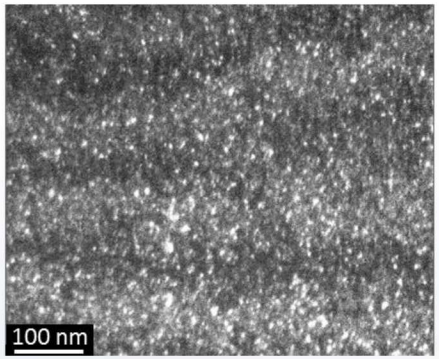
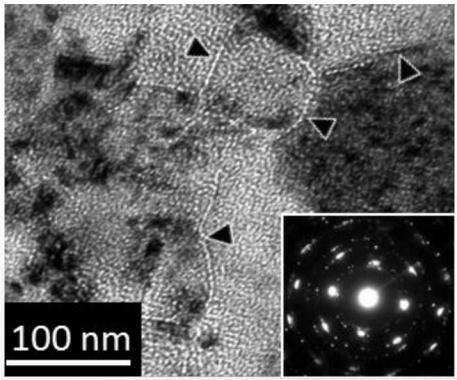
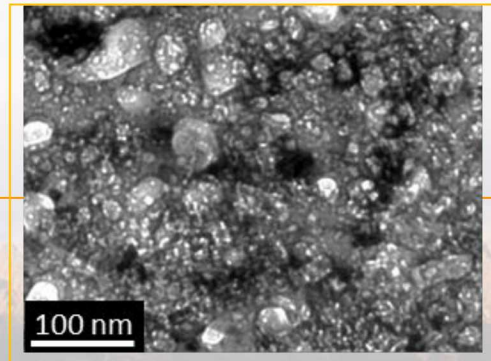
SAND2016-3226C

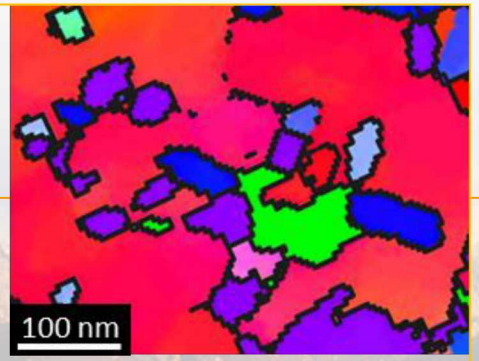
Concurrent and Sequential Hydrogen Isotope Implantation and Self-Ion Irradiation in Nickel



B. Muntifering, K. Hattar
Ion Beam Lab at Sandia National Laboratories
March, 2016







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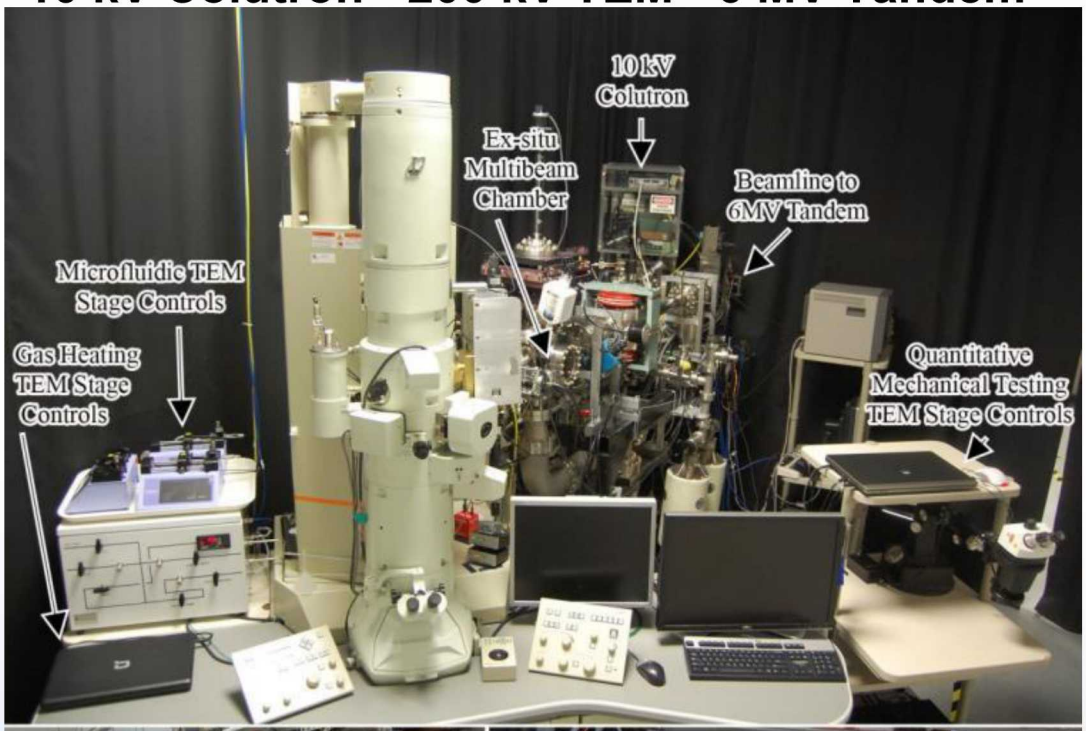
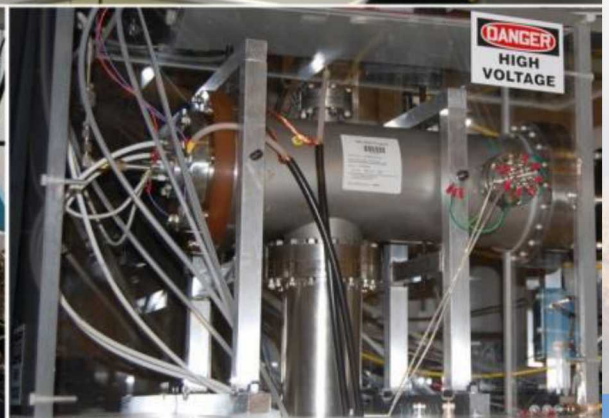
Sandia's Concurrent *In situ* Ion Irradiation TEM Facility

