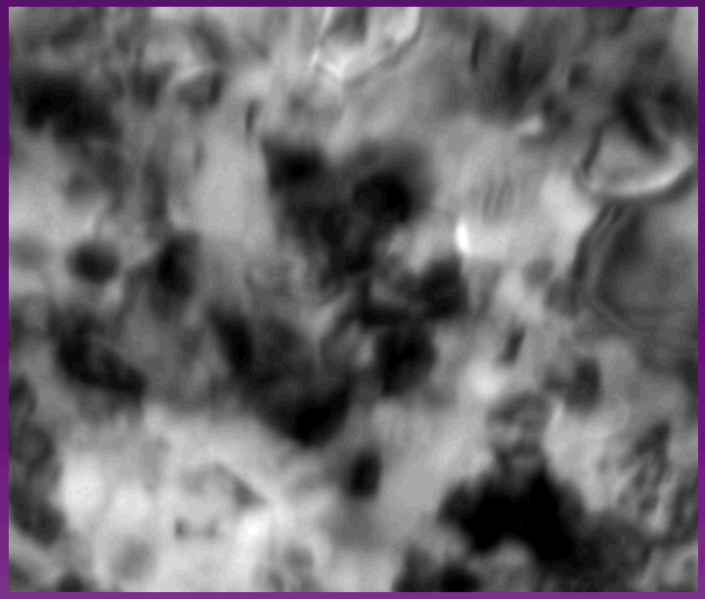
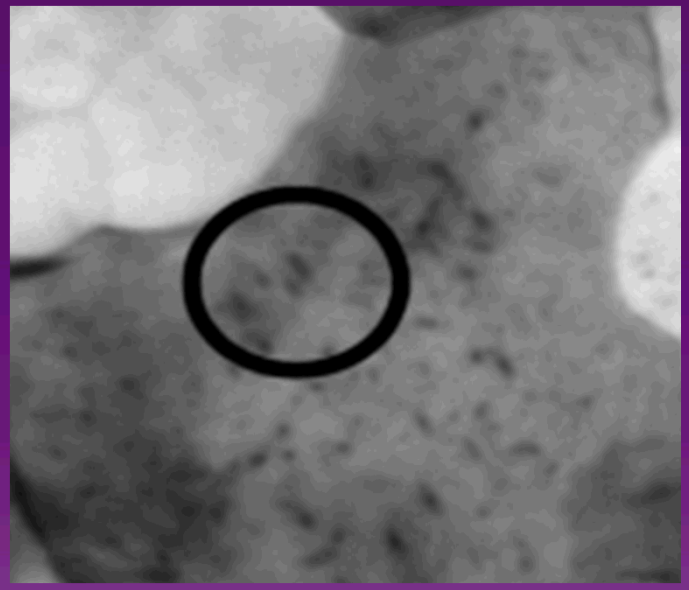
In-Situ He^+ Implantation and Thermal Aging of Nanocrystalline Iron

SAND2015-6215C

Brittany Muntifering, Sarah Blair, Youwu Fang, Aaron Dunn,
Remi Dingreville, Jianmin Qu, Khalid Hattar





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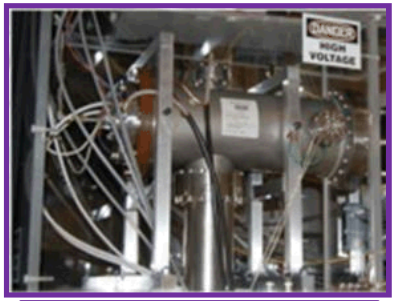
Sandia's I³TEM Facility

