Surface Morphology of He^+-Implanted Nano-Grain W Coatings for Fusion Reactor First-Wall Materials and Divertor Plates

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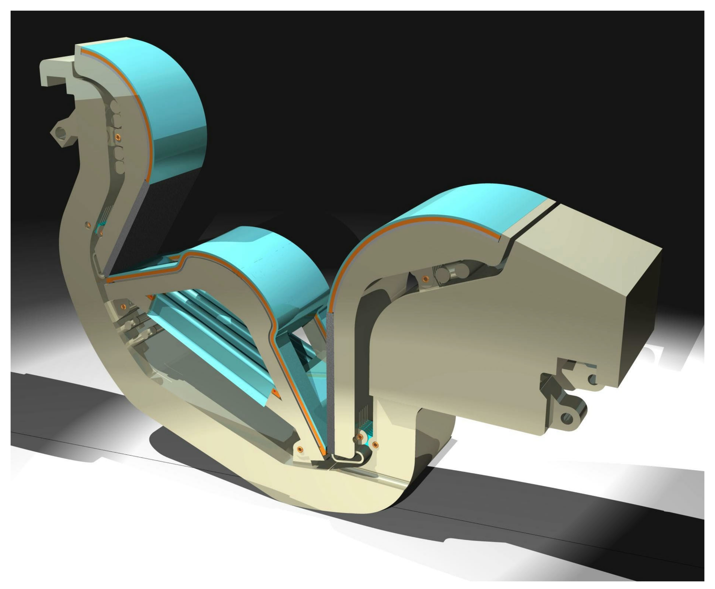
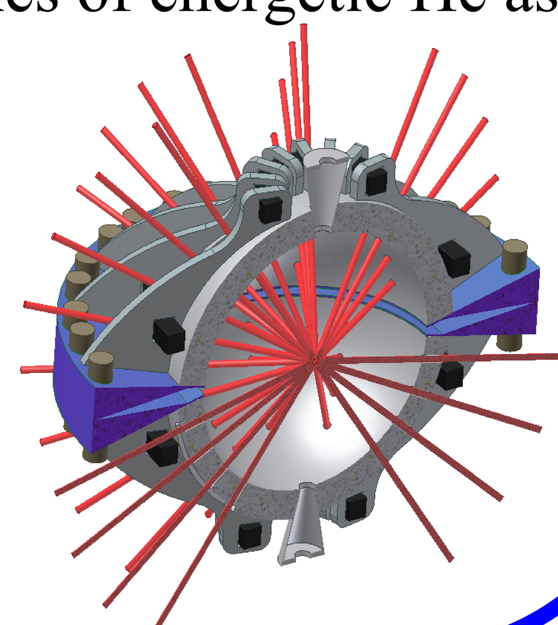
Motivation

"How can a 100-million-degree burning plasma be interfaced to its room temperature surroundings?"

- 2005 Scientific Challenges, Opportunities and Priorities for the U.S. Fusion Energy Sciences Program