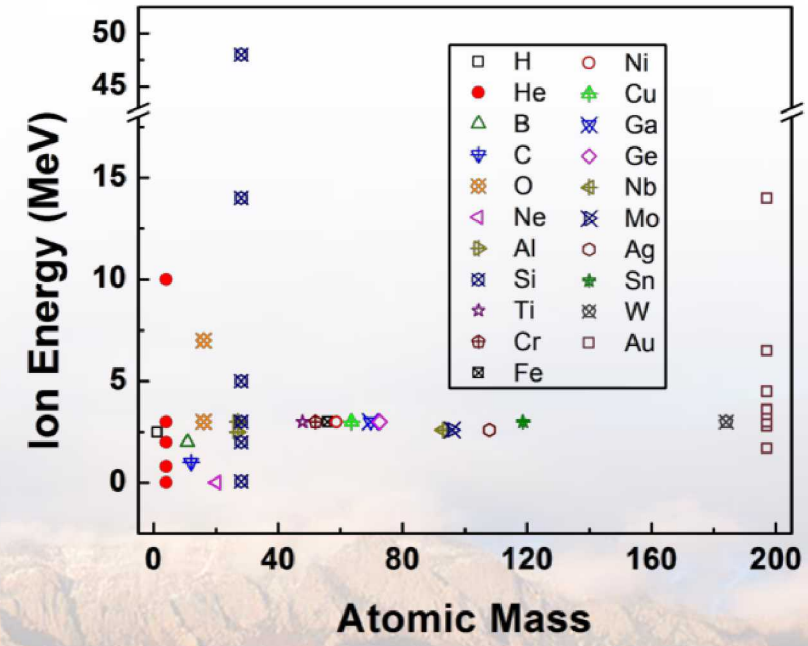
10 kV Colutron - 200 kV TEM - 6 MV Tandem





Direct real time observation of ion irradiation,

ion implantation, or both with nanometer resolution



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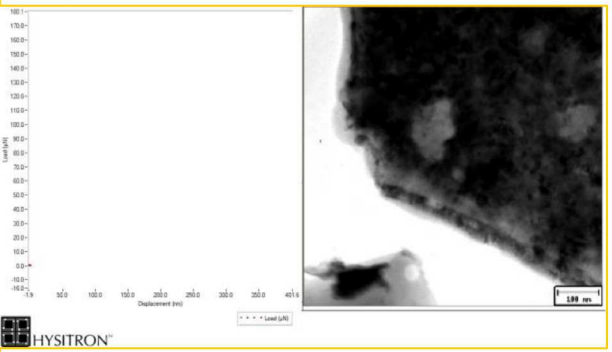
Radiation & Potential Synergistic In- Situ Capabilities

Mechanical Effects



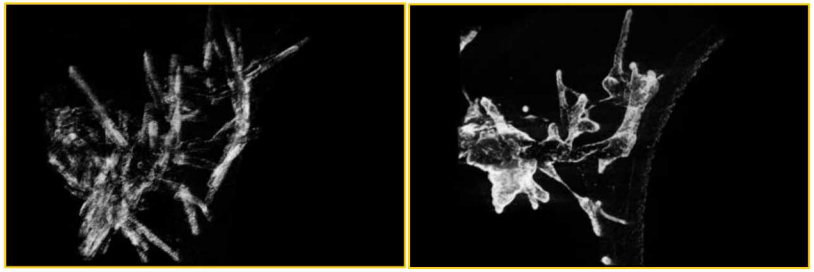
Hysitron PI95 TEM Picoindenter
Gatan 654 Straining Holder
Allows for direct correlation of dose and defect density with resulting changes in strength, ductility, and defect mobility

Environmental Effects

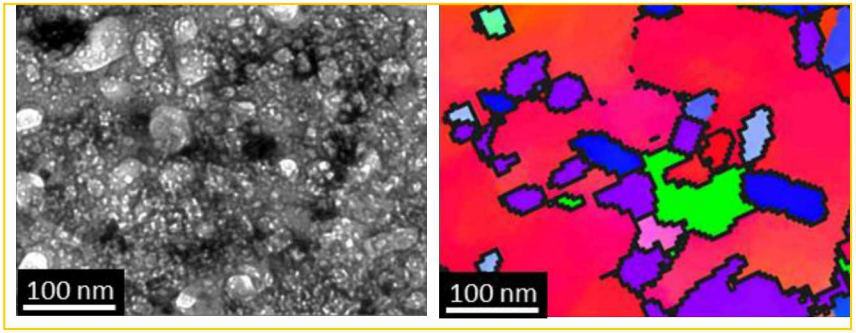
Protochips Liquid and Gas Flow
Study the material in different environments (flowing, mixing, temperature)

Structural Effects

Hummingbird Tomography Stage
Gatan 925 Double Tilt Rotate
Morphology changes as a result of radiation damage

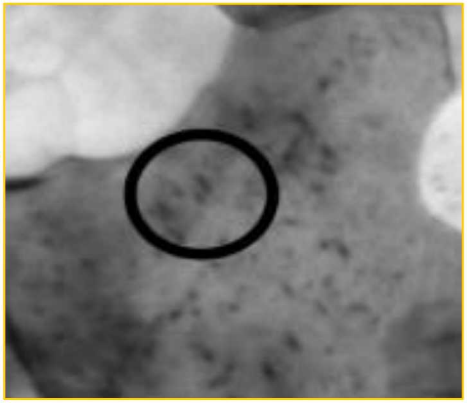


Nanomegas ASTAR
Grain structure changes as a result of radiation and implantation