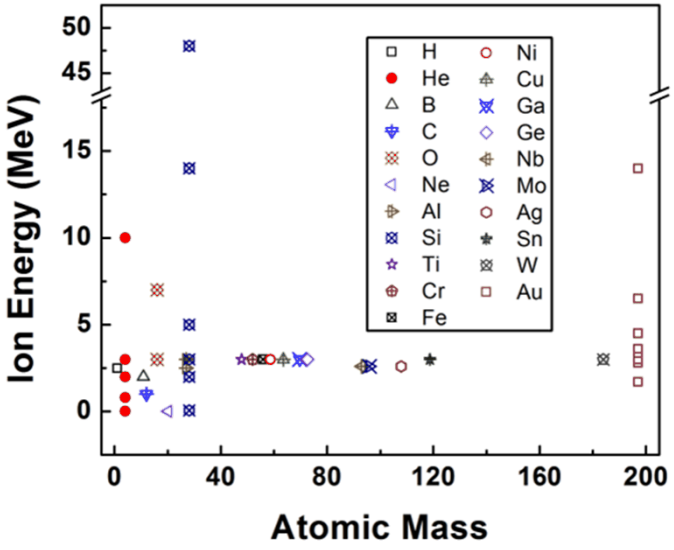
Sandia National Laboratories

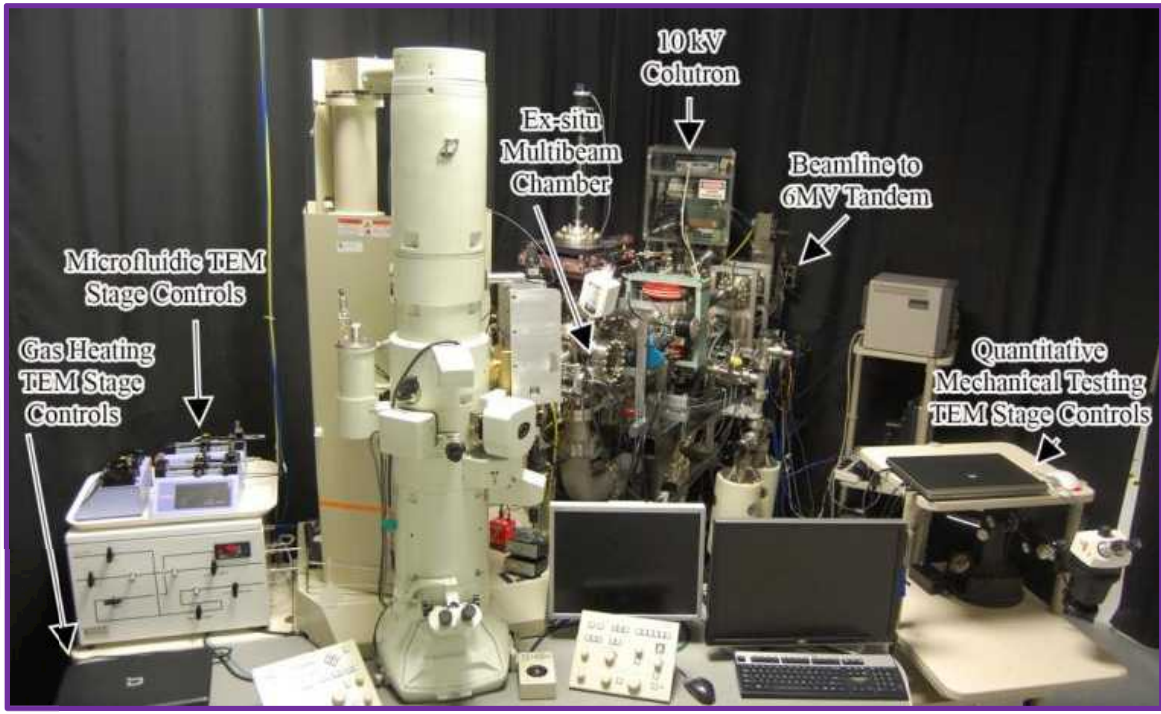
6 MV Tandem



10 kV Colutron

Heavy Ion Irradiation + Gaseous Implantation
Control ratio of dpa and gas species implantation and characterize coupling effects





200 kV JEOL 2100 TEM

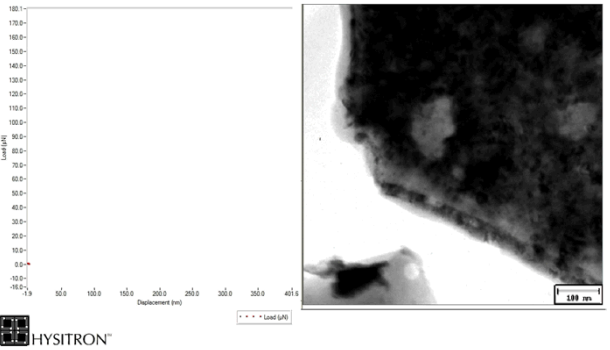
Direct real time observation of ion irradiation, ion implantation, or both with nanometer resolution

Radiation & Synergistic In- Situ Capabilities

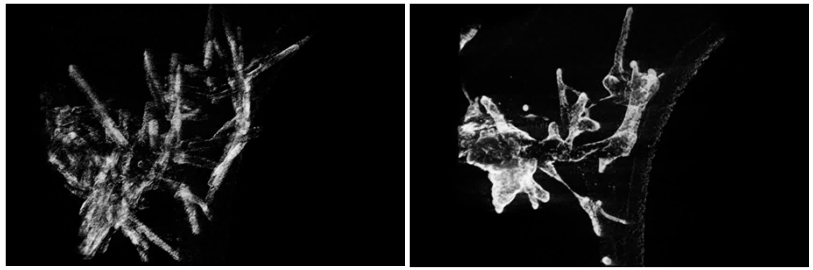
Structural Effects

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

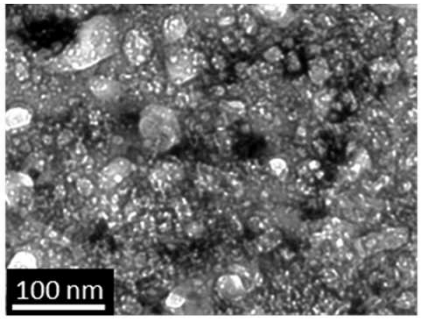
Mechanical Effects

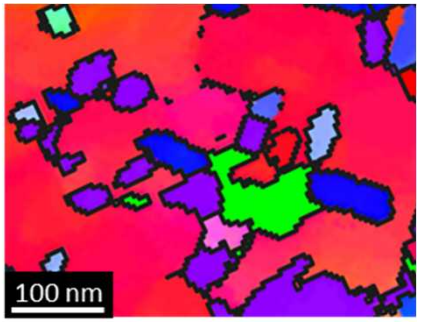


Hysitron PI95 TEM Picoindenter
Gatan 654 Straining Holder
Allows for direct correlation of dose and defect density with resulting changes in strength, ductility, and defect mobility



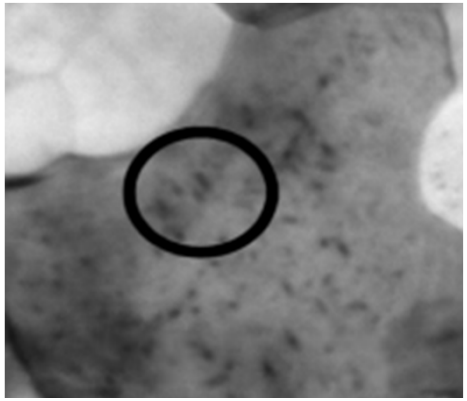
Nanomegas ASTAR
Grain structure changes as a result of radiation and implantation





Thermal Effects

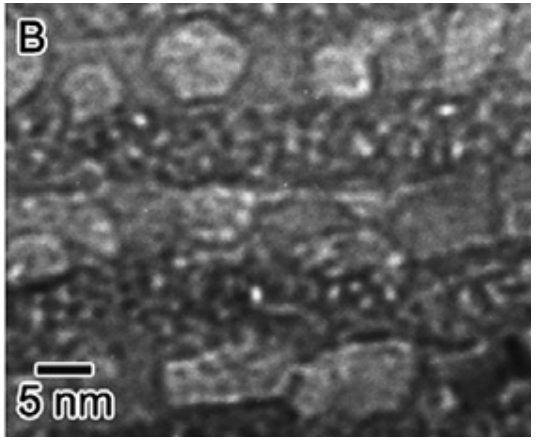
Hummingbird Heating Stage
Coupling effects of temperature and irradiation on microstructural evolution up to 800°C



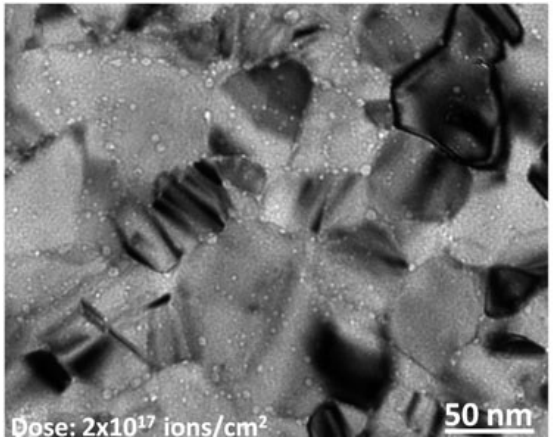
The application of advanced microscopy techniques to characterize synergistic effects in a variety of extreme environments