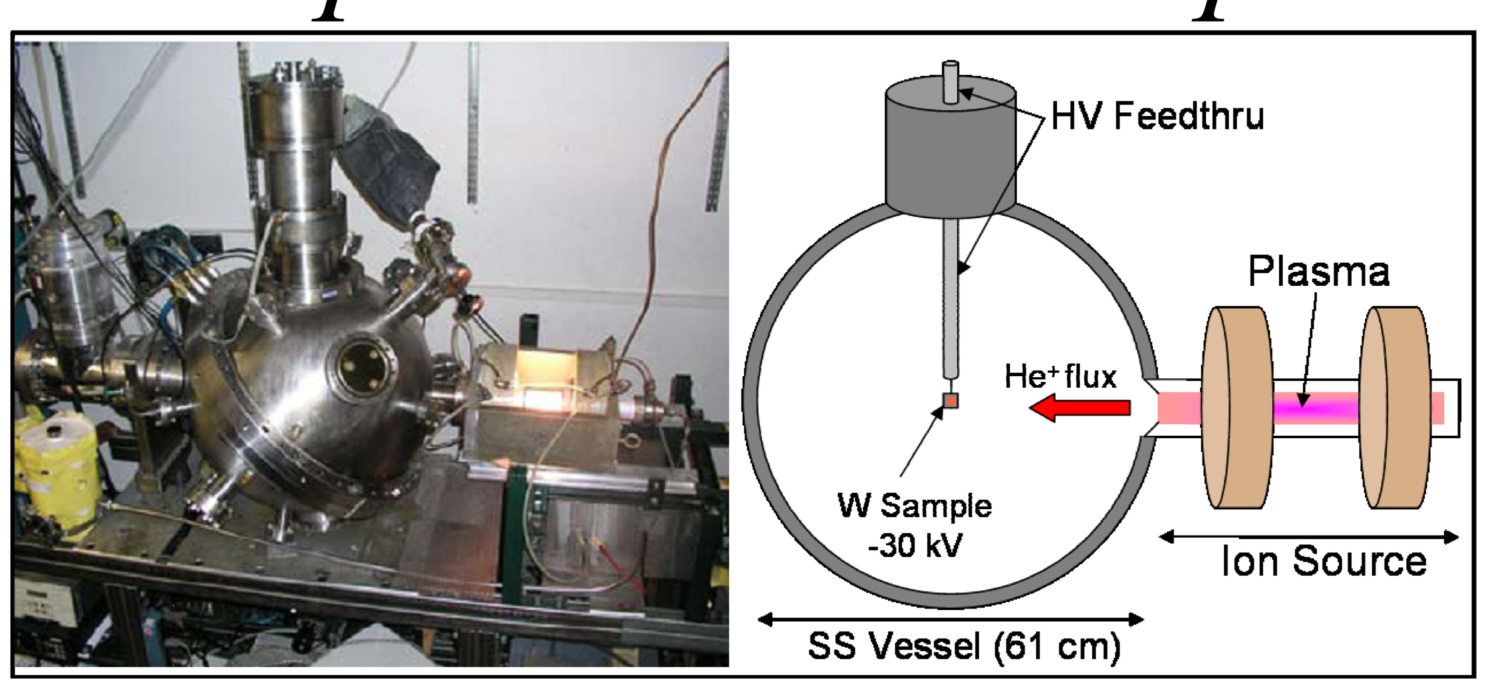


- Current designs of the dome & vertical targets of the ITER divertor use tungsten (W)
- These components experience high fluxes of energetic He ash



- Inertial Confinement Fusion concepts are considering W for the first wall armor

Experimental Setup

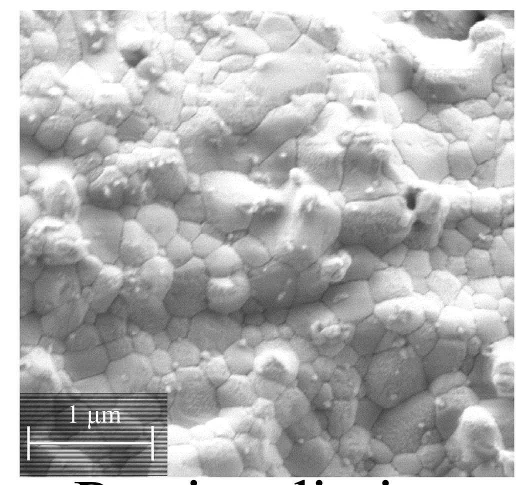


- Helium ions are generated using a helicon ion source
- A large negative potential difference (-30 kV) extracts He ions and accelerates them to ~30 keV
- Consequently, these ions energetically heat and bombard the W, implanting the specimen with He

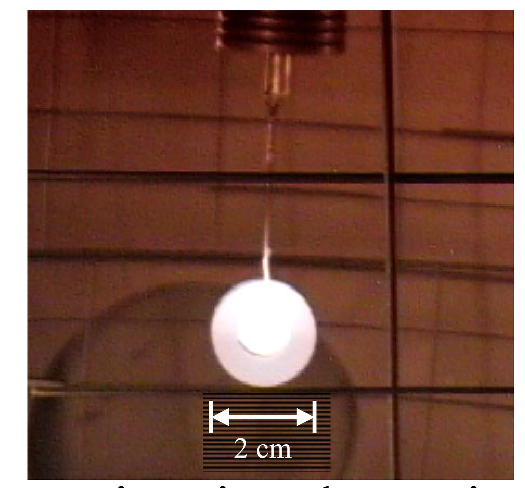
Results

Characteristics of nano-grain tungsten (NGW)