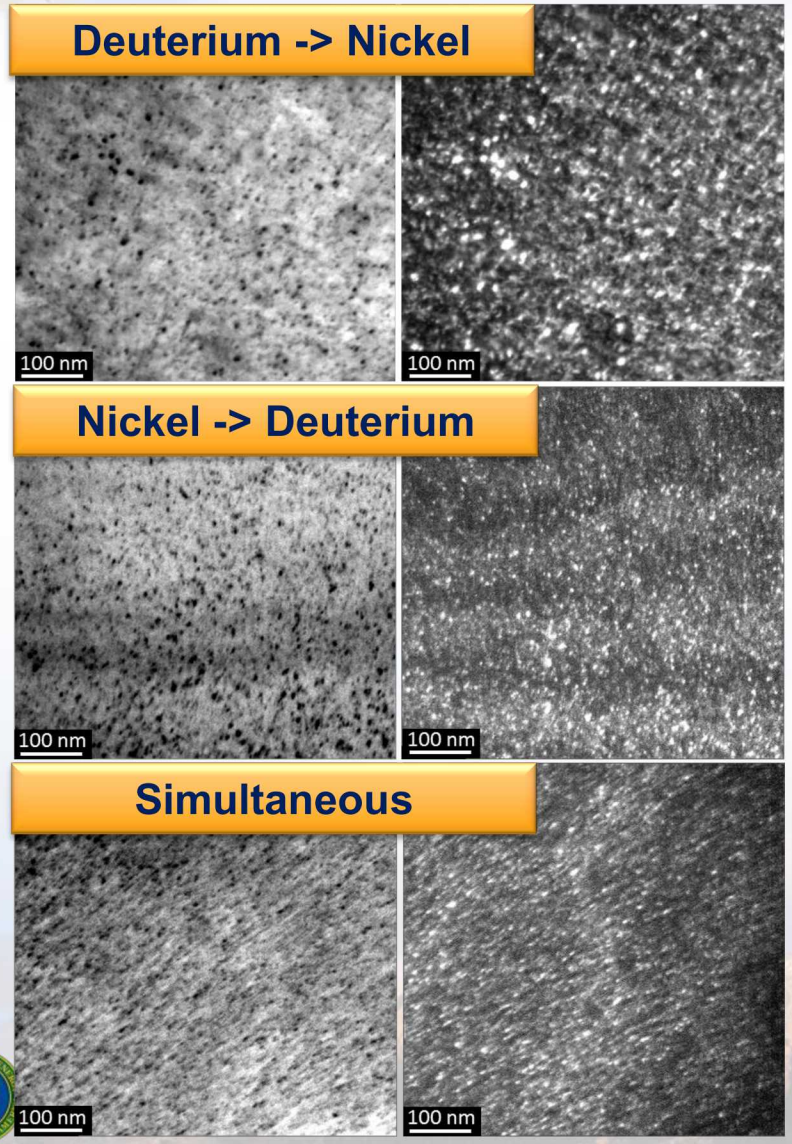
Thermal Effects

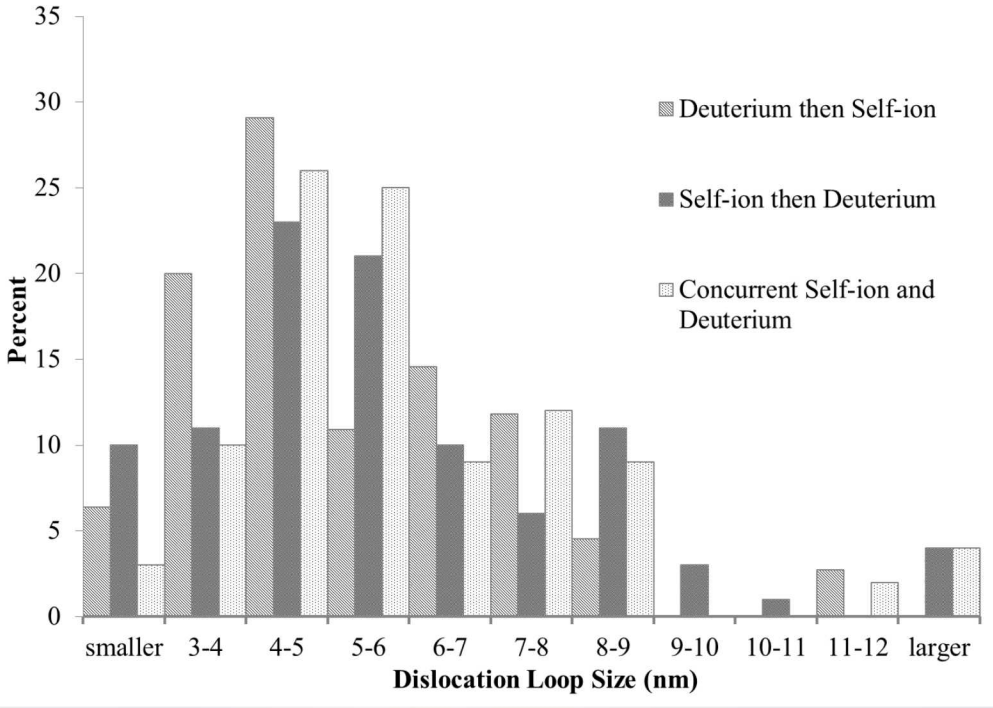
Hummingbird Heating Stage
Coupling effects of temperature and irradiation on microstructural evolution up to 800° C



The application of advanced microscopy techniques to characterize synergistic effects in a variety of extreme environments

