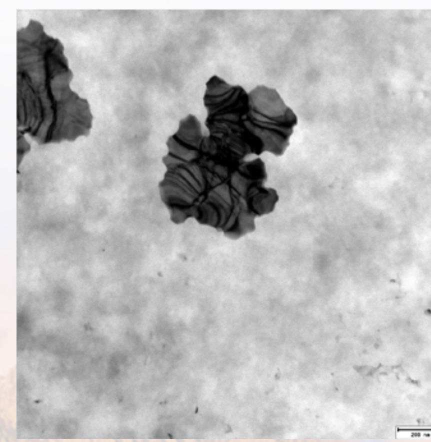












Pitting mechanisms during dilute flow of acetic acid over 99.95% nc-PLD Fe involves many grains.

Large grains resulting from annealing appear more corrosion tolerant

Contributors: D. Gross, J. Kacher, I.M. Robertson & Protochips, Inc.

Other Fun Uses of Microfluidic Cell

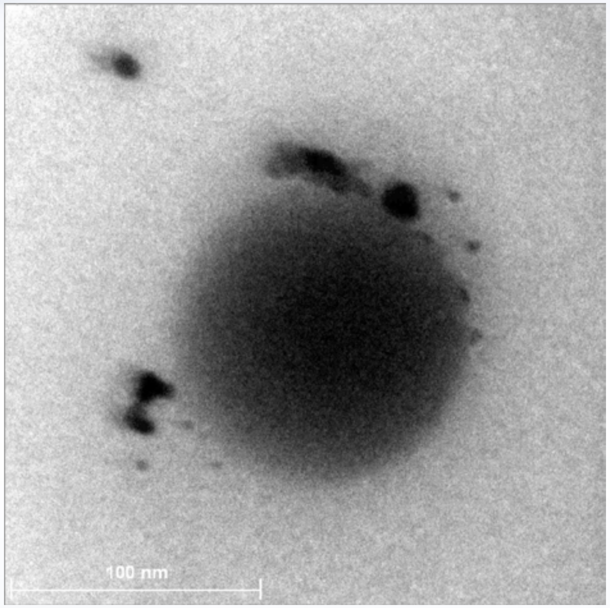
Protocell Drug Delivery

S. Hoppe,

E. Carnes,

J. Brinker

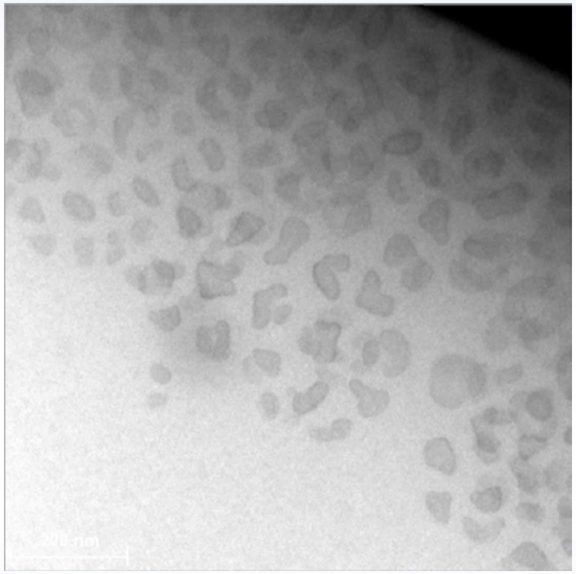
Liposome encapsulated Silica destroyed by the electron beam



