Examining Bubble Evolution in Materials with In-situ Ion Beam Irradiation Transmission Electron Microscopy

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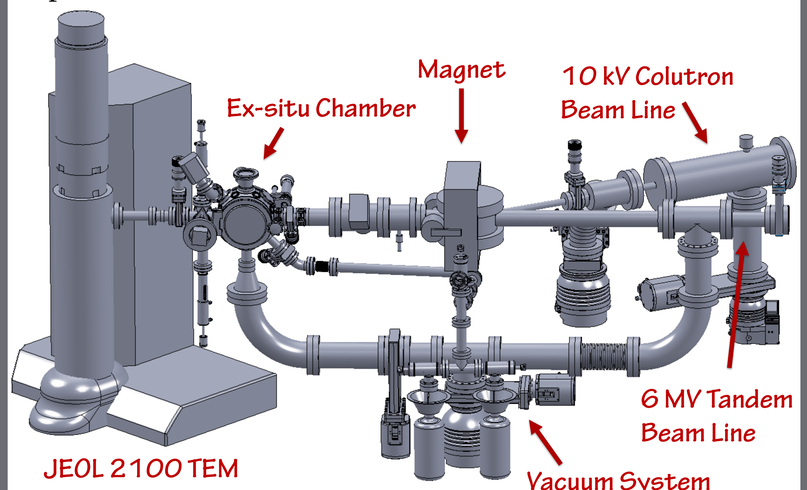
Experimental Approach

- Materials designed for nuclear applications will undergo extreme environments, consisting of: neutron irradiation damage, He and H accumulation, elevated temperatures, etc.
- Ion accelerators are often used as an accelerated aging technique to simulate reactor environments. Most labs attempt to simulate the interaction between displacement cascades and He/H build-up by performing sequential heavy-ion irradiation and He/H implantation, then studying the resulting microstructure with TEM.
- With the SNL Ion Beam Laboratory I^{3}TEM, we perform heavy-ion and He/D implantation simultaneously, which more accurately simulates reactor conditions. We observe the radiation effects in-situ inside the TEM, allowing us to quantify kinetic processes.



10 kV Colutron
He & D beams

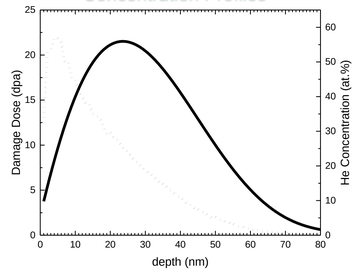
6 MV Tandem
Heavy Ion (e.g. Au) beams

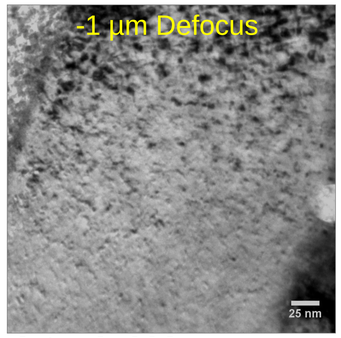
In-situ Experiments on Pd

Room Temperature He Implantation

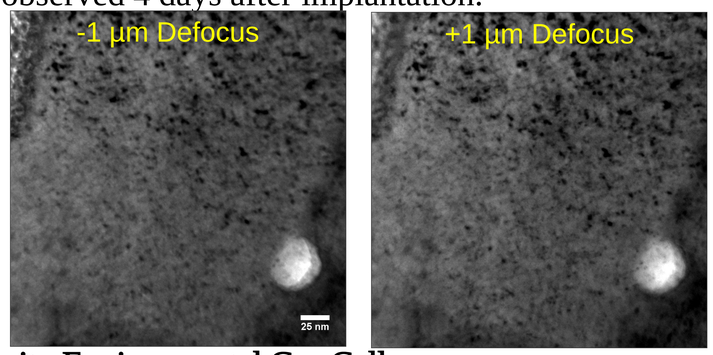
- No bubbles of observable size were identified during in-situ He implantation at 300K to 2.68×10^{17} ions/cm^2

SRIM Predicted Damage and Concentration Profiles



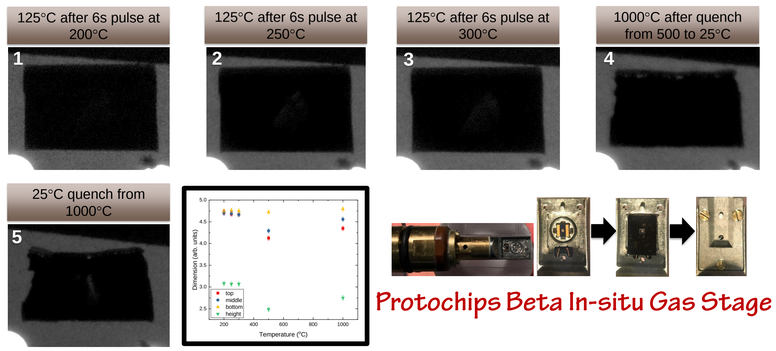


- Sample was stored in N_2 and tiny bubbles were observed 4 days after implantation.