Helium Interaction with Boundaries and Interfaces

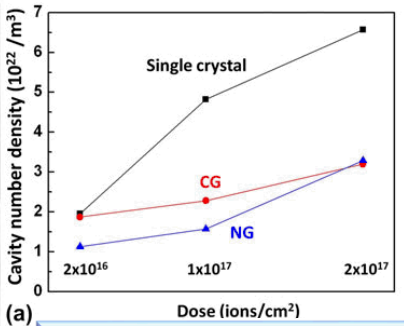
Helium effects embrittlement, void swelling, creep rupture, etc.

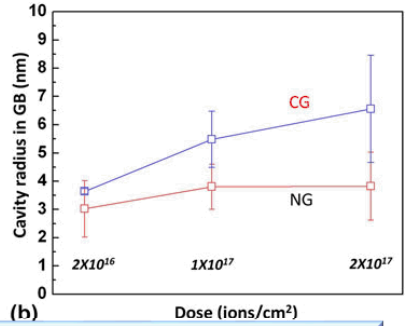


K. Hattar, et al. Arrest of He bubble growth in Cu–Nb multilayer nanocomposites. Scripta Materialia (2008)



Weizhong Hana, et al. Irradiation damage of single crystal, *coarse-grained, and nanograined copper under* helium bombardment at 450 °C. J. Mater. Res. 2013



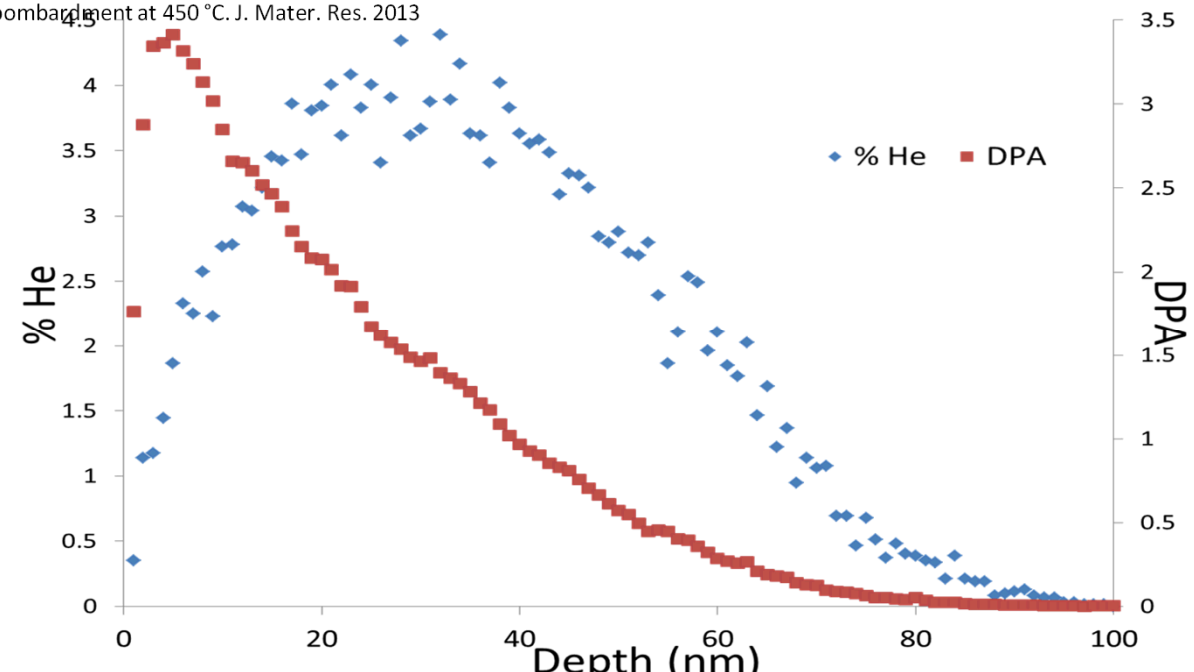


- Defects attracted to interfaces where they can annihilate
- Interfaces may limit cavity growth