BSA Crystallization

S. Hoppe

Crystallization of excess Bovine Serum Albumen during flow

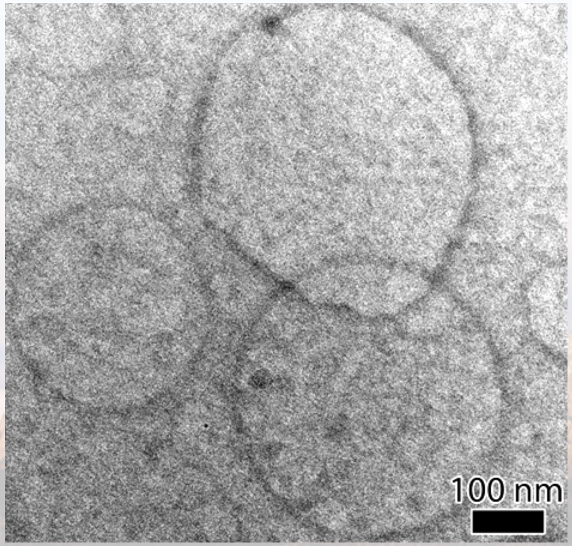


Liposomes in Water

S. Hoppe,

D. Sasaki

Liposomes imaged in flowing aqueous channel

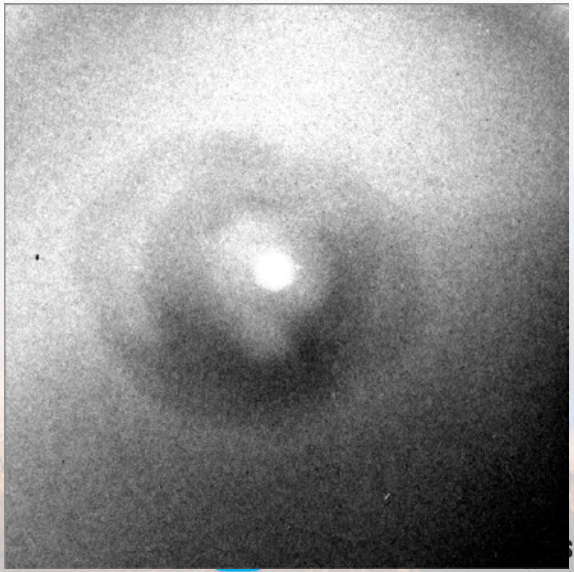


La Structure Formation

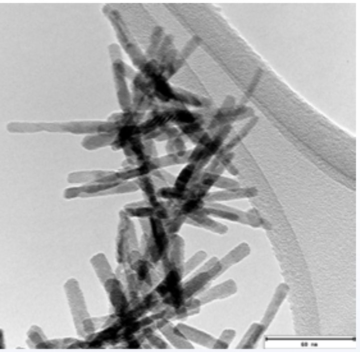
S. Hoppe,

T. Nenoff

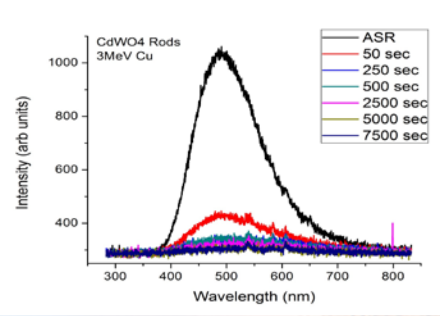
La Nanostructure form from $LaCl_3$ H_2O in wet cell due to beam effects



Radiation Tolerance is Needed in Advanced Scintillators for Non-proliferation Applications



