The Response of Polycrystalline Tungsten to 30keV Helium Ion Implantation at High Temperatures and Its Dependence on the Angle of Incidence

Samuel J. Zenobia, Lauren M. Garrison*, Gerald L. Kulcinski
University of Wisconsin-Madison, Fusion Technology Institute

TMS 2011•San Diego, CA• February 27-March 3

1. Introduction

•Tungsten will be used as a divertor plate material in ITER and was selected for the first wall armor of the High Average Power Laser (HAPL) chamber.

•The newly constructed Materials Irradiation Experiment (MITE-E) was used to irradiate polycrystalline tungsten (PCW) samples for this study.

•The MITE-E has improved current monitoring, temperature control, and dose rate variability as compared with previous devices used for materials tests at the UW-IEC.

2. Experimental Setup

Samples: electropolished PCW

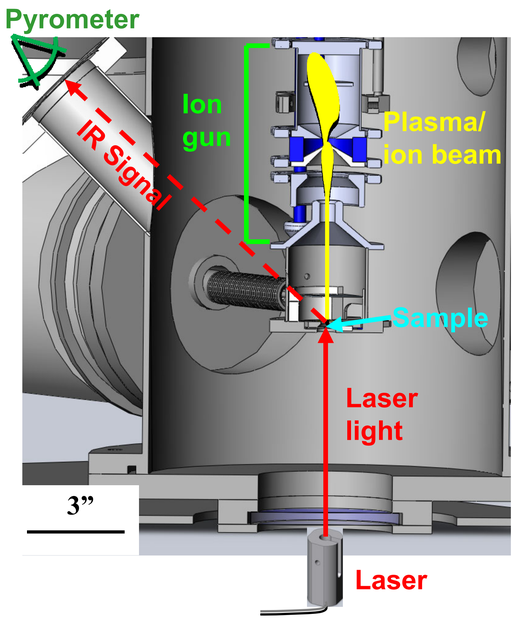

Figure 1: Solidworks™ model of the inside of the MITE-E vacuum vessel.

Features of the MITE-E:

•Ion gun: 8 mm diameter, normal incidence beam of 30 keV He ions; I= 75 μA
•Nd-YAG laser: additional sample heating

*Corresponding author:
lgarrison@wisc.edu

3. Results

3.1 Fluence Scan at 900 °C

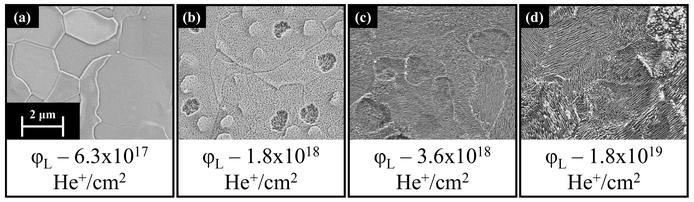

Figure 2: As fluence was increased on PCW samples irradiated with 30 keV He^+ at 900 °C the surface morphology changes became more severe—starting with (a) small pores and grain shifting, evolving to (b) blisters and pores, then (c) blister remnants and “grass,” and finally (d) “grass” alone.

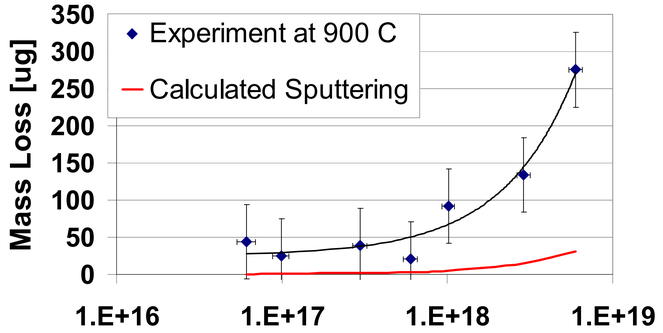

Figure 4: Fluence scan samples—mass loss increased with increased fluence

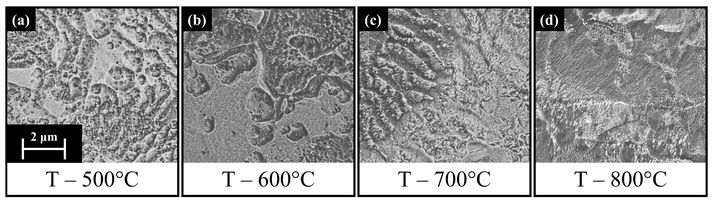

Figure 5: Results of the temperature scan with fluence of 3x10^19 He^+/cm^2 and 30 keV He^+ for all PCW samples. Different surface structures dominate at different temperatures (a) pitting (b) pitting (c) a mountainous structure and “grass” (d) “grass” only.