10 keV He^+ into Nanocrystalline Iron

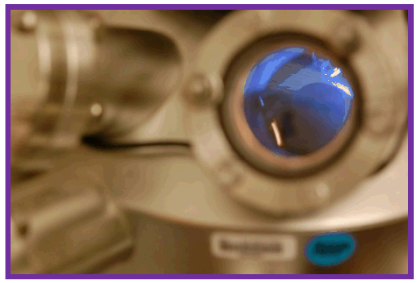
10^{13} He^+/cm^2s

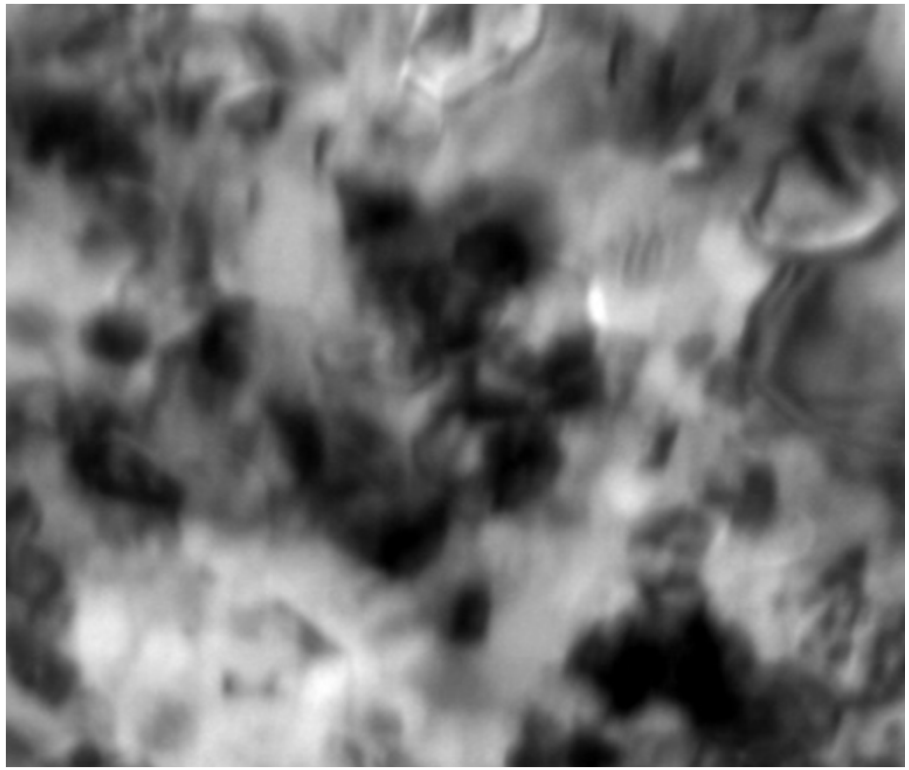
2.6 x 10^{16} He^+/cm^2 ≈ 2% He

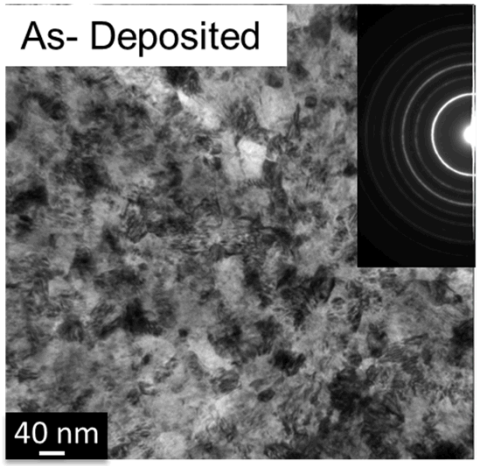


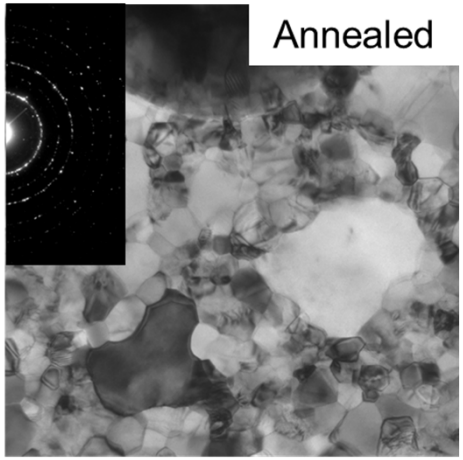
Deposition & Grain Size Tailoring of Iron Films

- KrF Excimer laser
- 35 Hz
- 4.5 x 10^{-5} Pa







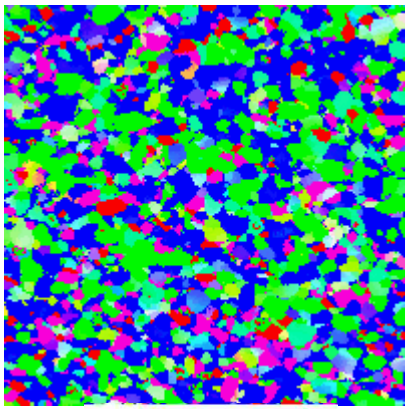


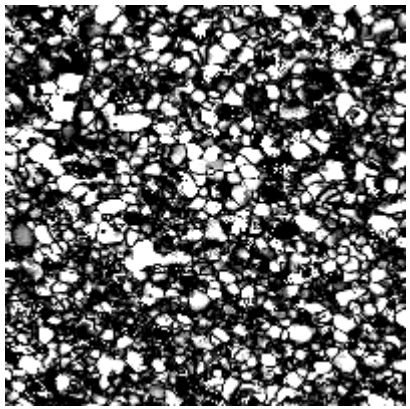
Control grain size within the nanometer regime

Grain Size and Texture Modification of Iron Films

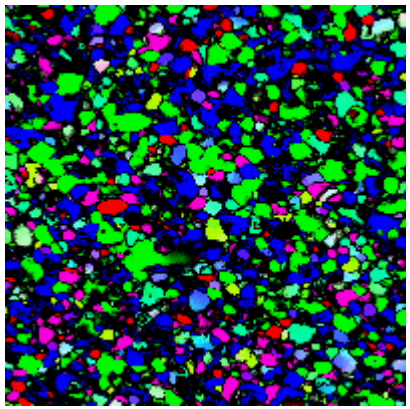
Annealing results in a stronger texture and loss of (001) oriented grains

As Deposited



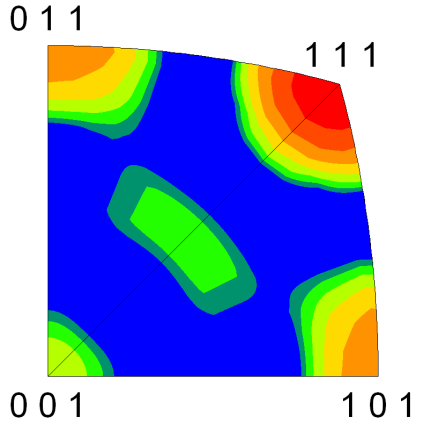


Reliability = 10-30

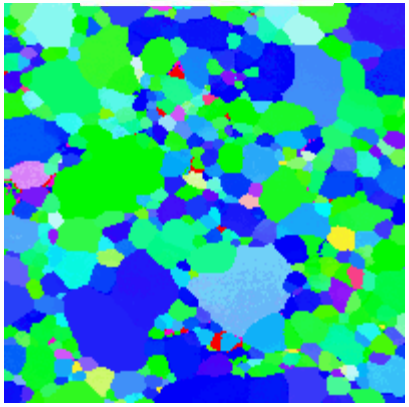


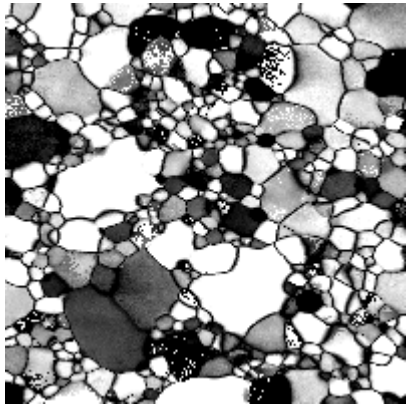
Combination

[001]