High-Z nanoparticles ($CdWO_4$) are promising, but are radiation sensitive

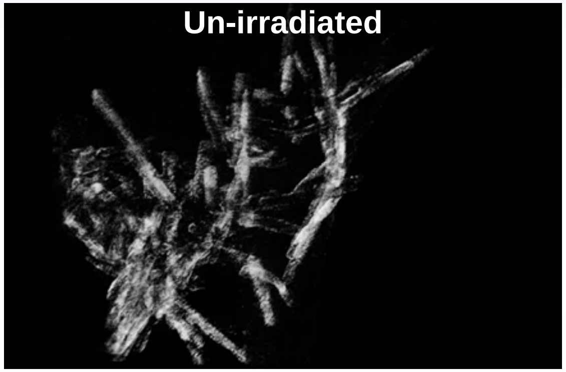


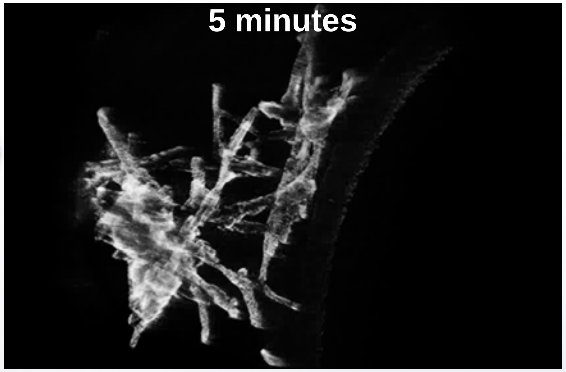
First IBIL in TEM

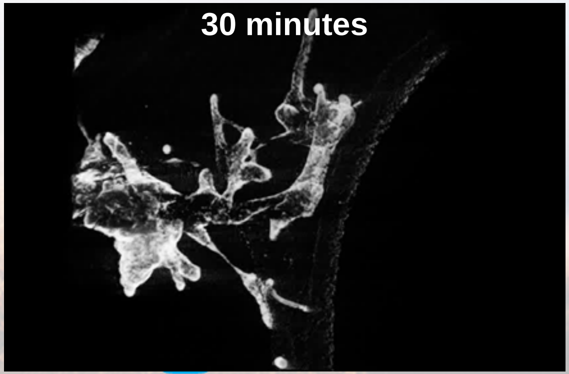
***In situ* Ion Irradiation TEM (I³TEM)**

Hummingbird tomography stage

Tomography of Irradiated $CdWO_4$: 3 MeV Cu^{3+} at ~30 nA







Contributors: S.M. Hoppe, B.A. Hernandez-Sanchez, T. Boyle

In situ TEM Quantitative Mechanical Testing

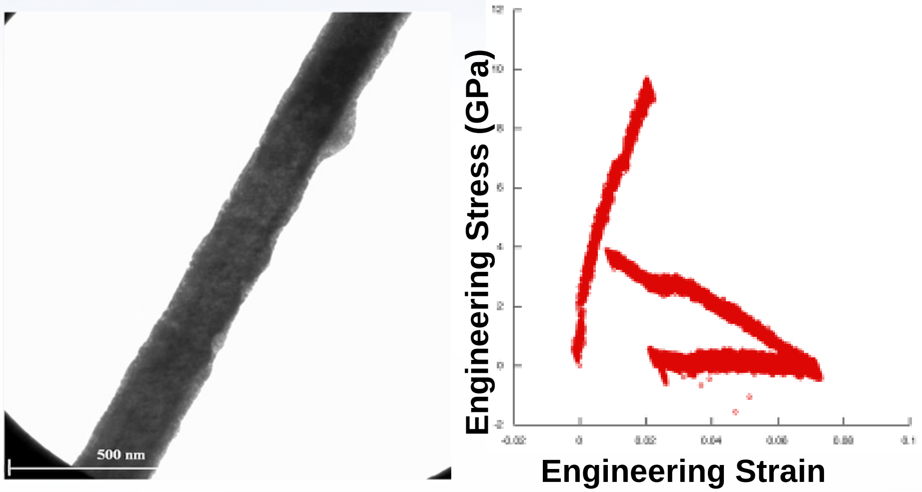
Hysitron Stage

Radiation effect on mechanical properties

- Direct correlation of dose and defect density with resulting change in strength and ductility
- Failure of Mo-wire after 3 MeV Cu irradiation