Self Ion irradiation and Deuterium Implantation





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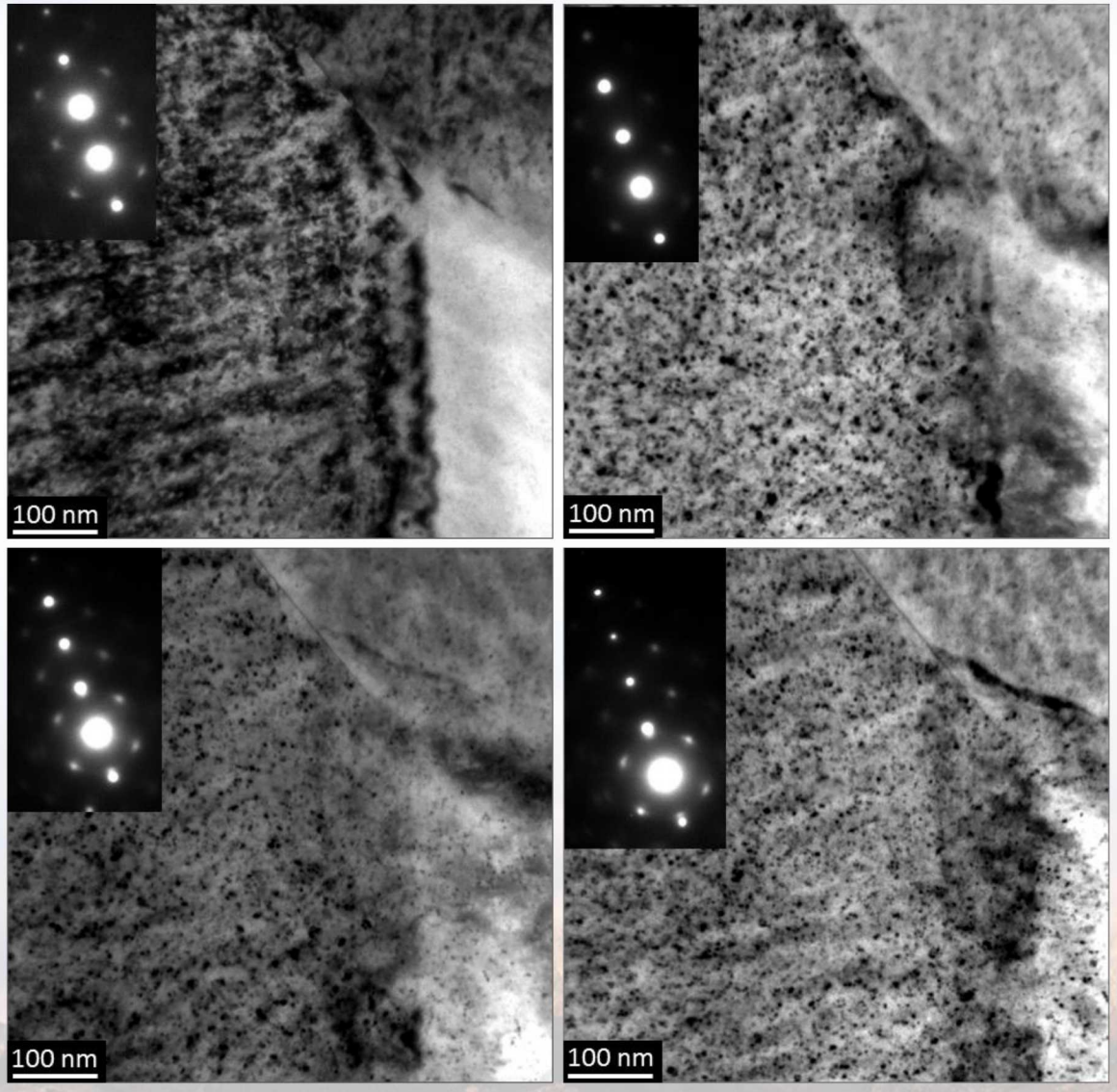
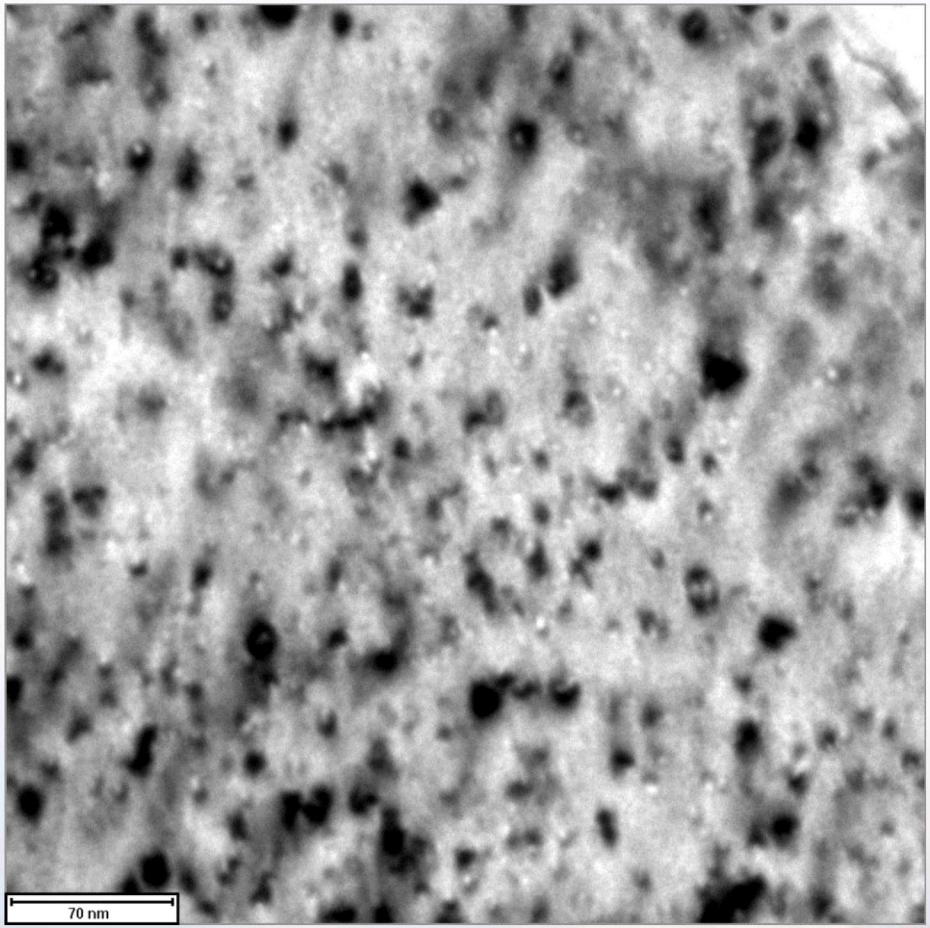
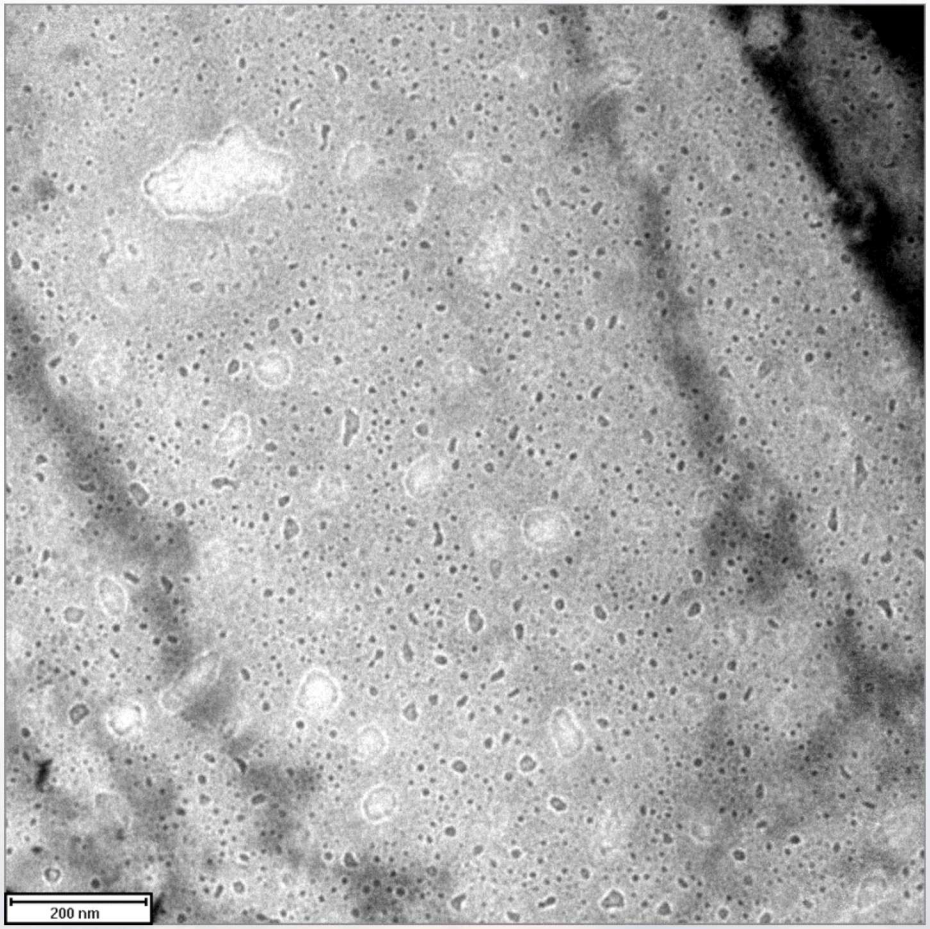
Tilting Effects on Loop Appearance