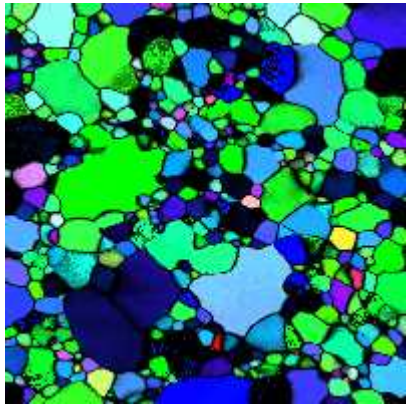


Annealed



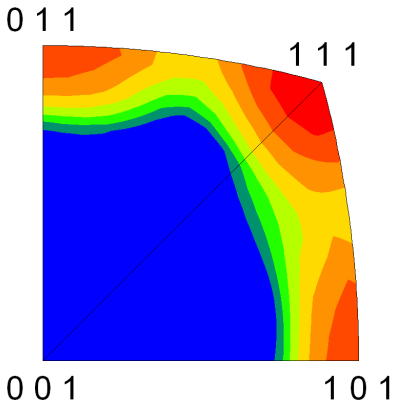


Reliability = 10-50

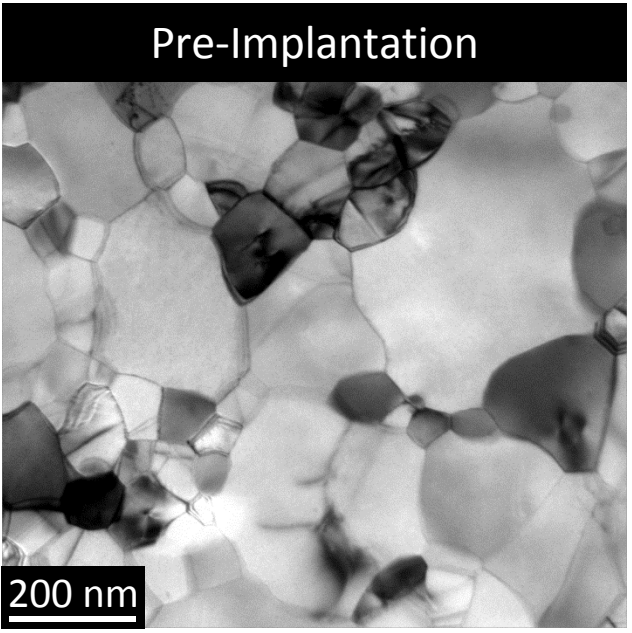


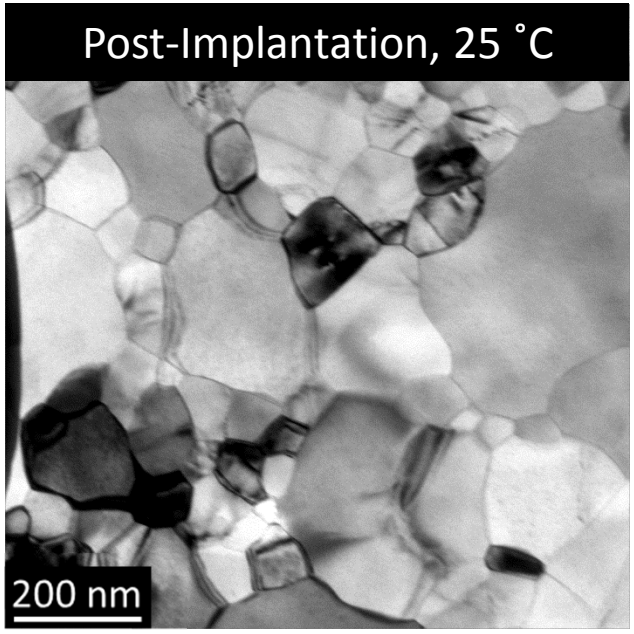
Combination

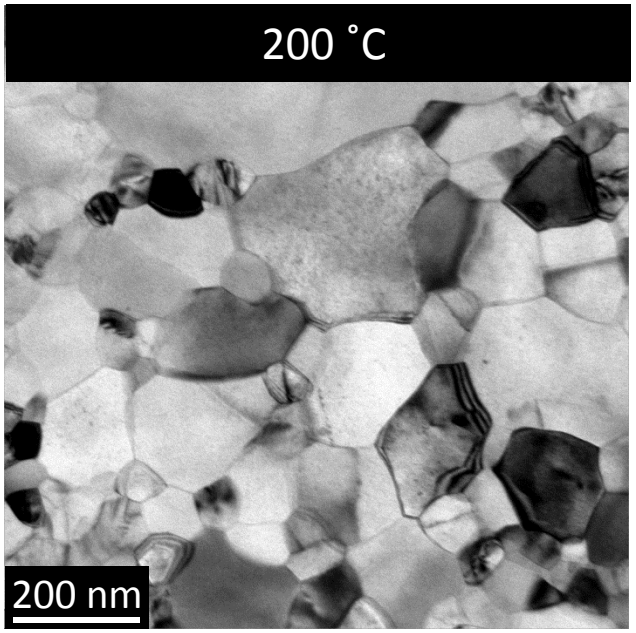
[001]