•80-90% dense •~240 nm average grain size



Pre-irradiation

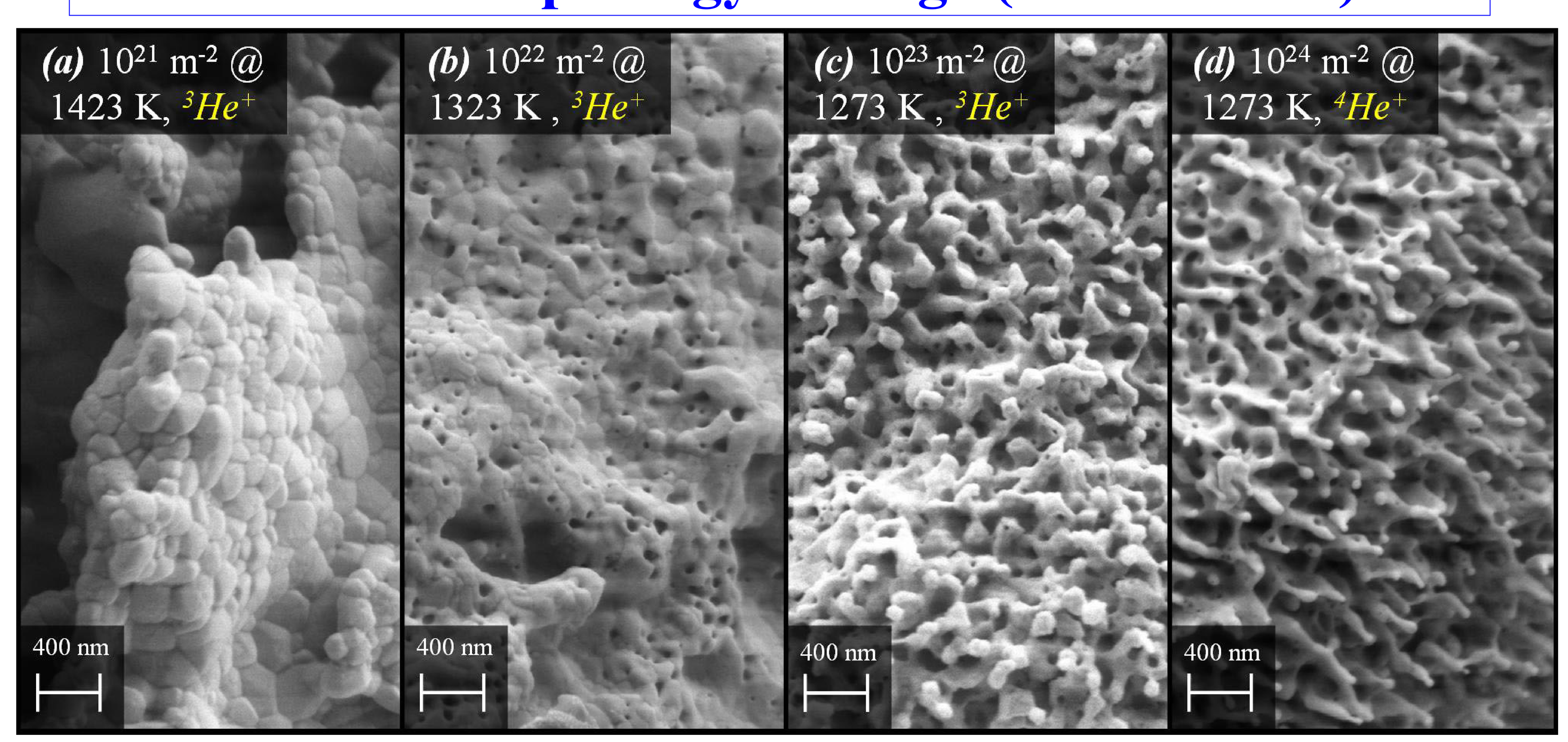


During implantation

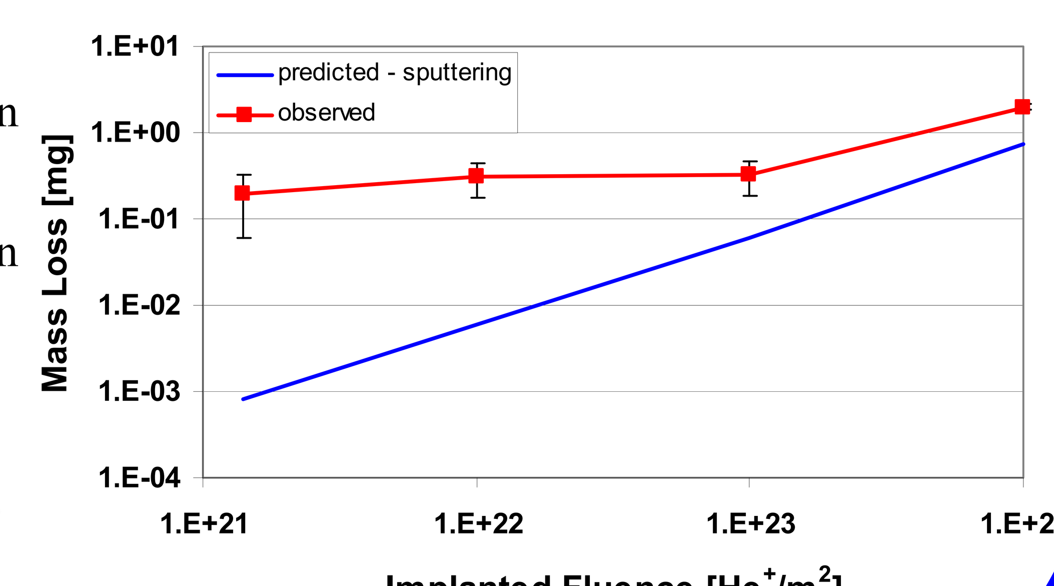
Implantation Test Matrix using 30 keV He^+

	$^3He^+$	$^3He^+$	$^3He^+$	$^4He^+$
φ	10^{21} m^{-2}	10^{22} m^{-2}	10^{23} m^{-2}	10^{24} m^{-2}
T	1423±50 K	1323±50 K	1273±50 K	1273±50 K

Surface Morphology Change (SEM & FIB)