0.4° between each g condition

Annealing to 400 °C

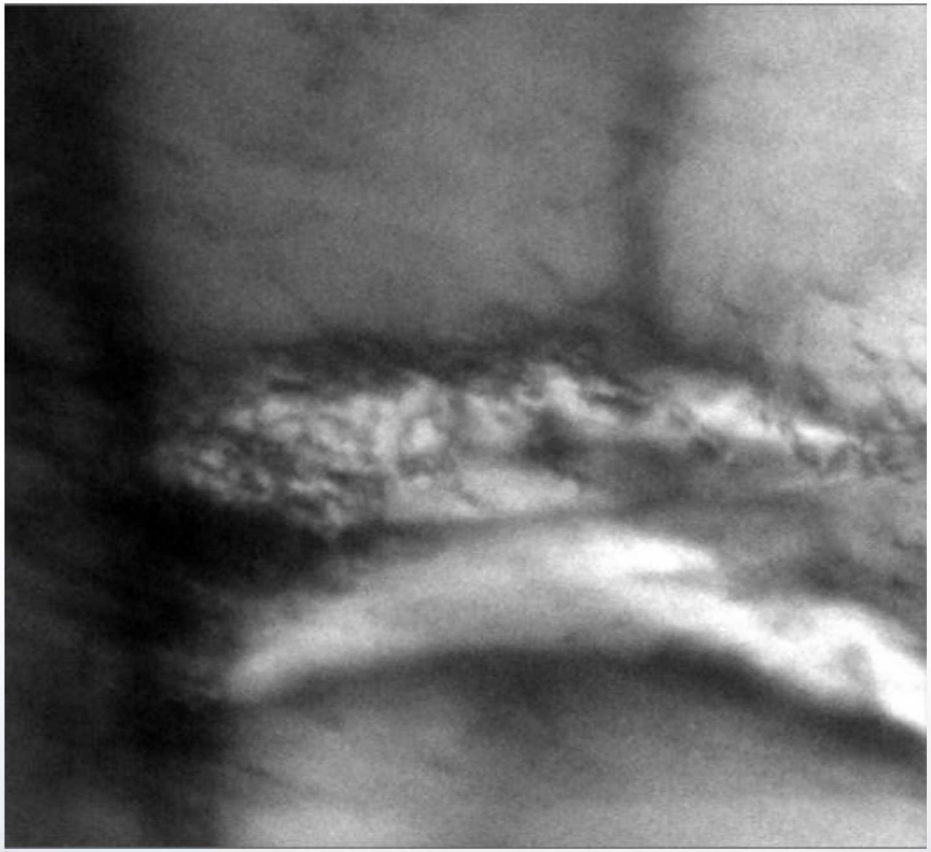


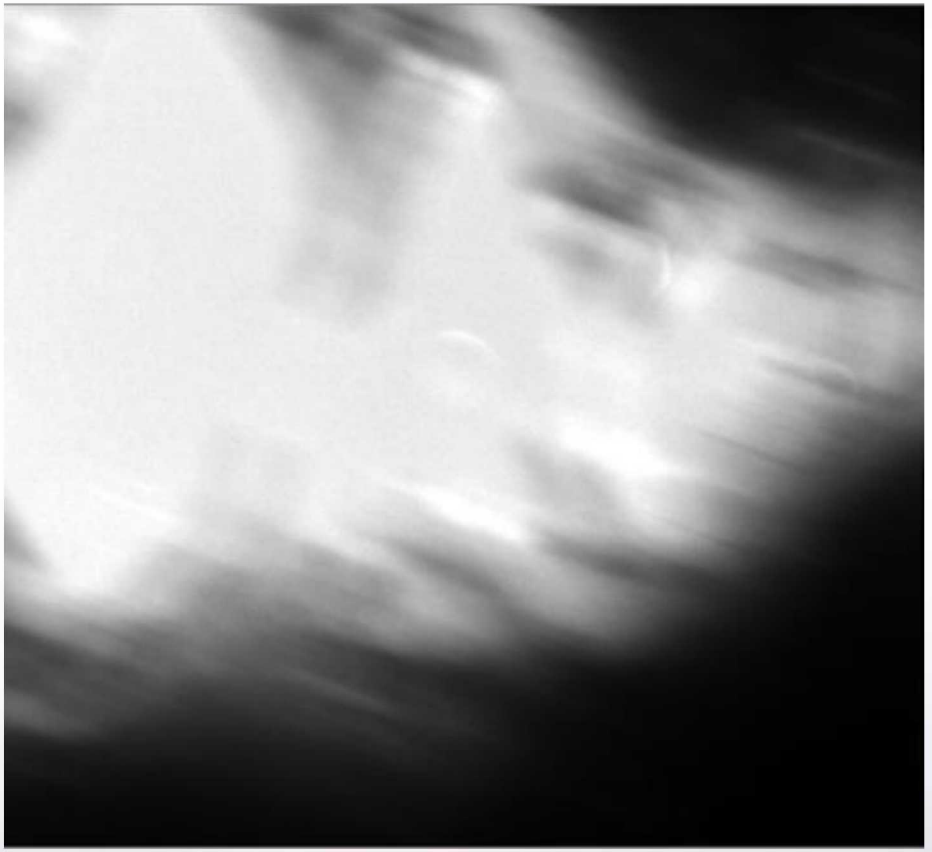


Cavities?

Ideas?