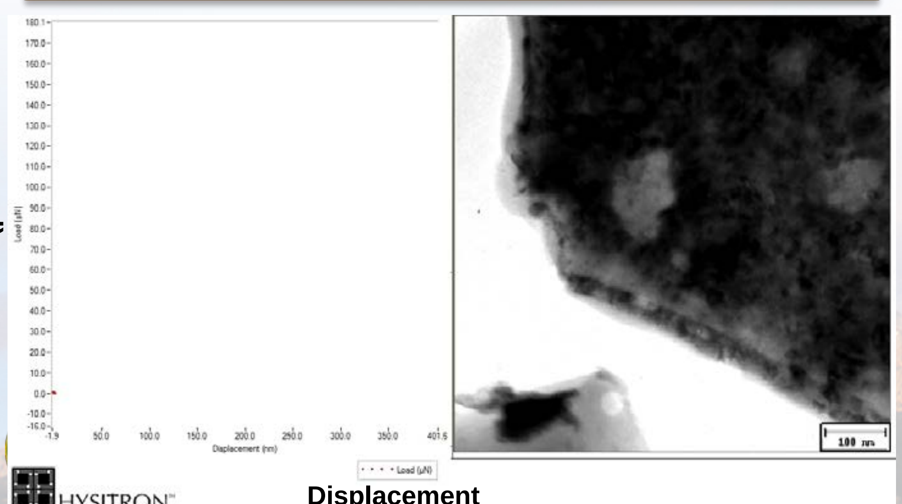
Contact and fatigue effect on structure

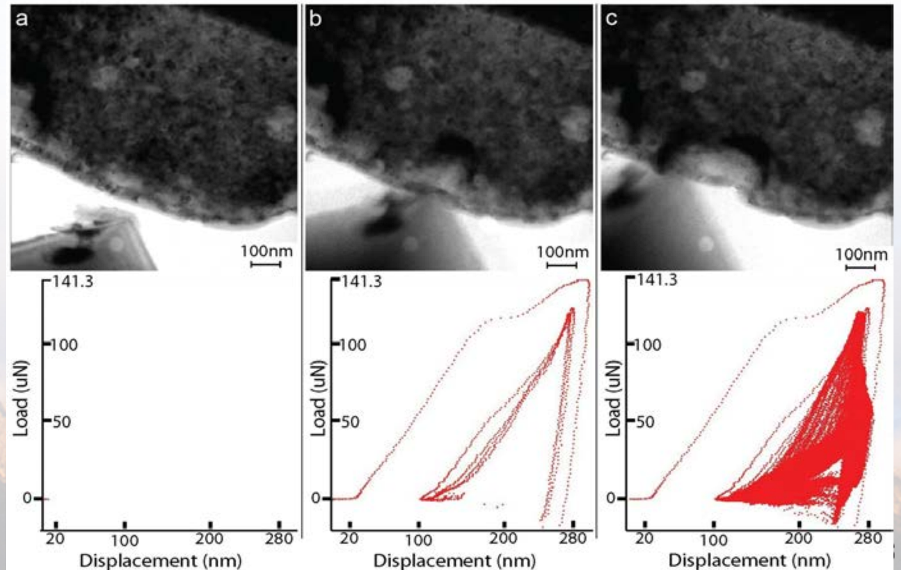
- Associate change in local hardness and fatigue with corresponding nanostructure
- Indent and Fatigue of nanocrystalline Cu film



Displacement damage effect on mech. prop.

