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Quantification of Cavity Evolution in Nanocrystalline Ni after Helium Implantation followed by Self-Ion Irradiation

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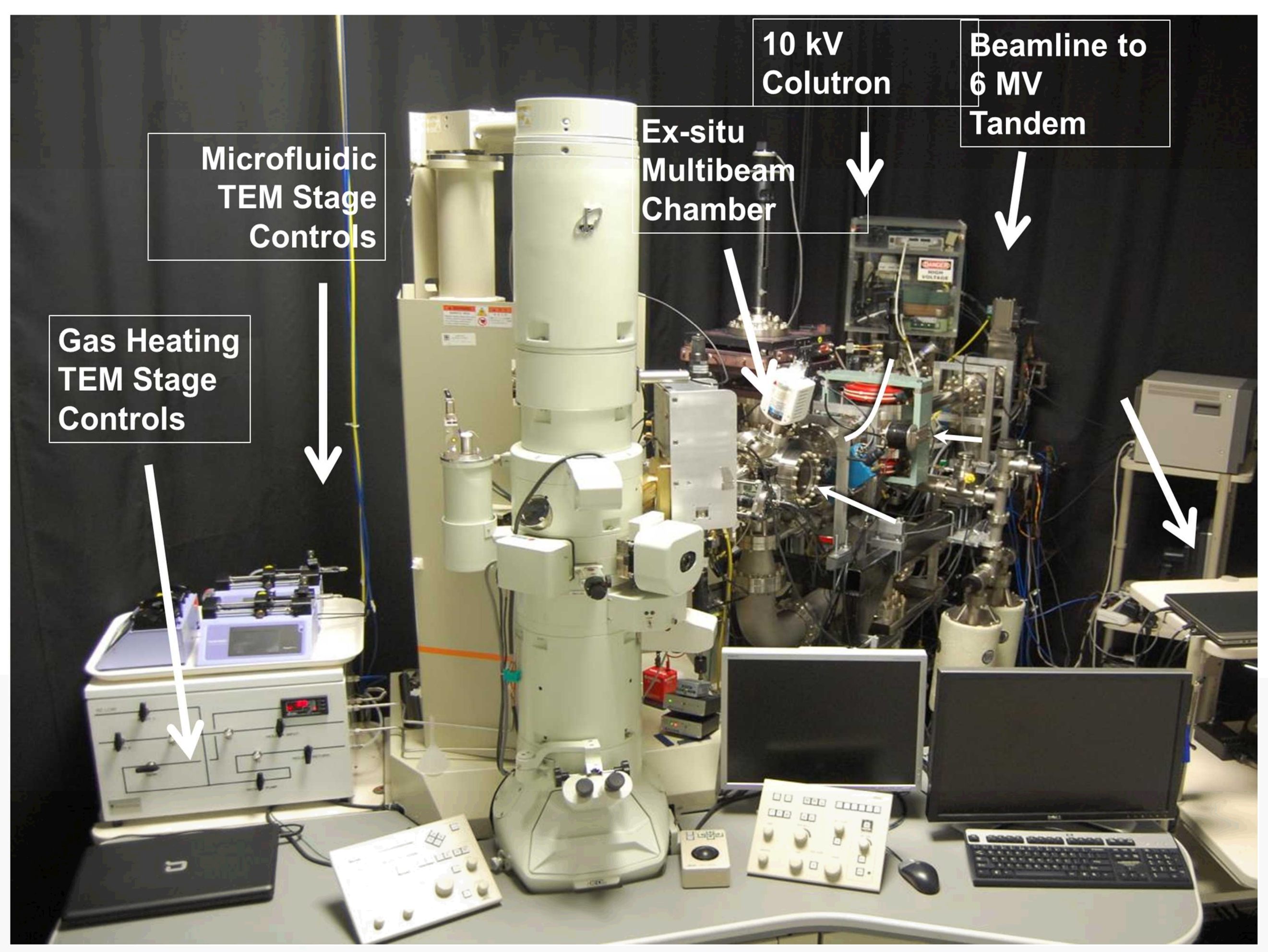
Motivation

- Radiation environments subject materials to damage which decreases lifetime of reactor components.
- Nanocrystalline materials have been shown to demonstrate increased resistance to irradiation damage compared to coarser-grained materials.
- Characterization of cavity growth could lead to the development of materials with tailored macroscopic properties.