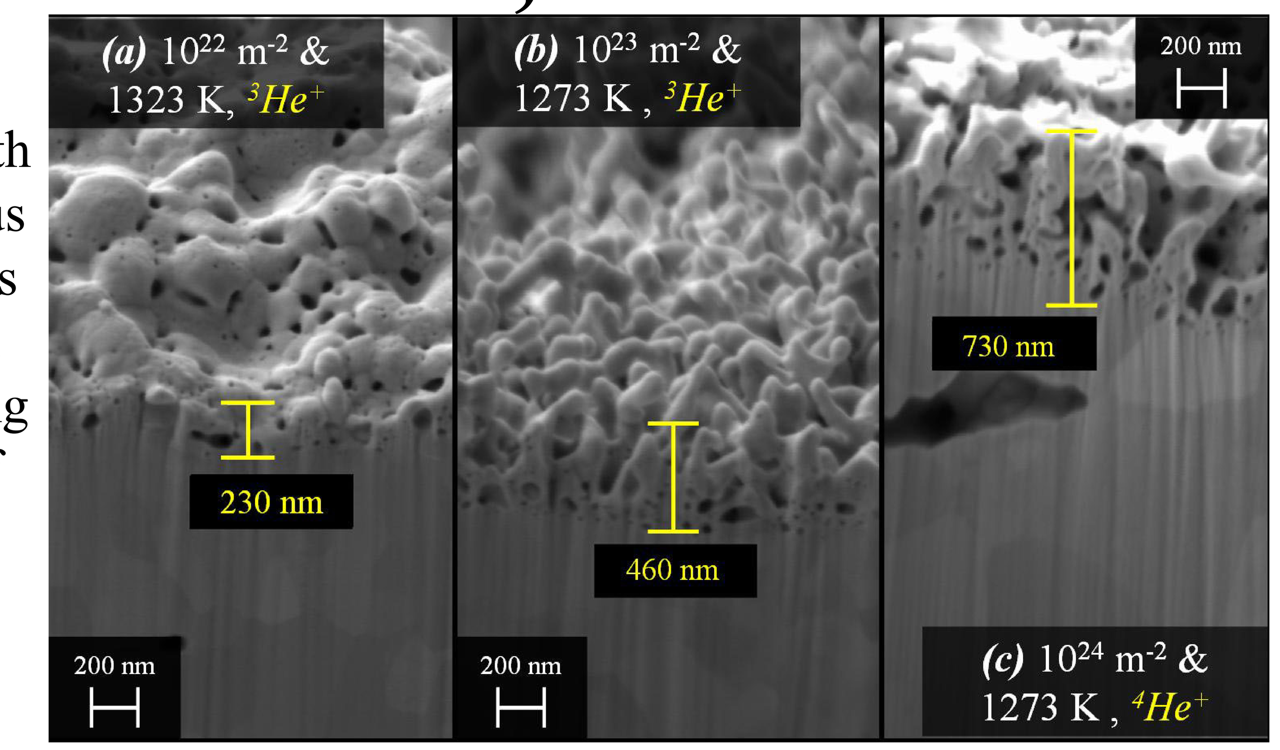


- Threshold fluence (φ) necessary for surface pore formation in NGW is between 10^{21} m^{-2} and 10^{22} m^{-2}
- Increasing fluence results in increased pore density and enhanced dendritic surface structure
- Measurable mass loss was observed on each specimen, and increased with increasing fluence

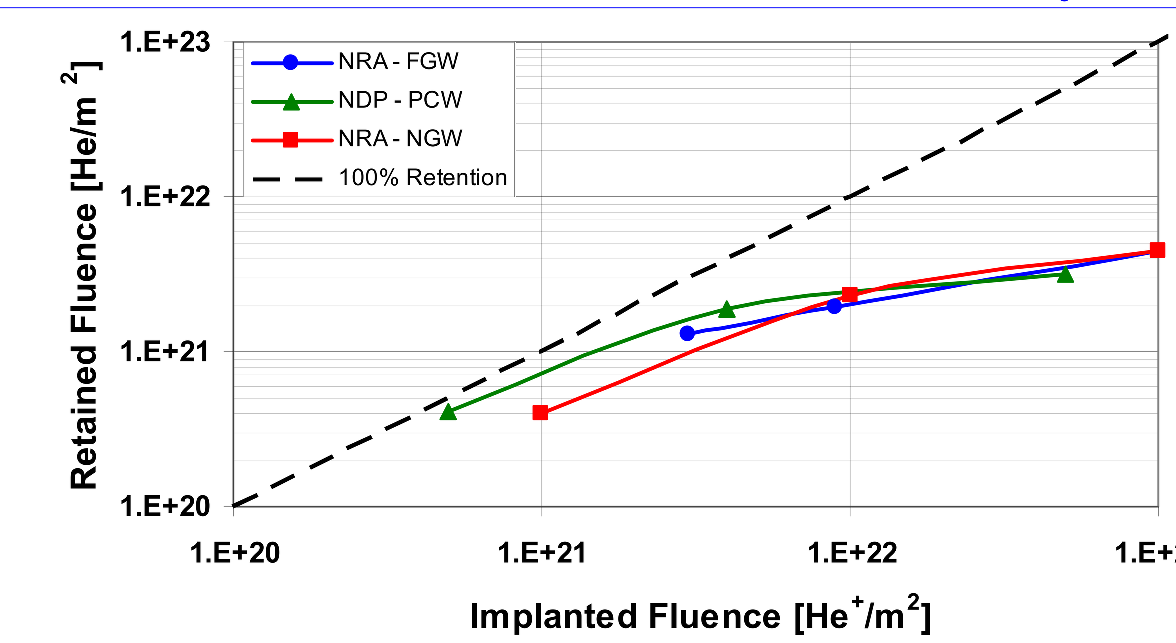


Results, cont.

- Subsurface penetration depth of visibly porous region increases with increased fluence, reaching a maximum of approximately 730 nm



Helium Retention – Nuclear Reaction Analysis (NRA)



- Retention of implanted He in NGW appears to be similar to that of fine-grain (FGW) and polycrystalline (PCW) tungsten

Conclusions

- The threshold for pore formation lies between 10^{21} –10^{22} m^{-2} in NGW and becomes extensive at 10^{23} m^{-2}, increased from standard PCW by about a factor of 10
- Sub-surface pores penetrate much deeper than the calculated range of 30 keV He^+ (~80 nm), up to 730 nm in NGW
- NRA shows the retention characteristics of standard PCW, FGW & NGW are very similar at fluences above ~10^{21} He^+/m^2 over the examined temperature range
- The surface morphology response of FGW & NGW does not appear to be better than standard PCW at intermediate (10^{22} m^{-2}) and high (10^{23} m^{-2}) implanted He^+ doses

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