

IVEM-TANDEM FACILITY



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Outline

- Specification of in-situ ion irradiation in IVEM
 - Irradiation condition
 - TEM holders
 - Microscope and Imaging system
- Capability highlights
 - Implementation of computer vision for analyzing in-situ data
 - Irradiation experiment with strain/stress

Accelerators

Dual ion beam in-situ irradiation

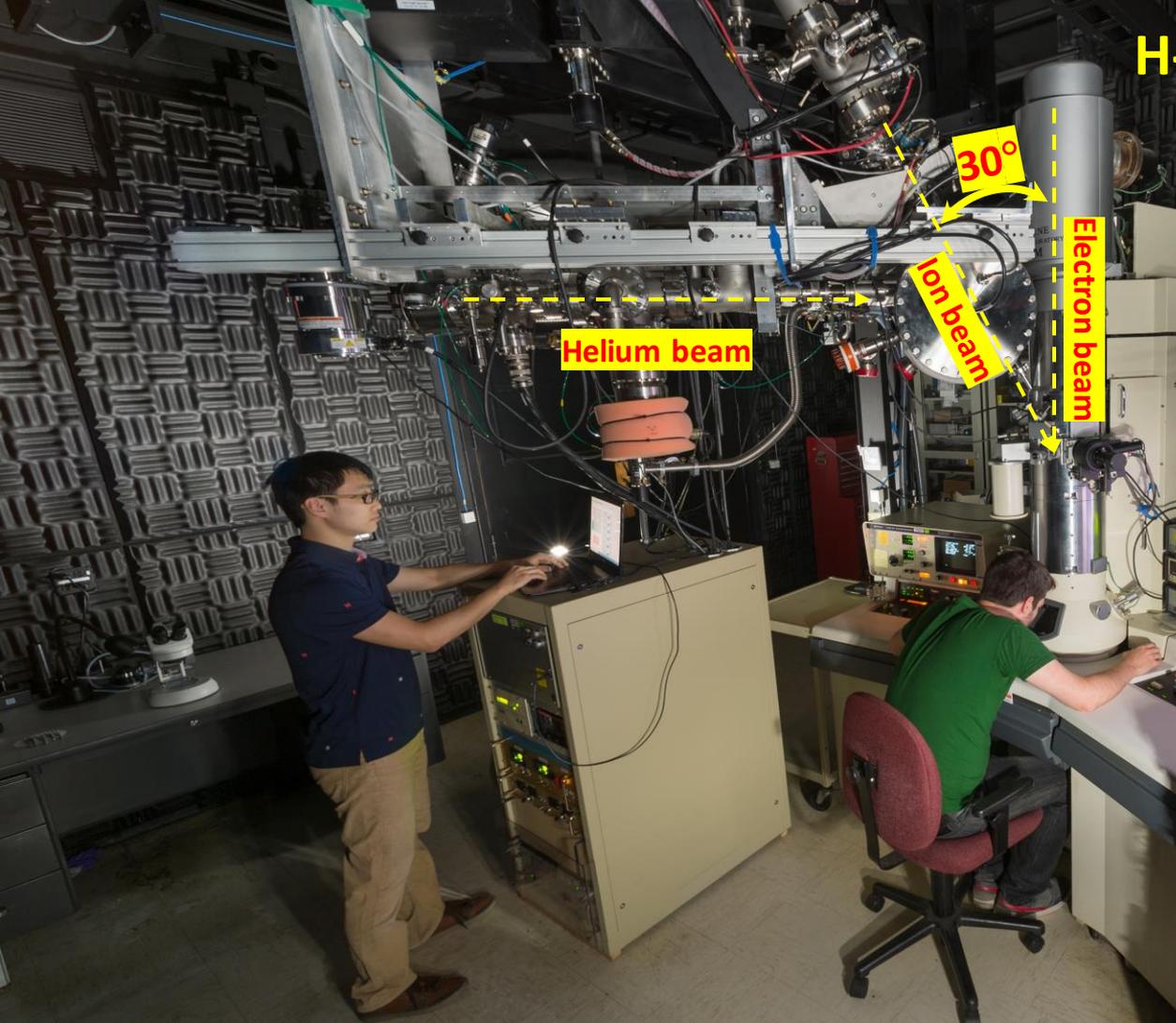
- **500 kV NEC Ion Implanter**
 - Max. beam energy: 1 MeV
 - Dose rate: 10^{-5} to 10^{-3} dpa/s
 - Ion source: Danfysik 911
 - Ions include H, inert gases, and many elements from Al to Au