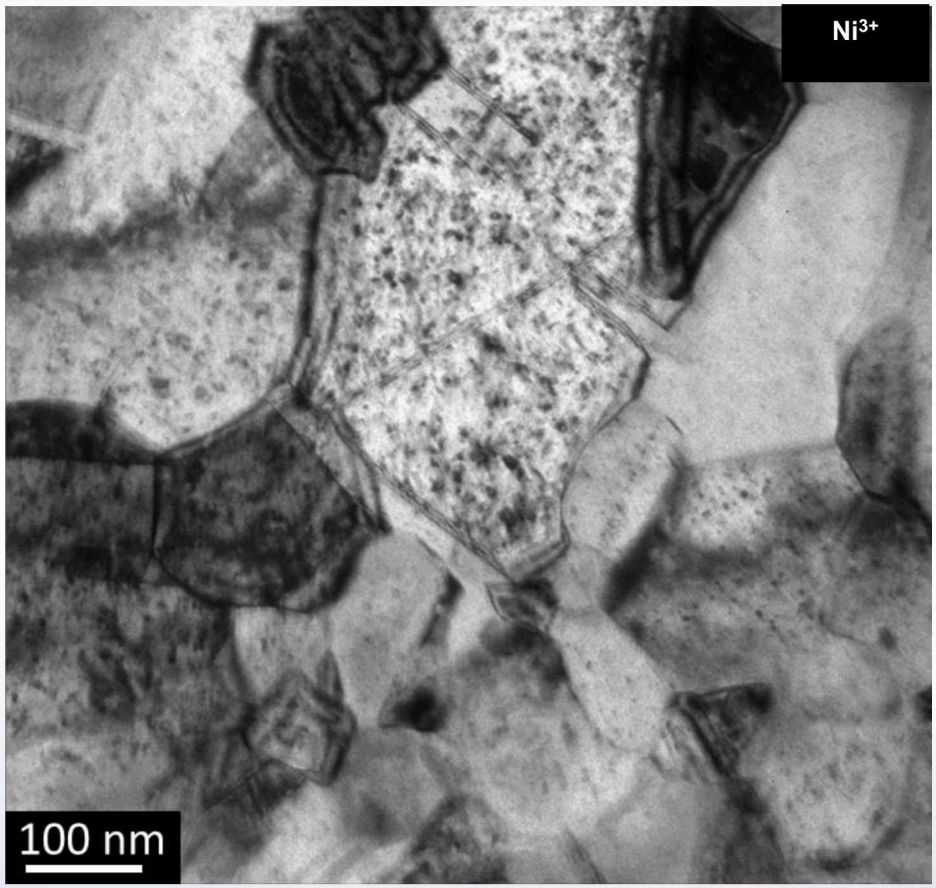
Straining of Un-irradiated Nickel

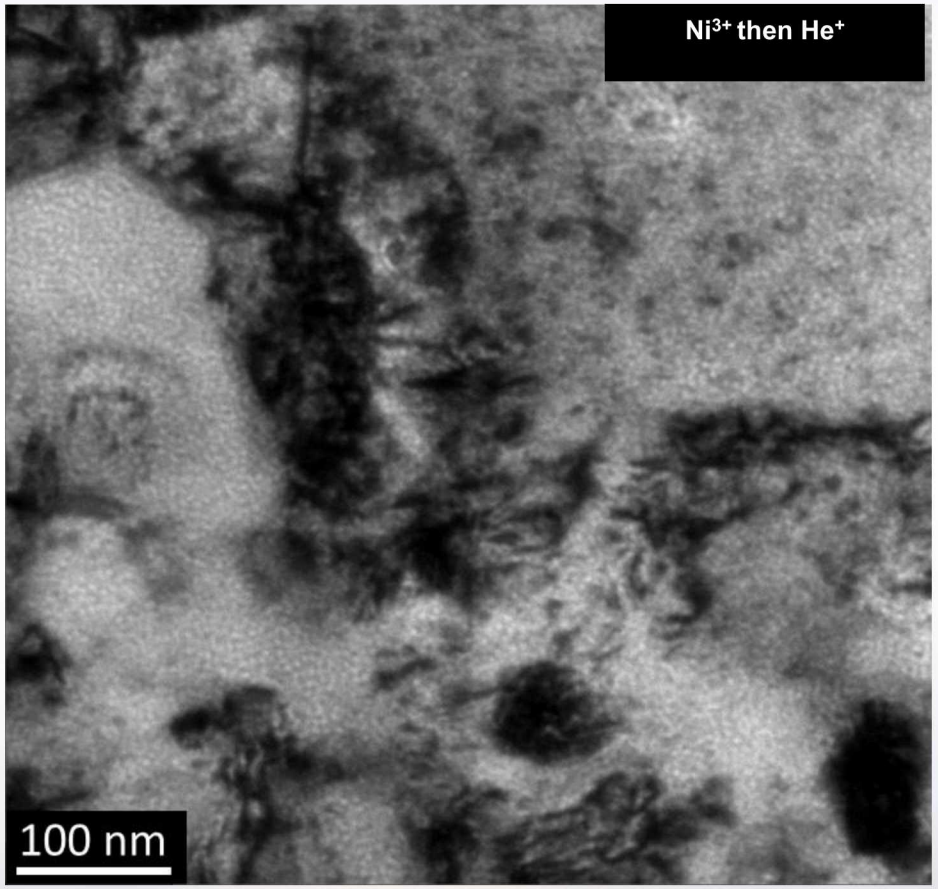




Next Step: Irradiate and Strain

3 MeV Ni^{3+} Irradiation followed by 10 keV He^{+} Implantation

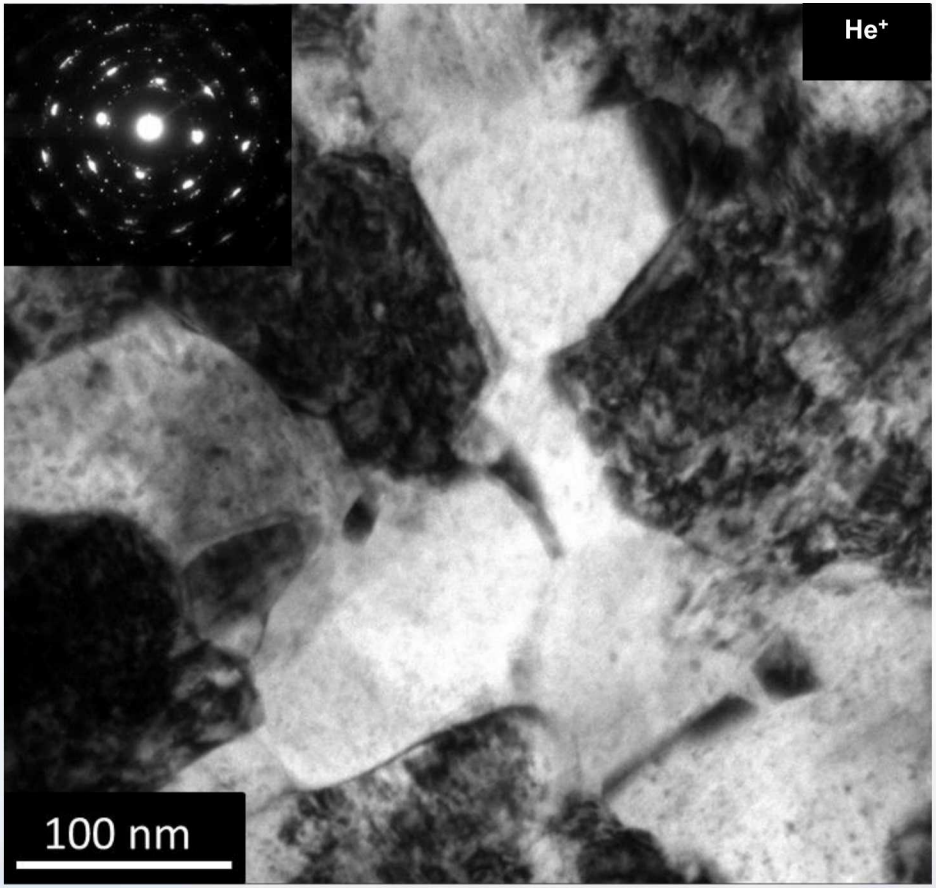


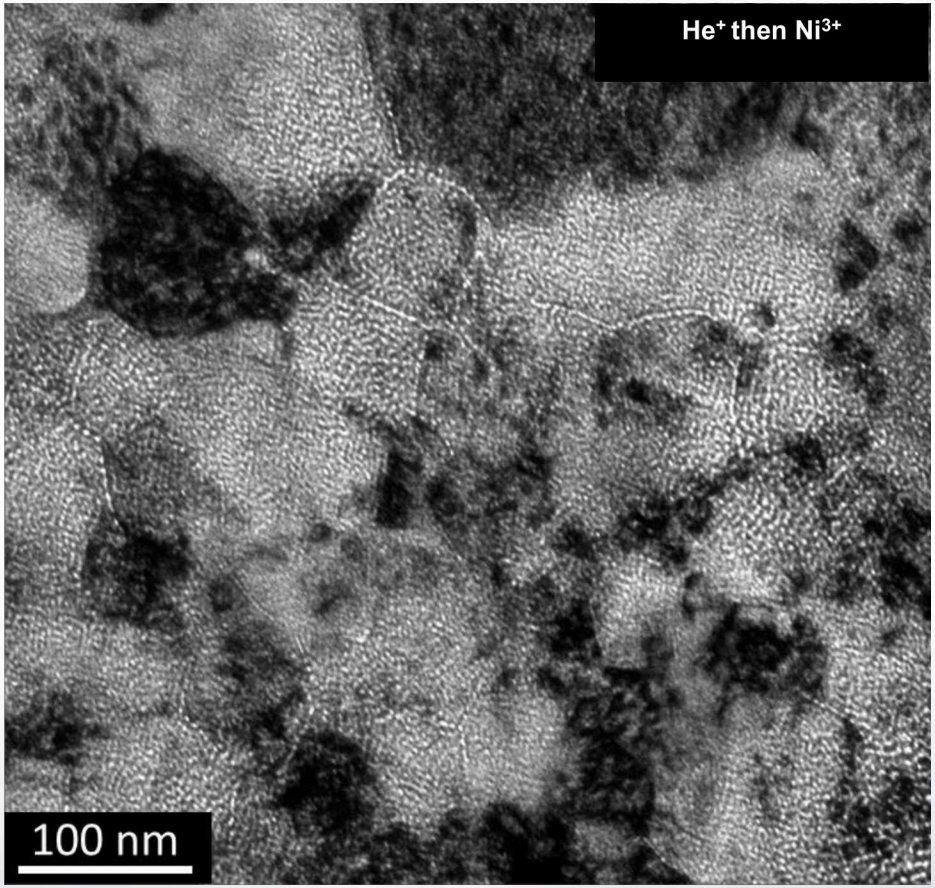


1.8 dpa Ni^{3+} irradiation
Dislocation loops and SFT are present