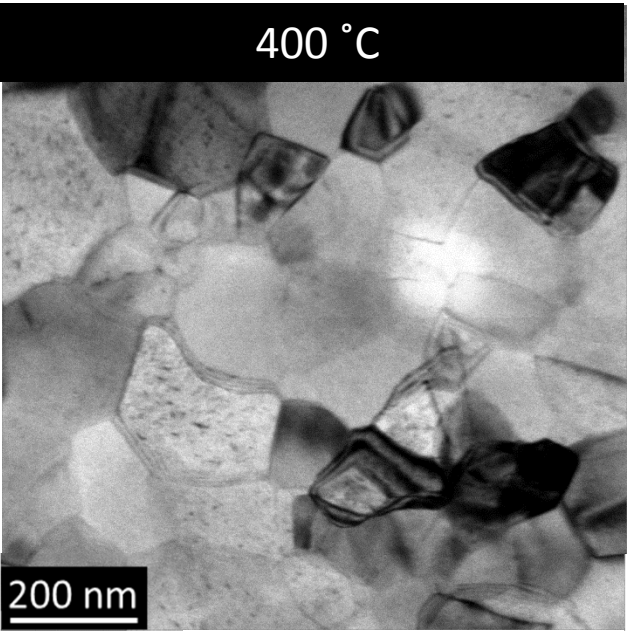


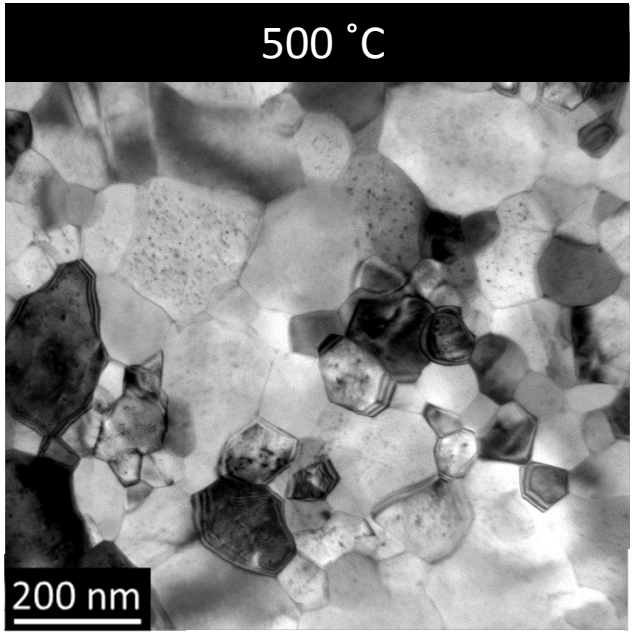
Helium Implantation at Room Temperature

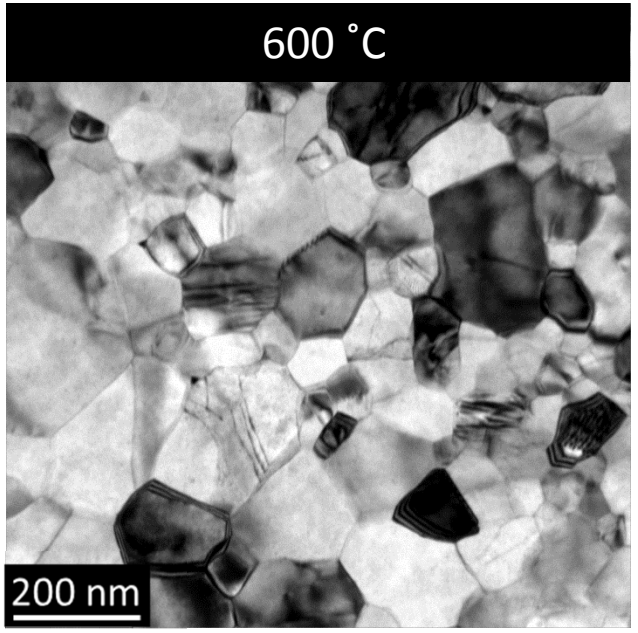






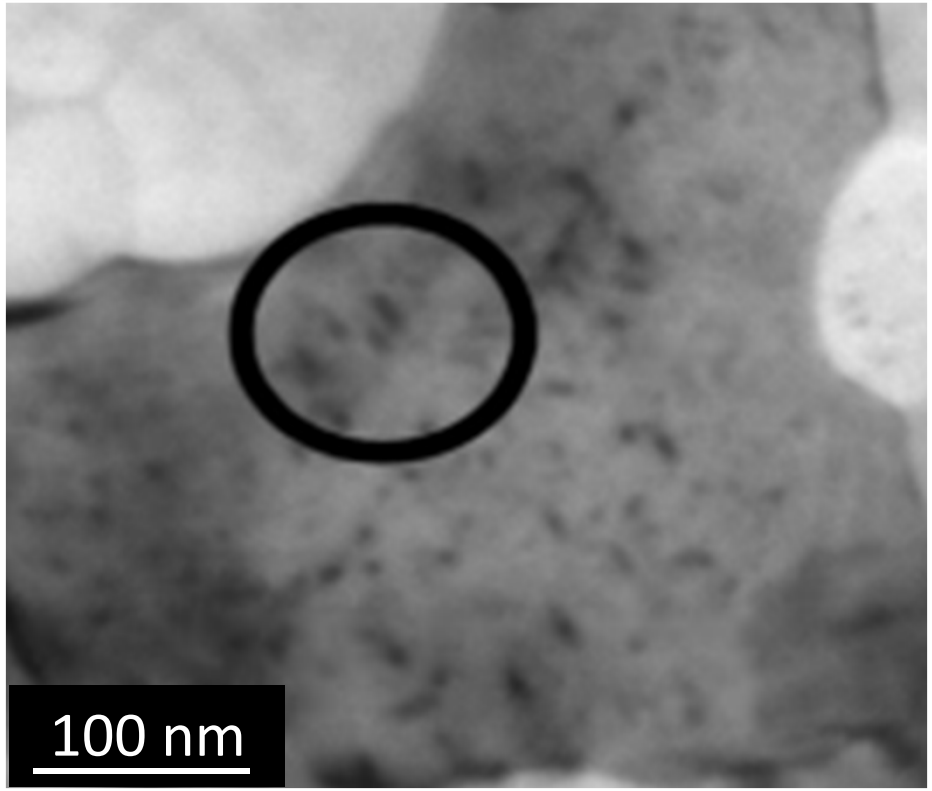




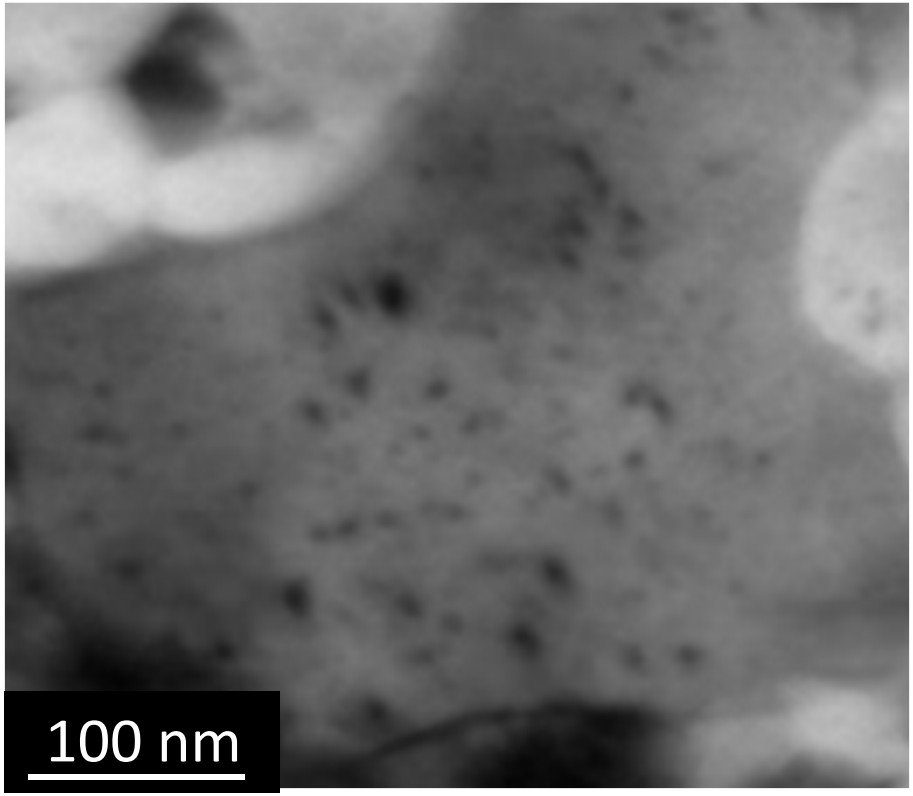


Dislocation Loop Mobility 500 ˚C to 600˚C

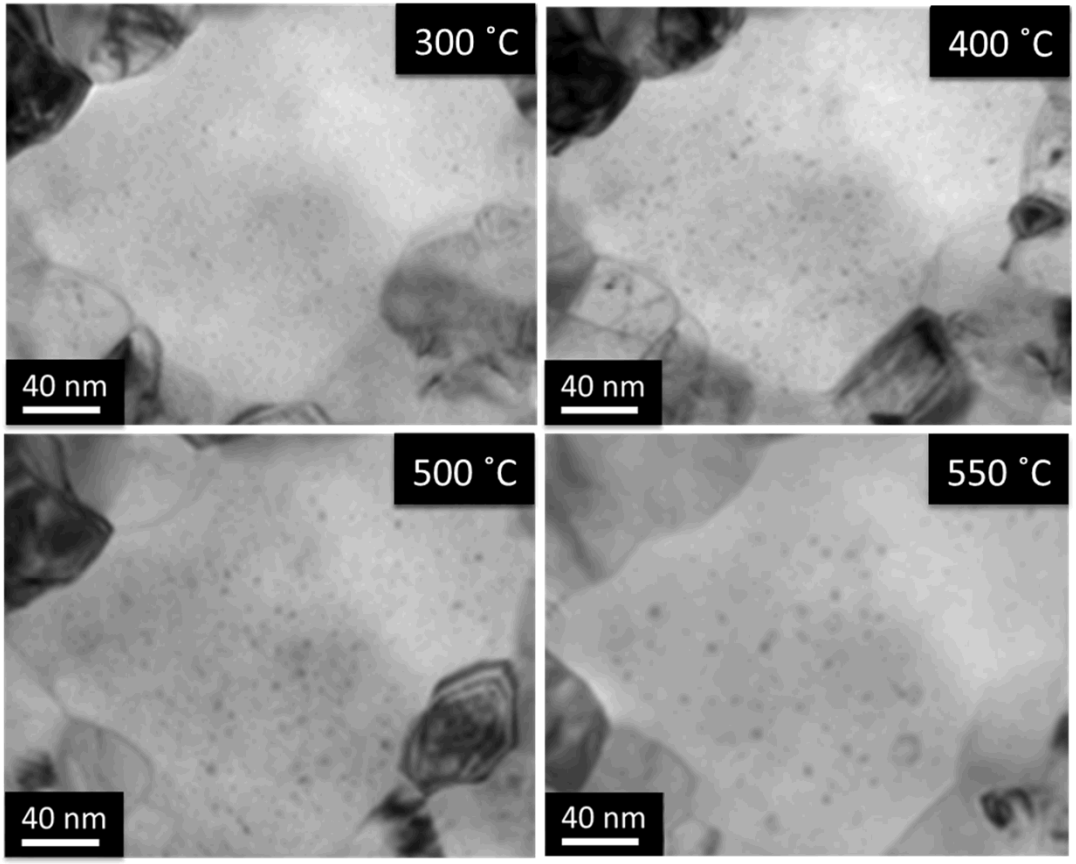
Dislocation Loop Coalescence

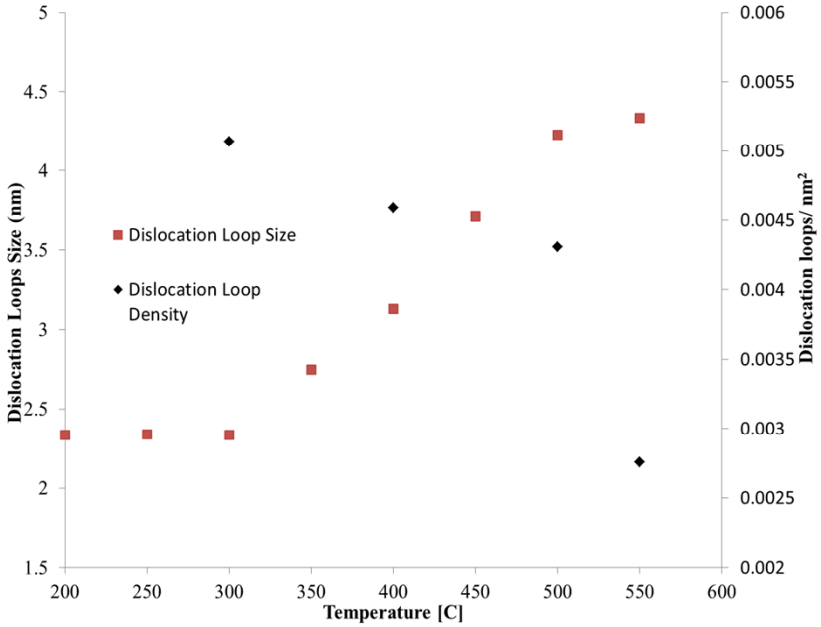