- **20 kV Helium implanter**
 - Max. beam energy: 20 keV
 - Dose rate: up to a few %He/hr
 - ions: He



- **2 MV Tandem**
 - Max. beam energy 5 MeV
 - Dose rate: $<10^{-4}$ dpa/s (in TEM)
 - Ion source: SNICS (Alphatross)
 - Ion types: Fe, Ni, Au, Si, etc. (H, He)

H-9000NAR TEM



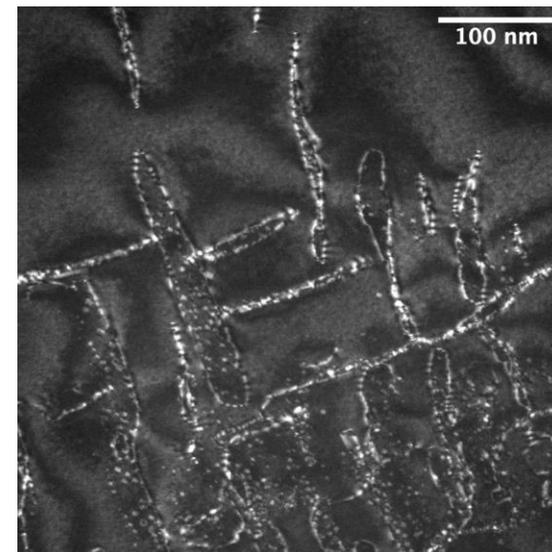
- Ion and electron beam angle, 30° allowing for real-time imaging
- Dual-beam irradiation capability
- LaB₆ filament, high current, high brightness, excellent for real-time imaging
- Electron energies, 100-300 keV,
- Minimum Spot Size: 25 nm
- Point resolution: 0.25 nm at 300 keV
- Gatan OneView camera enabling Video recording up to 313 fps
- Vacuum: 5x10⁻⁸ to 4x10⁻⁷ torr
- Bruker Xflash 6160 EDS detector



TEM holders

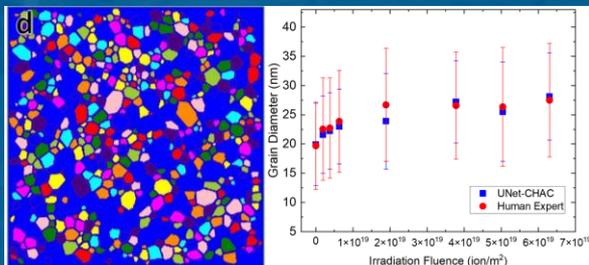
<p>Heating (20 to 1100°C)</p>	<ul style="list-style-type: none"> - Gatan High temperature (20-800°C), double tilt ($\pm 40^\circ$, $\pm 20^\circ$) - Gatan High temperature (20-1100°C), single tilt ($\pm 40^\circ$)
<p>Cooling (20 to 300 K)</p>	<ul style="list-style-type: none"> - Gatan Low temperature, double tilt ($\pm 40^\circ$, $\pm 20^\circ$)
<p>Straining (100 K to 400°C)</p>	<ul style="list-style-type: none"> - Gatan Straining, high temperature (20-400°C), single tilt ($\pm 40^\circ$) - Gatan Straining, low temperature (100-300°K), single tilt ($\pm 40^\circ$) - Bruker picoindenter PI95 (20°C) - New
<p>Corrosion</p>	<ul style="list-style-type: none"> - Environmental Cell TEM Stage: <ul style="list-style-type: none"> ▪ Environmental chamber (20-300°C) ▪ TEM stage (20 - 700°C)
<p>Tomography</p>	<ul style="list-style-type: none"> - Gatan tri-axes tomography holder