The I^{3}TEM Facility



In situ Ion Irradiation TEM Facility

- JEOL 2100 TEM
- 6 MV Tandem Van de Graaff ion accelerator
- 10 kV Colutron ion accelerator

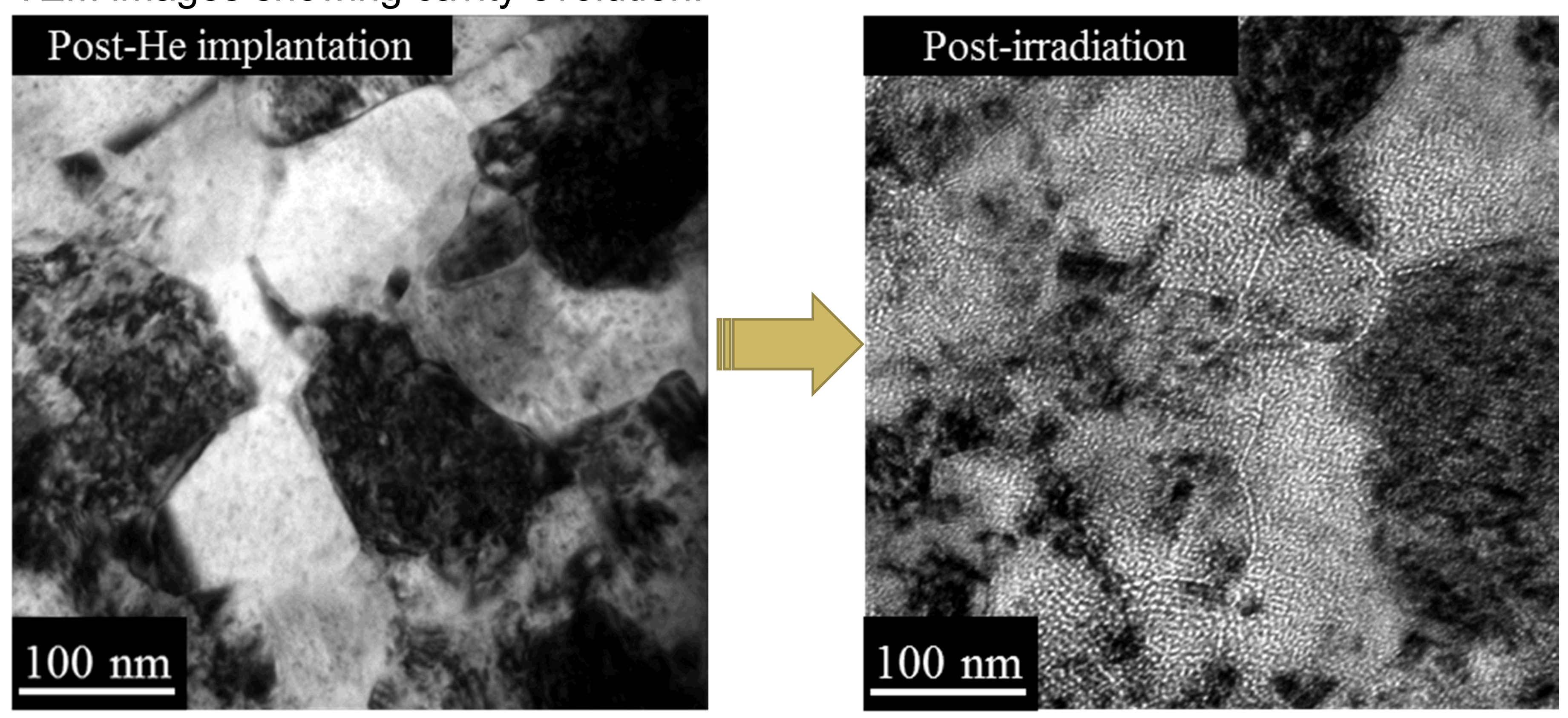
Goals and Approach

Characterize cavity evolution and thermal stability in nanocrystalline Ni after helium implantation followed by self-ion irradiation