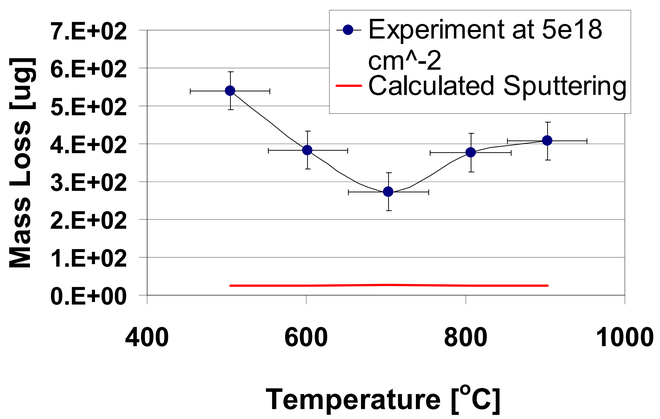

Figure 6: Temperature scan samples—no clear trend of mass loss with increasing temperature

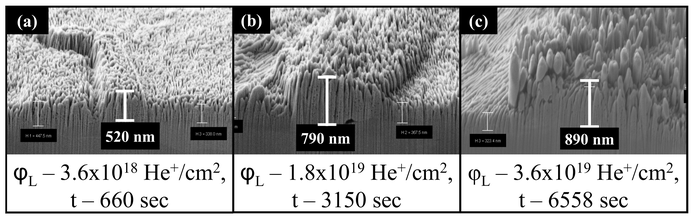

Figure 3: Focused ion beam cross-section analysis of PCW samples irradiated to different fluences with 30 keV He^+ at 900 °C.

4. Discussion

4.1 “Grass” Structure

Factors that contribute to growth of “grass” structure:

•Helium bubble movement
•Orientation dependence of sputtering yield

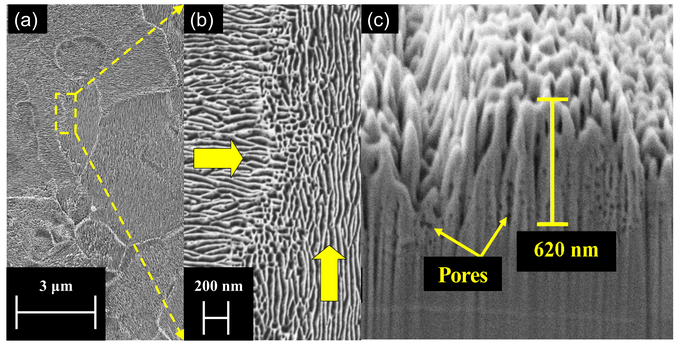

Figure 7: PCW implanted to 6x10^17 He^+/cm^2 at 900 °C (a) “grass” structure is distinct on each grain (b) close-up on the “grass” structure at a grain boundary (c) cross-section of the sample reveals sub-surface pores

4.2 Blisters

•Key factor: mono-energetic ions
•Unlikely that fusion reactors’ plasma facing components (PFCs) will form blisters
•No second generation of blisters was observed.

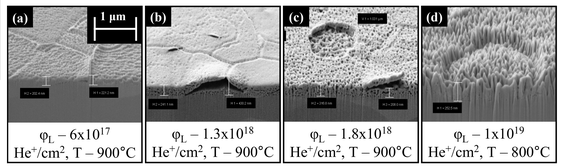

Figure 8: Progression from blisters to “grass” structure: (a) initial sub-surface bubbles form, (b) trapped gas raises blister cap, (c) blister cap ruptures or erodes completely, and (d) “grass” morphology overwhelms depression left by blisters.

4.3 Mass Loss

Table 1: Measured mass losses extrapolated for fusion reactor full power days (FPD).

PCW Specimen, 5x10^18 He^+/cm^2	HAPL (kg/FPD)	ITER (kg/FPD) *[400 s pulse]*
500°C	15±2	2.0±0.3
700°C	7±1	1.0±0.2
900°C	11±2	1.6±0.2

5. Conclusions

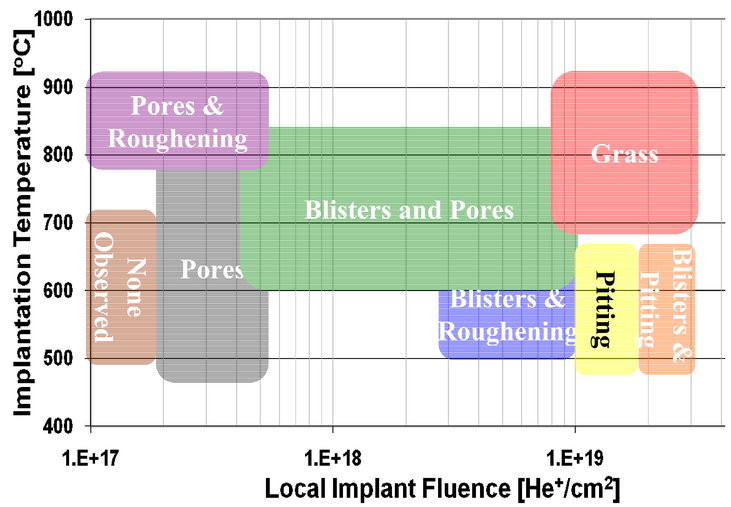

Figure 9: Simplified summary of the parameter regimes where different surface morphologies are observed.

•The angle of incidence of He bombardment of PCW greatly impacts the surface morphologies that develop.

•The grass structure is believed to be influenced by helium bubble movement and sputtering variation across grains.

•If fusion reactors experience mass loss near what was observed on the samples, it will make PFC lifetimes too short to be viable.