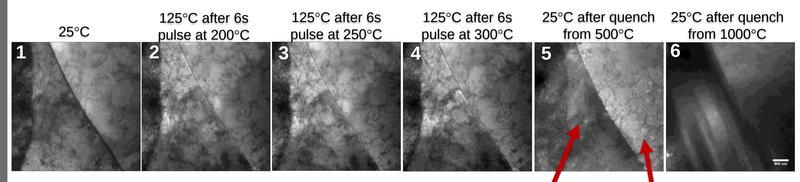


In-situ Environmental Gas Cell

- Pd FIB liftout mounted on a Protochips Si_3N_4 window was exposed to air in-situ at elevated temperature.



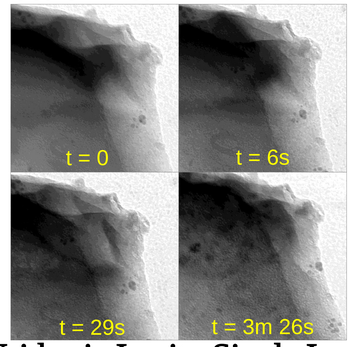
Protochips Beta In-situ Gas Stage

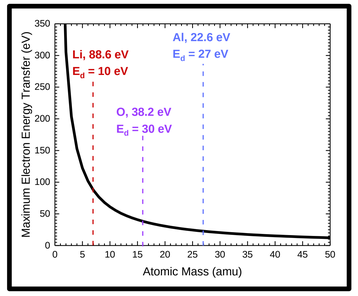


In-situ Experiments on $LiAlO_2$

Electron Beam Induced Void Formation

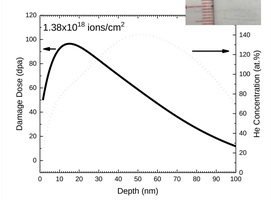
All TEM images shown in underfocus

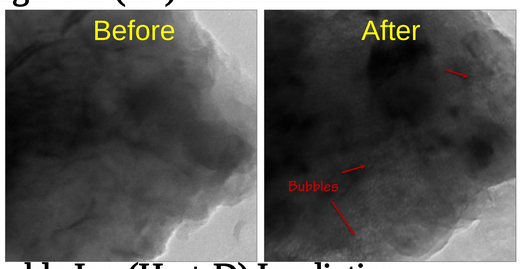




Voids via In-situ Single Ion (He) Irradiation

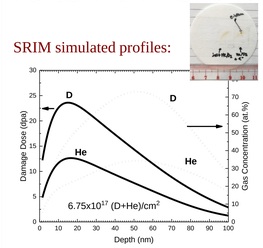
SRIM simulated profiles:

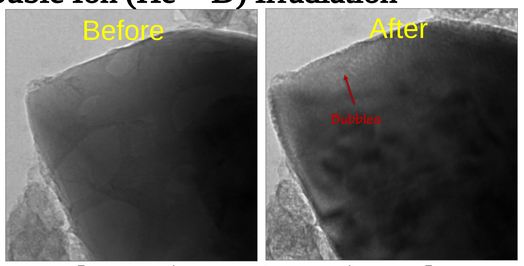




Voids via In-situ Double Ion (He + D) Irradiation

SRIM simulated profiles:

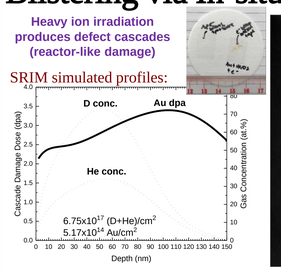


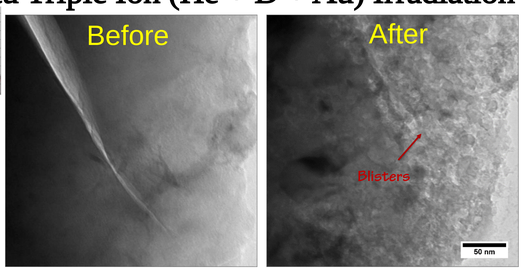


Blistering via In-situ Triple Ion (He + D + Au) Irradiation

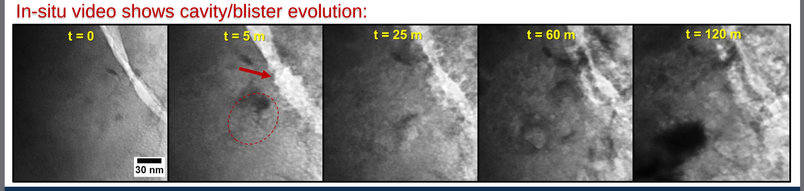
Heavy ion irradiation produces defect cascades (reactor-like damage)

SRIM simulated profiles:





In-situ video shows cavity/blister evolution:



Acknowledgements

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