- Analyzed TEM images following implantation/irradiation sequence
- Quantified cavity size distributions at sequential annealing temperatures
- Orientation map overlaid onto TEM images to investigate grain boundary effects on cavity evolution

Cavity evolution after He implantation followed by self-ion irradiation

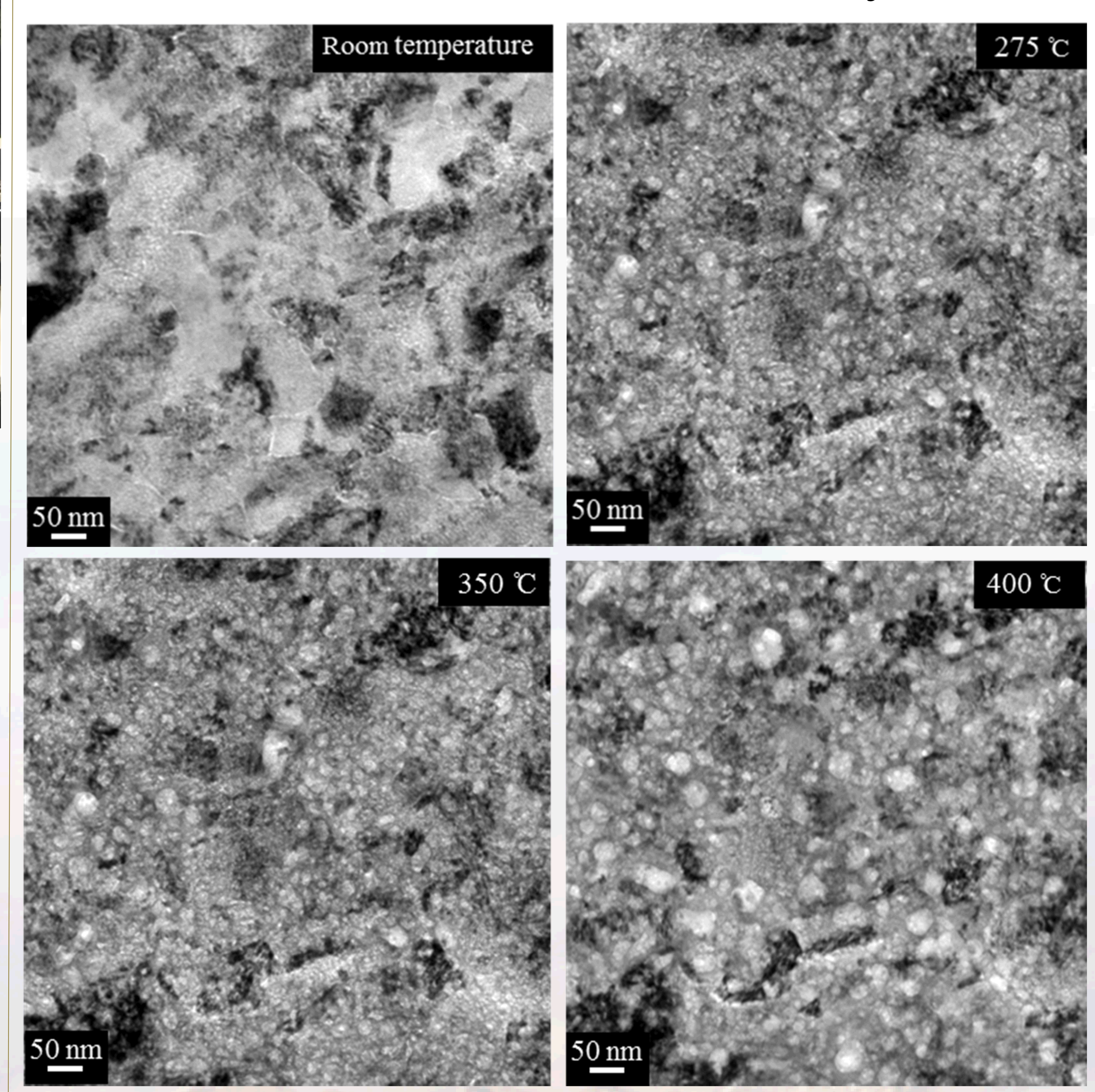
TEM images showing cavity evolution:



Preferential cavity formation near grain boundaries

Helium diffused to grain boundaries, resulting in higher cavity density and larger cavity size at grain boundaries compared to bulk.

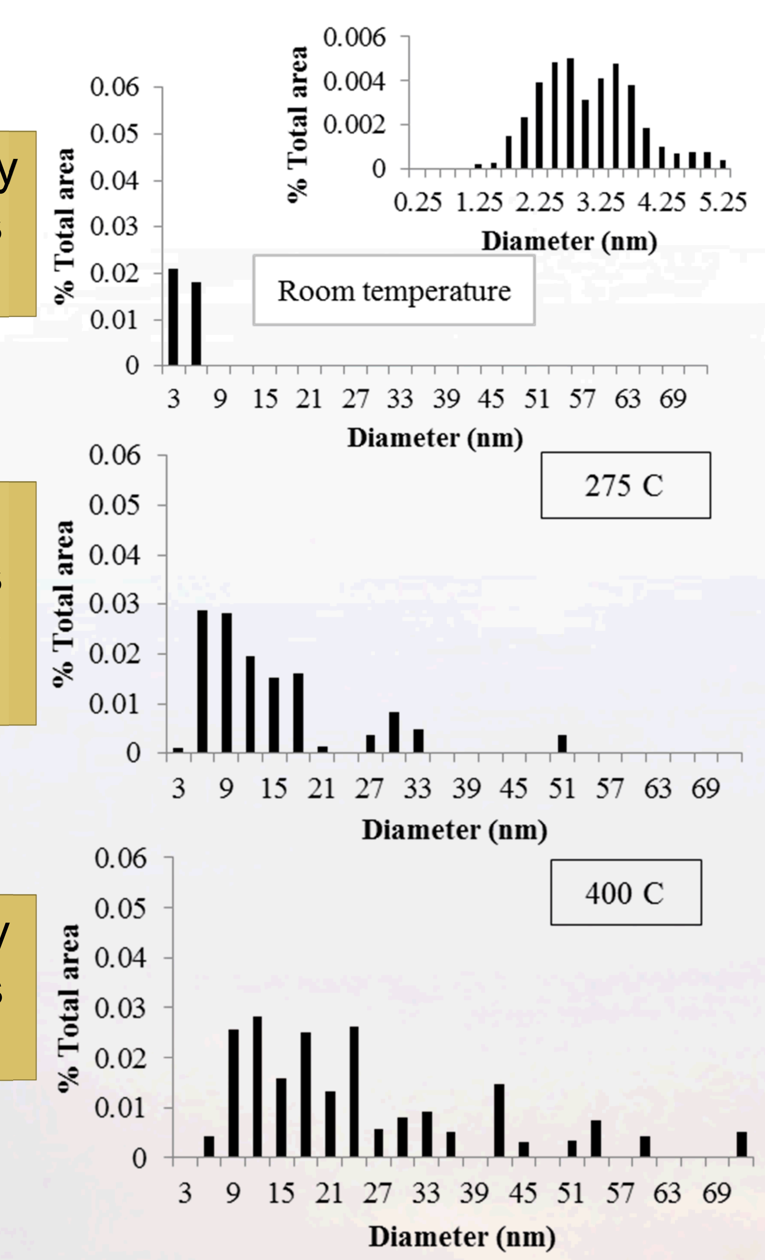
Thermal stability of cavities during annealing