Bubble-loop complex
Ni *in-situ* irradiated with 16 keV He ions



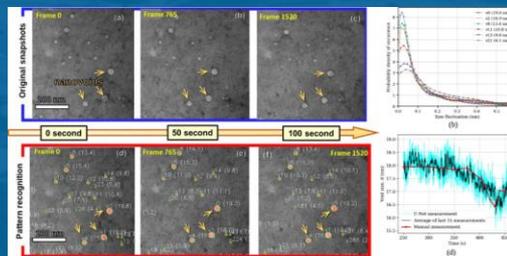
COMPUTER VISION FOR ANALYZING IN-SITU DATA

Penn State University (A. Motta)
Grain growth of nanocrystalline UO_2



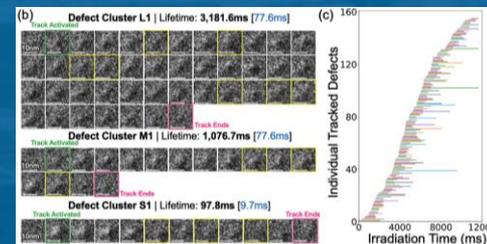
X. Xu, et al., J Nucl. Mater. 588 (2024) 154813

Purdue University (X. Zhang)
Voids Stability under irradiation



M. Nasim et al. J Nud. Mater. 574 (2023) 154189

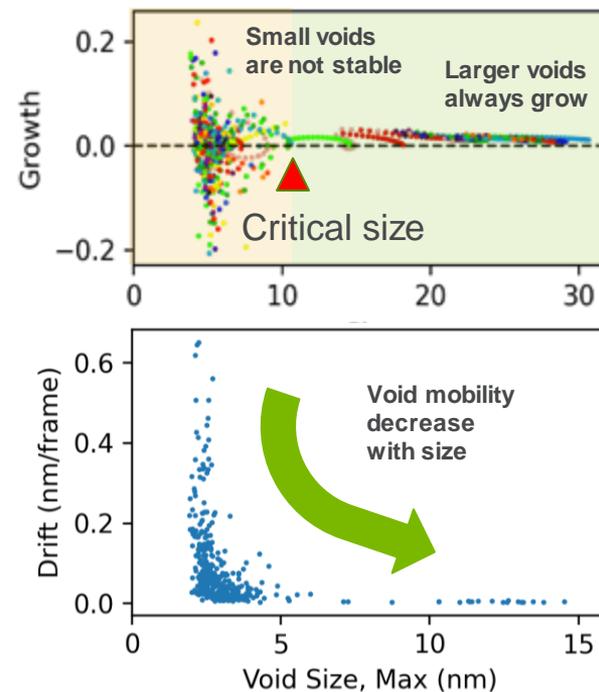
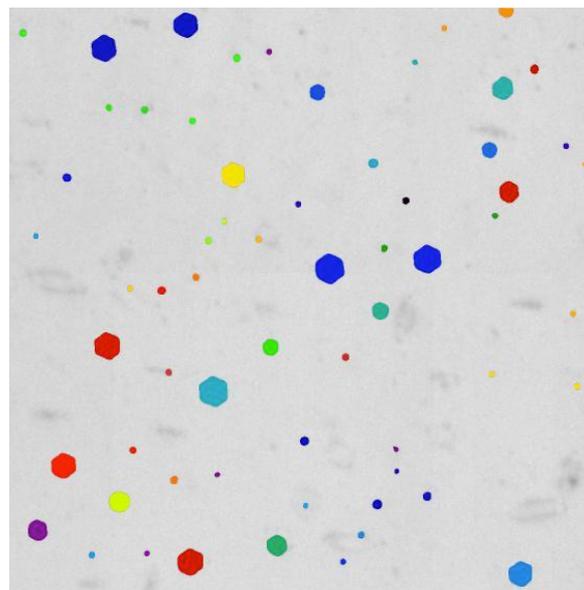
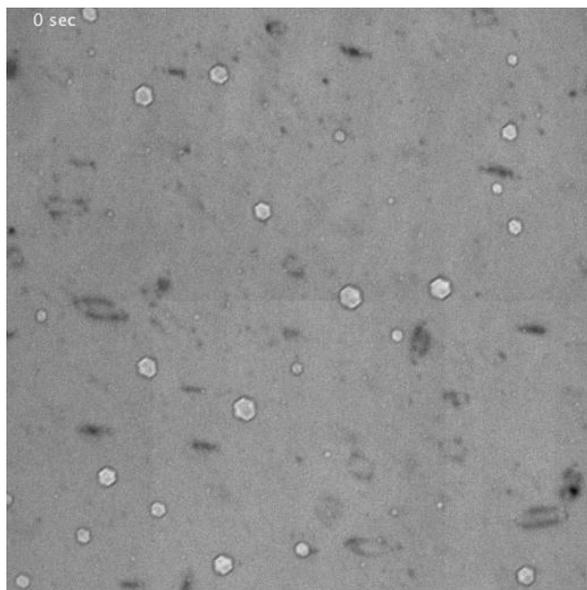
University of Connecticut (Y. Zhu)
Stability of vacancy clusters