Additional $2x10^{16}$ He^{+}/cm^{2}
Evenly distributed nanometer size cavities

10 keV He^+ Implantation followed by 3 MeV Ni^{3+} Irradiation

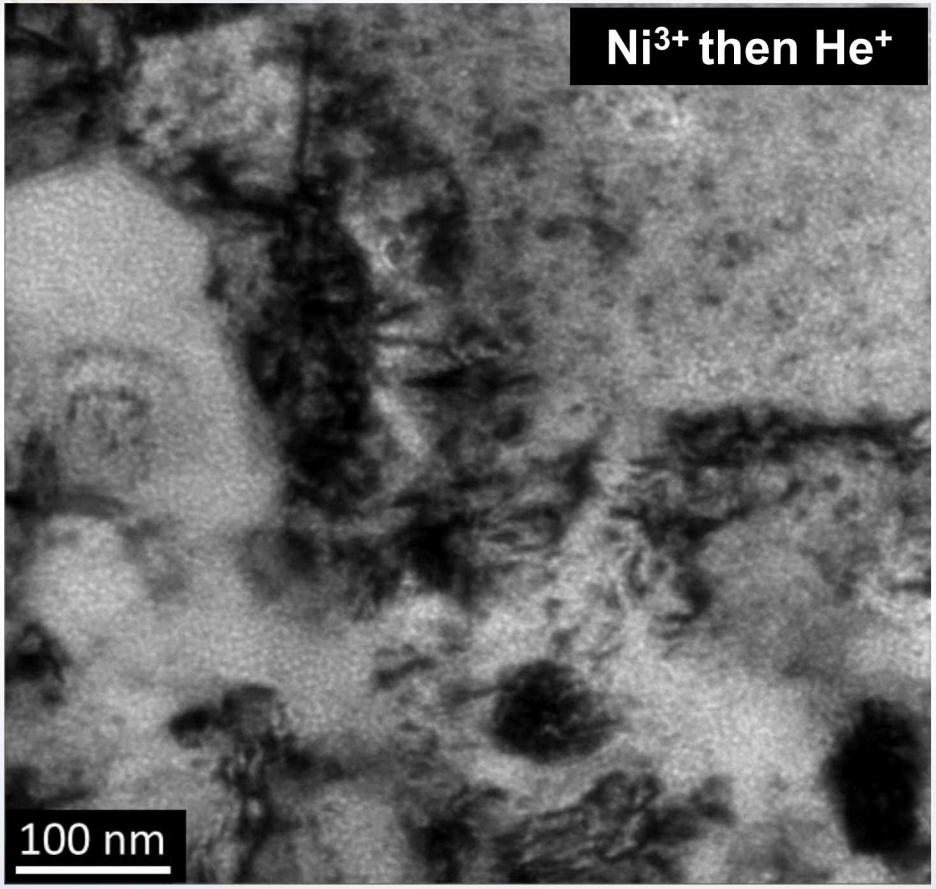


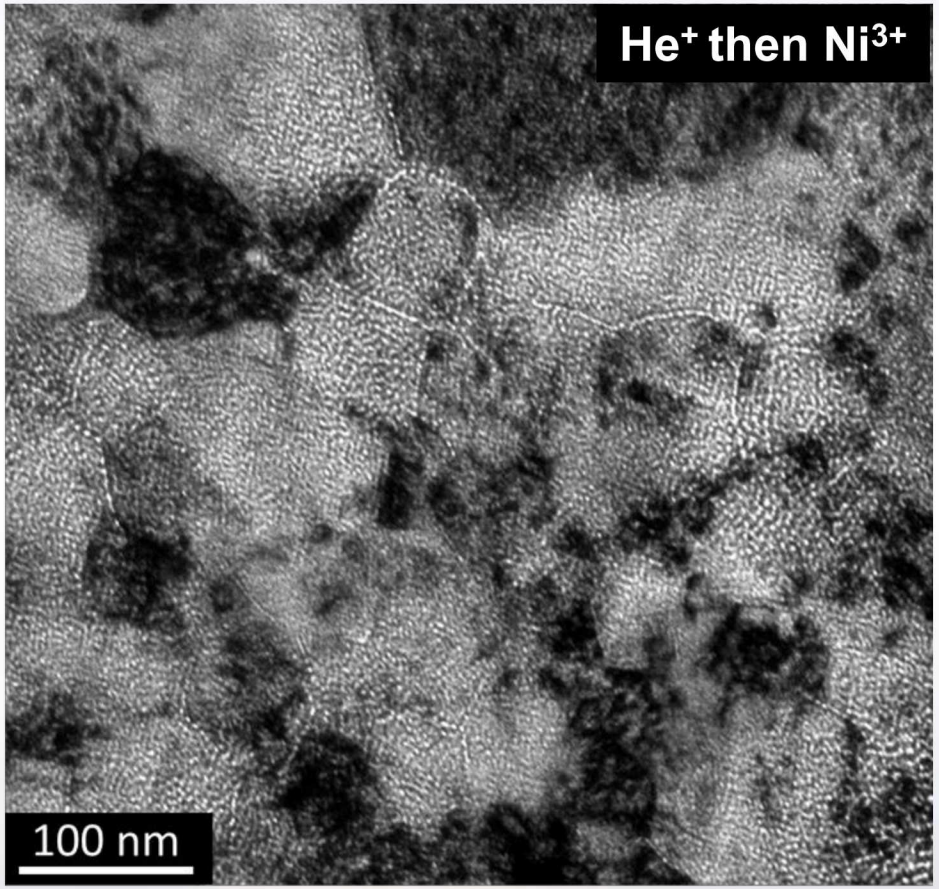


10^{17} He^+/cm^2
Visible damage

0.7 dpa Ni^{3+} irradiation
High concentration of cavities along grain boundaries