Monomodal cavity size distributions until 275 ºC

Bimodal cavity size distributions between 275 º C and 400 º C

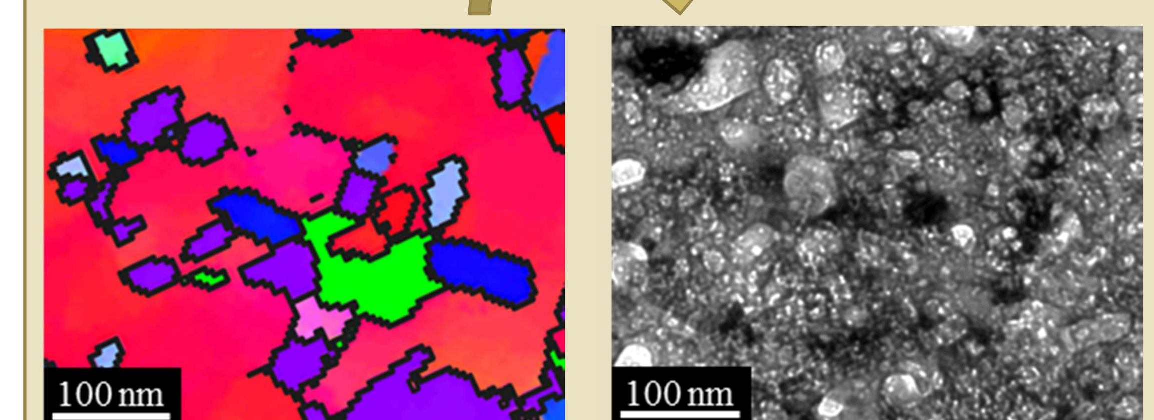
Multimodal cavity size distributions above 400 º C



No preferential cavity growth along grain boundaries during annealing compared to bulk

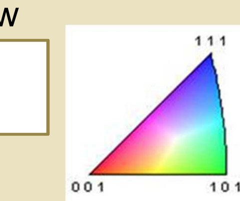
Post-annealing grain boundaries

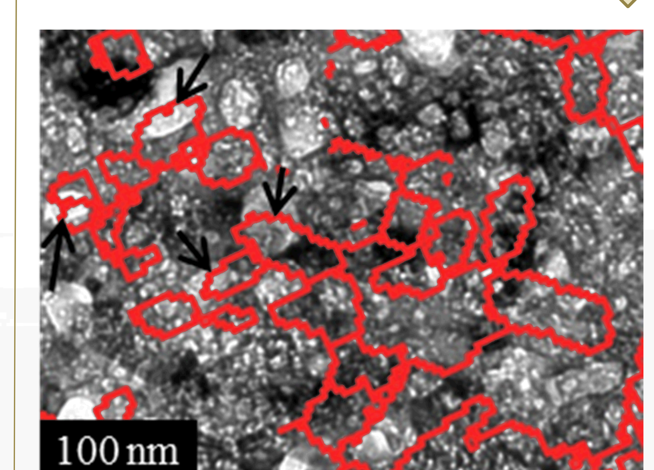
Overlay of ASTAR orientation map onto post-annealing TEM image:



ASTAR orientation map with key shown below

Post-annealing TEM image





Grain boundaries did not significantly grow during annealing.

Many cavities span multiple grains (see arrows).

Conclusions

- Grain boundaries did not significantly hinder cavity growth in nickel.
- High grain boundary density may not prevent irradiation damage in nickel; therefore, macroscopic material changes such as swelling may still be observed.

Future Work

- Investigate other metal systems in order to determine if grain boundaries affect cavity growth.
- Examine bulk nanocrystalline Ni and test macroscropic material properties following He implantation and self-ion irradiation.

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