Implantation of D^+ and He^+ in Candidate Fusion First Wall Materials

R.F. Radel and G.L. Kulcinski

Fusion Technology Institute – University of Wisconsin

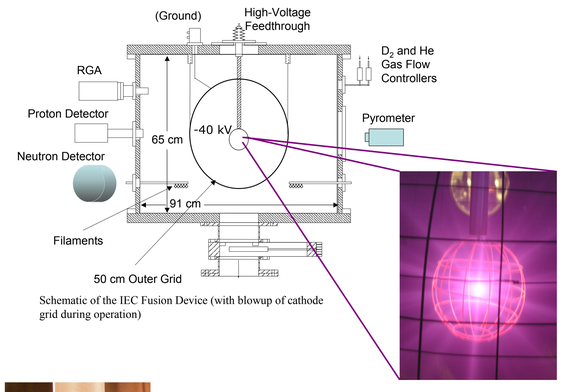
Background

Objective

Evaluate surface damage due to helium implantation in tungsten for use in fusion first walls.

Inertial Electrostatic Confinement

Electron-emitting filaments ionize fuel gas in the source region. These ions are then spherically accelerated towards the inner cathode grid using an electrostatic potential difference.

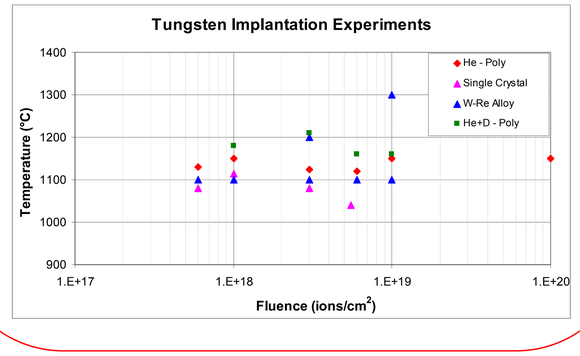


Schematic of the IEC Fusion Device (with blowup of cathode grid during operation)

Sample mounted in the IEC during irradiation at 1150 °C.

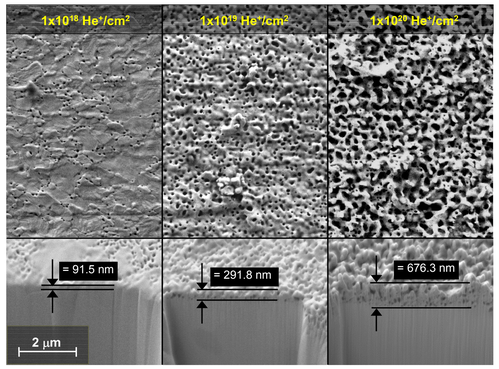
The IEC fusion device was modified to conduct this set of experiments. The inner grid was replaced by solid target samples. The device was then run at lower pressure to ensure a more uniform 30 keV ion energy distribution impacted the samples.

The graph below summarizes the work that is discussed in this poster.