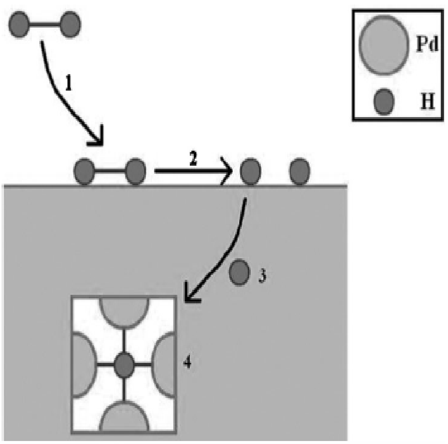
Fundamentals of contact reliability



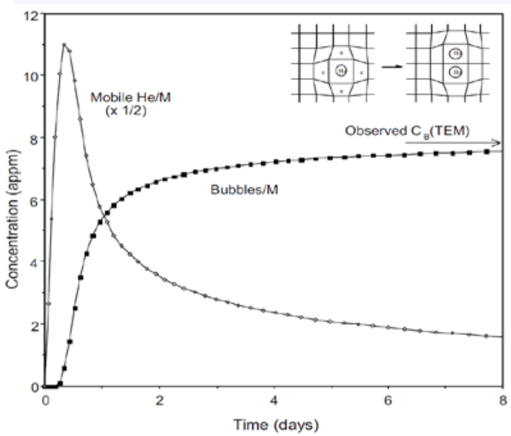


Contributors: J. Sharon, B. L. Boyce, C. Chisholm, H. Bei, E.P. George, P. Hosemann, A.M. Minor, & Hysitron Inc.

Can *In situ* TEM Address Hydrogen Storage Concerns in Extreme Environments?



R. Delmelle, J., Phys. Chem. Chem. Phys. (2011) p.11412



Cowgill, D., Fusion Sci. & Tech., 28 (2005) p. 539

Trinkaus, H. *et al*., JNM (2003) p. 229

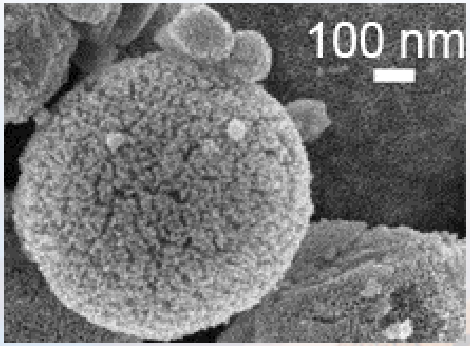
Thiebaut, S. *et al*. JNM (2000) p. 217

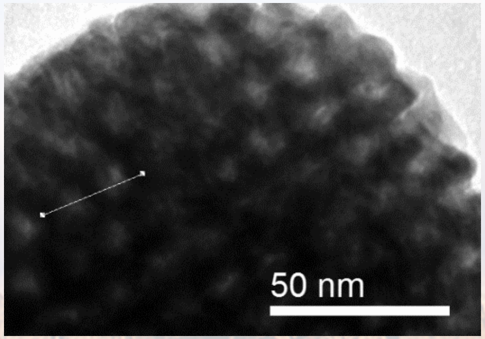
Vapor-Phase Heating TEM Stage

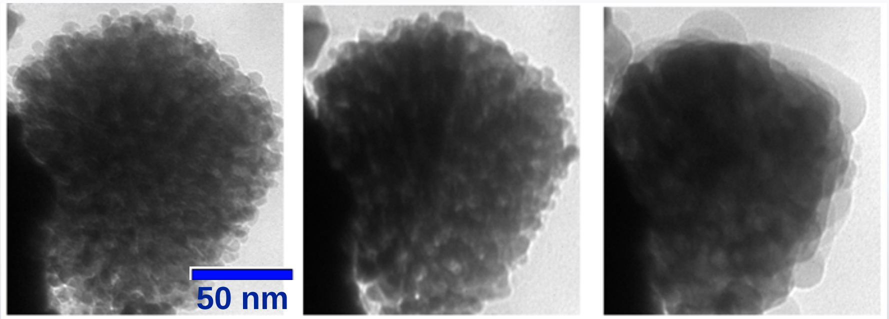
- Compatible with a range of gases
- *In situ* resistive heating
- Continuous observation of the reaction channel
- Chamber dimensions are controllable
- Compatible with MS and other analytical tools

- 1 atm H_2 after several pulses to specified temp.

Harmful effects may be mitigated in nanoporous Pd







125° C 200° C 300° C

New *in situ* atmospheric heating experiments provide great insight into nanoporous Pd stability

Contributors: R.G. Clark, R.J. Cappillino, B.W. Jacobs, M.A. Hekmaty, D.B. Robinson, L.R. Parent, I. Arslan, & Protochips, Inc.