Irradiation / Implantation Sequence Effect on Cavity Structure





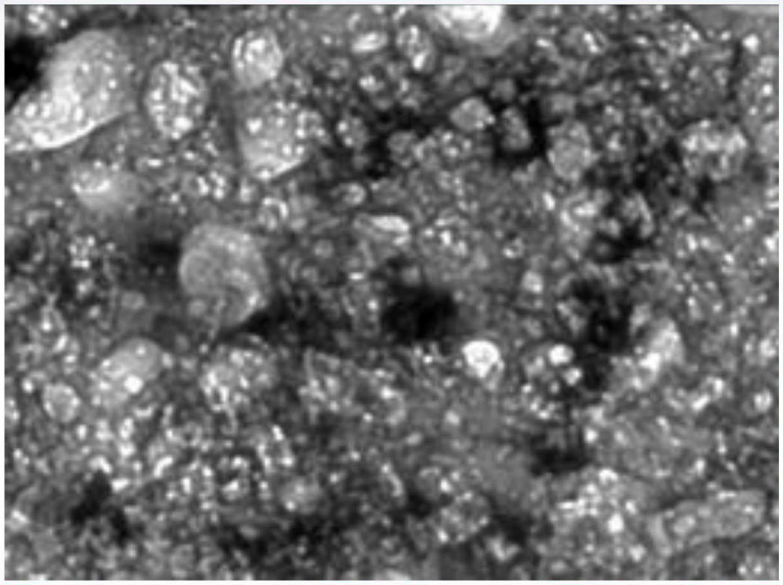
Evenly distributed cavaties over the entire grain structure

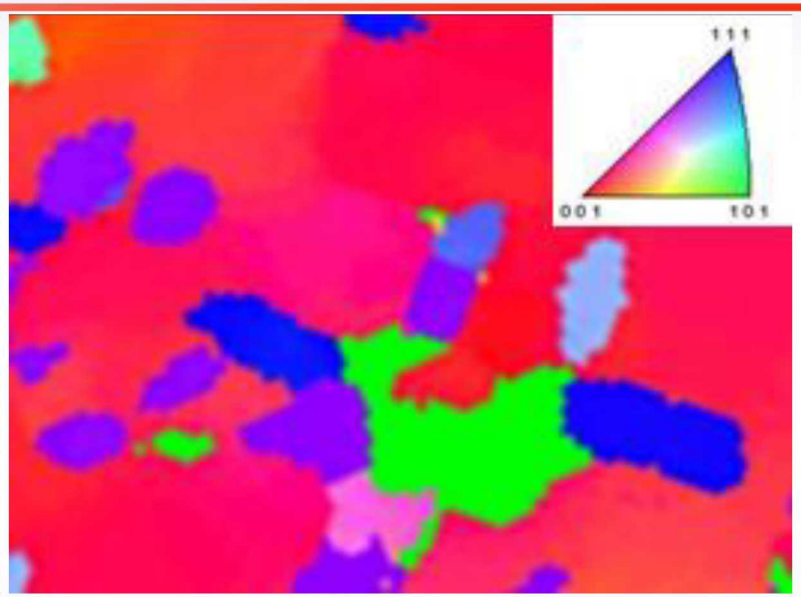
Apparent higher concentration of cavities along grain boundaries

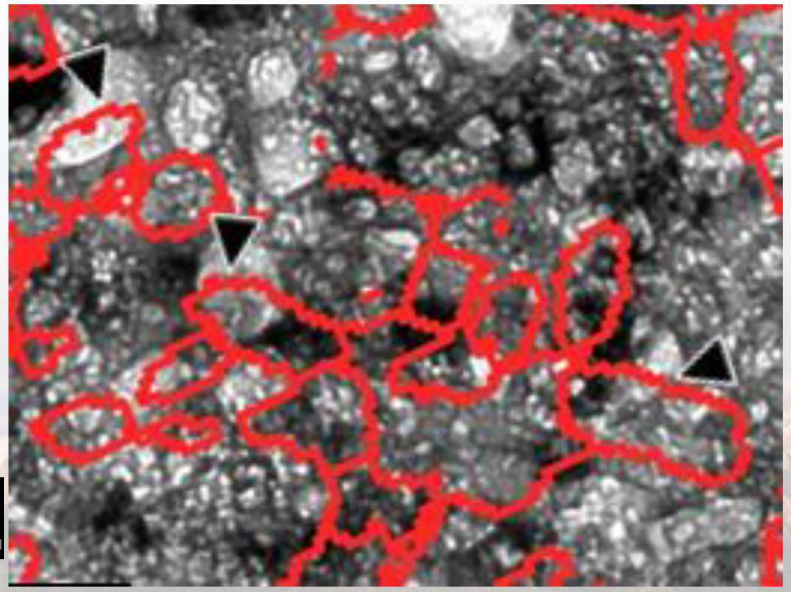
Precession Electron Diffraction Reveals Hidden Grain Structure

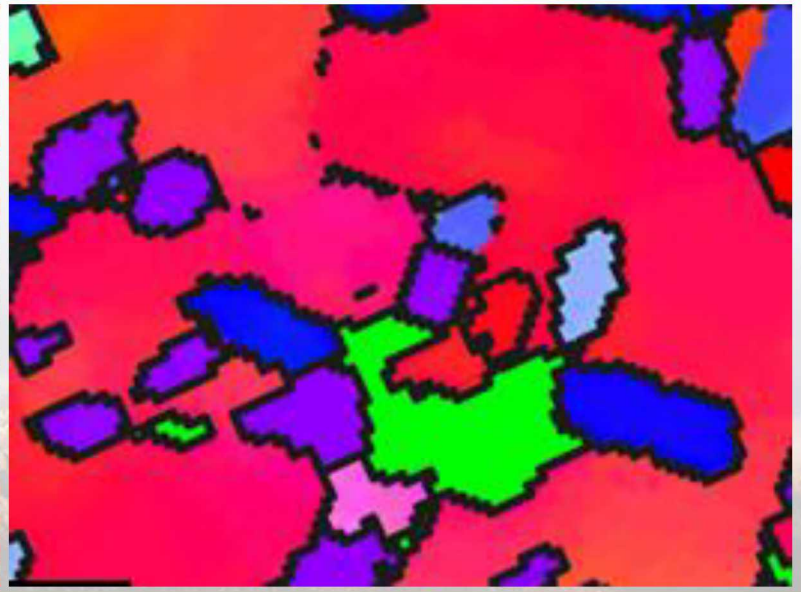
Cavities in helium implanted, self-ion irradiated,

nc nickel film annealed to 400 ˚C









Cavities span multiple grains at identified grain boundaries

100 nm

Summary