Dislocation Loop Migration to Surface



Defect Size & Density Evolution with Annealing

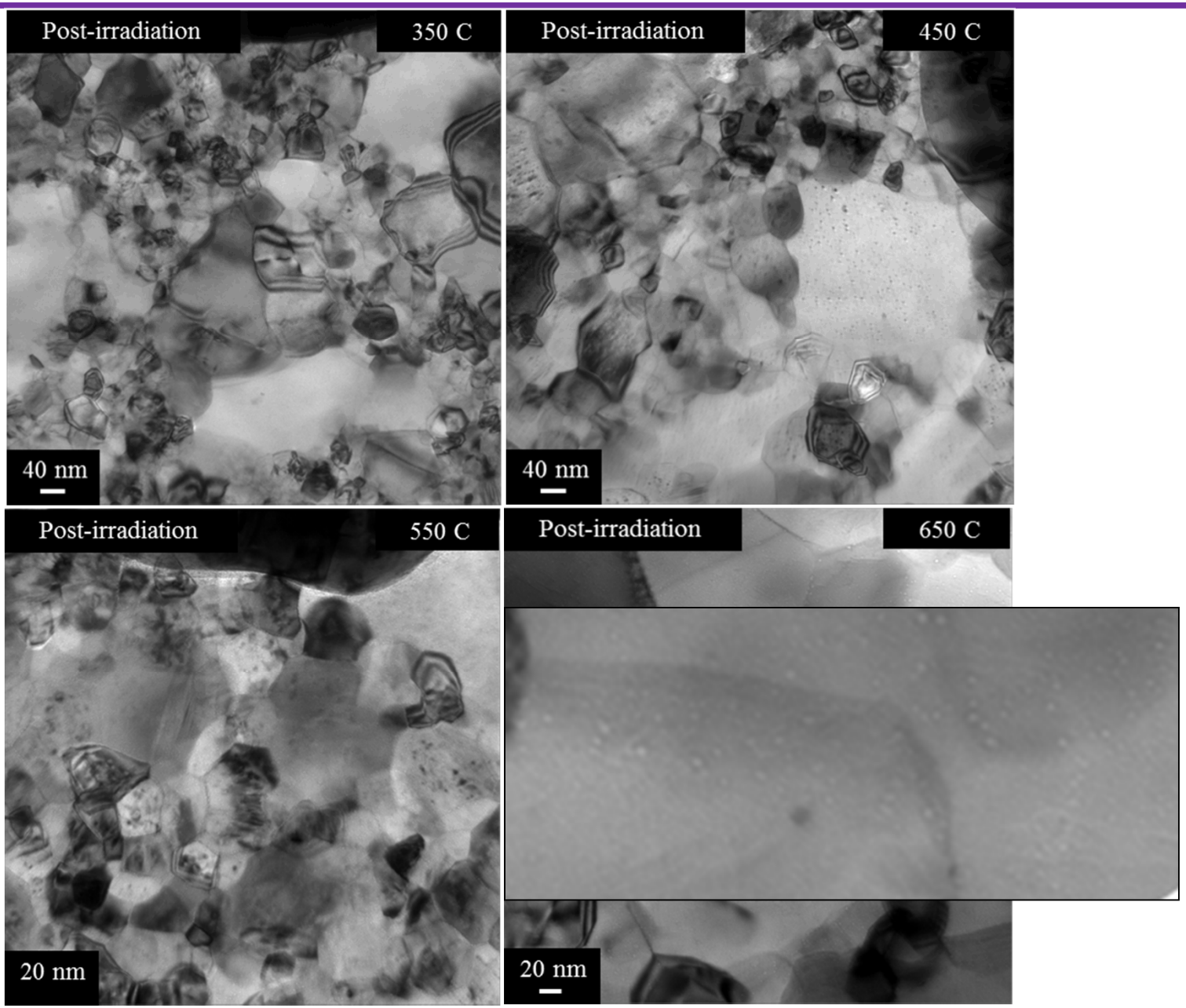




Defect Size Increases, Density Decreases

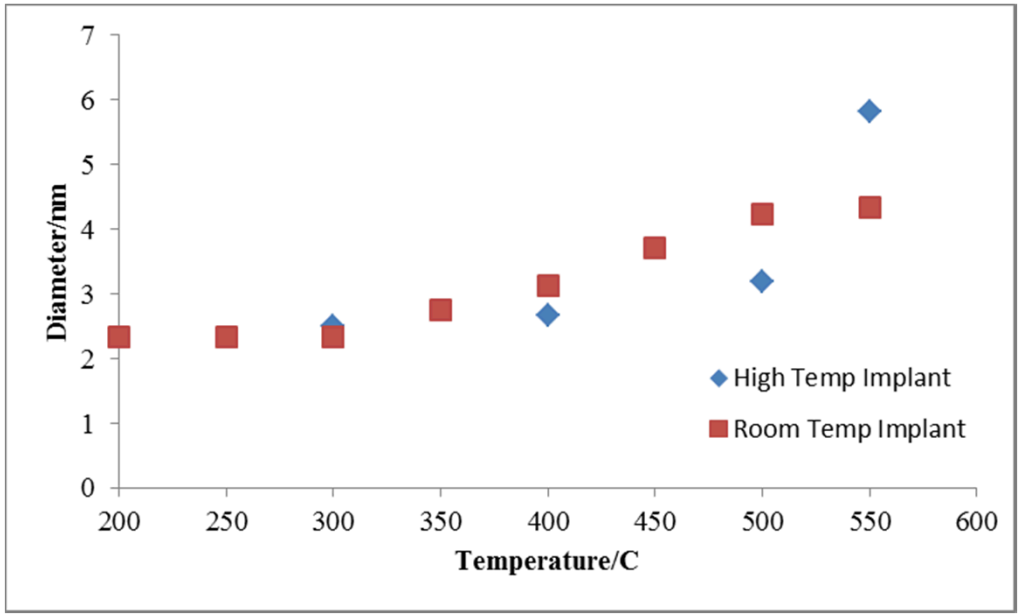
No visible Cavities

Elevated Temperature Helium Implantation



Summary

- PLD used to create nano-grained Iron films
- Grain size can be controlled
- Annealing results in textured samples
- 10 keV He^+ implantation at Sandia's I^3TEM
- Thermal effects studied
  - Room-temperature implantation then Annealing
  - High temperature implantation
- Similar size defects in both thermal conditions
- Cavities only appear during high-temp implantation



Acknowledgments

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Interest in post doctoral research or collaborations contact: Khalid Hattar, khattar@sandia.gov