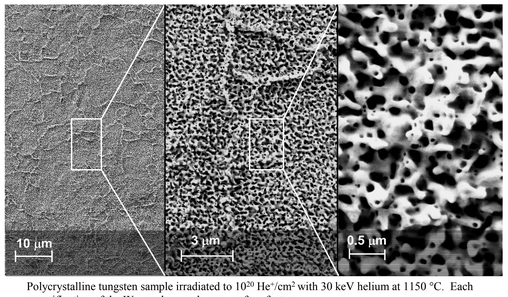


Results and Discussion

Increasing He^+ Fluence Degrades the W Surface at 1150 °C

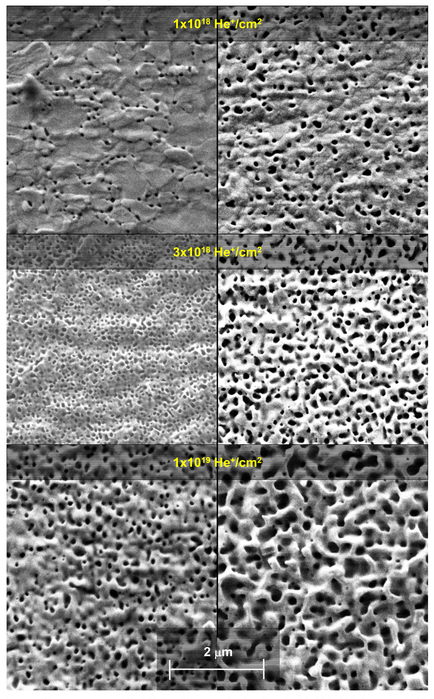


Polycrystalline tungsten samples irradiated at ~1150 °C to 10^{18}, 10^{19}, and 10^{20} He^+/cm^2, respectively. A Focused Ion Beam was used to mill a channel in each sample, as shown in the lower micrograph.



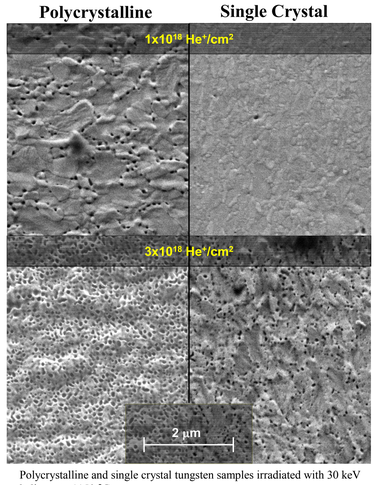
Polycrystalline tungsten sample irradiated to 10^{20} He^+/cm^2 with 30 keV helium at 1150 °C. Each magnification of the W sample reveals new surface features

Tungsten-Rhenium Alloy Offers No Advantage at ~1150 ° C



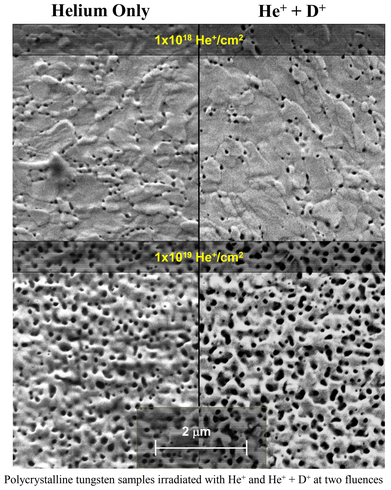
Polycrystalline tungsten and W-25%Re alloy samples irradiated with 30 keV helium at ~1150 °C.

Single Crystal W has a Higher Threshold for Pore Formation



Polycrystalline and single crystal tungsten samples irradiated with 30 keV helium at ~1150 °C

Simultaneous D^+ and He^+ has Little Effect on Pore Density at ~1150 °C



Polycrystalline tungsten samples irradiated with He^+ and $He^+ + D^+$ at two fluences

Conclusions

- Helium implantation to 10^{20} He^+/cm^2 at 1150 °C created substantial surface degradation and resulted in mass loss greater than that expected from physical sputtering.
- Simultaneous implantation of D^+ and He^+ at ~1150 °C created a lower pore density than pure He^+ irradiation at $1x10^{18}$ ions/cm^2, but produced similar damage at higher fluences.
- Single crystal tungsten has a higher fluence threshold for the formation of surface pores than the polycrystalline tungsten at ~1100 °C and had a lower density of surface pores at higher helium fluences.
- Alloying tungsten with 25% rhenium does not appear to improve the resistance to damage from helium implantation at ~1150 °C.

Future Work

Elastic Recoil Detection Analysis

- Examine helium retention in 10^{20} He^+/cm^2 sample
- Evaluate deuterium retention rates and profiles using Elastic Recoil Detection analysis

Pulsed IEC Operation

- Pulsed operation will better simulate the operating conditions of an ICF reactor
- Repeat D^+ and He^+ Irradiations to 10^{19} ions/cm^2 with pulsed operation

Helium Bubble Depth Profiling

- Perform temperature scans on polycrystalline samples to study effects on bubble depth profile