R. Sainju et al. Sci. Rep. 12 (2022) 15705

USING AUTOMATIC DETECTION AND TRACKING TO MEASURE SIZE-DEPENDENT STABILITY AND MOBILITY OF VOIDS UNDER IN-SITU OBSERVATION

Ni under in-situ 1 MeV Kr ion irradiation at 625°C with a dose rate of 10^{-3} dpa/s

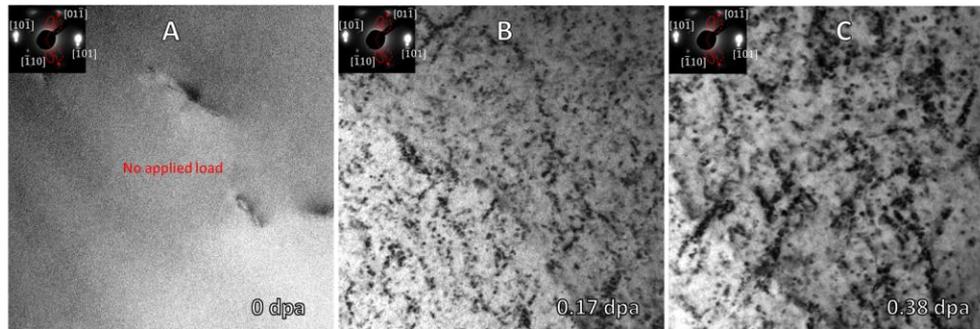


Logan Ward, Zhi-Gang Mei, Wei-Ying Chen (Argonne National Laboratory)
Unpublished work

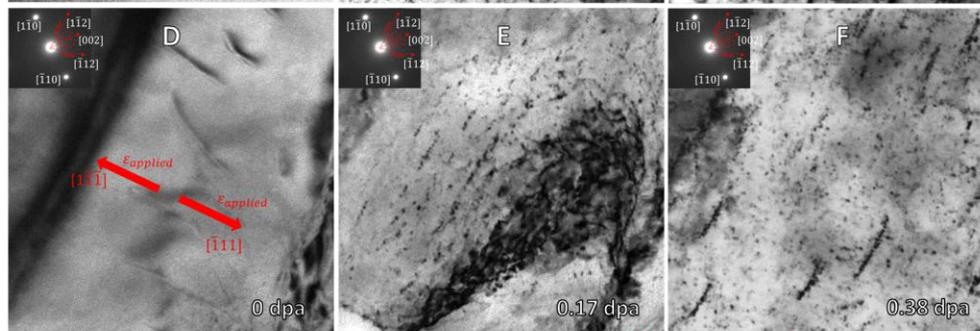
DIRECTIONAL DEFECT ACCUMULATION IN MATERIALS UNDER STRESS

RTE 23-1845 LANL (Hi Vo)

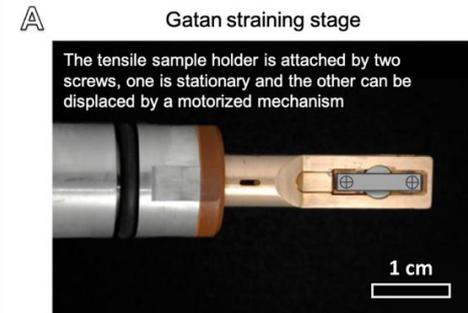
Stress-free



Under stress



200 nm \bigcirc $\frac{1}{2}$ -<111>{111} loops \bigcirc <100>{200} loops



- 1 MeV Kr ion irradiation
- Molybdenum
- 400 °C

ACKNOWLEDGEMENT

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