Helium exposure effects on tungsten surfaces: induced bubbles and roughness changes


Aix-Marseille Université, CNRS, PIIM UMR 7345, F-13397 Marseille, France
CEA, IRFM, 13108 Saint Paul-lez-Durance, France
Physics Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831-6372 USA
Aix-Marseille Université, CP2M, F-13397 Marseille, France
NINS, National Institute for Fusion Science, Toki, Gifu 509-5292, Japan
Department of Physics and Astronomy, Rutgers University, Piscataway, NJ08854, USA

celine.martin@univ-amu.fr

Because of its high melting temperature, high sputtering threshold energy, low hydrogen retention and acceptable induced radioactivity tungsten (W) is the material used for plasma facing components (PFCs) receiving highest fluxes in operating tokamaks (ASDEX-upgrade, JET-ILW, WEST) and will compose the ITER divertor. Under burning plasma W surfaces are simultaneously exposed to hydrogen isotope fuel and helium (He) ash and are exposed only to helium during the He operation phases in ITER and WEST. Unlike hydrogen, exposure to helium induces strong changes on the micro and nanostructure of the W surface (fuzz, bubbles, undulating surfaces[1-3]) significantly modifying their properties.

We report measurements of the surface topography changes together with the sub-surface He bubbles formation induced by He ion bombardment of tungsten. Polycrystalline W samples of various grades, some of which comply with the ITER tungsten grade specification, were exposed at T= 873-1273 K, for typical fluences of $10^{23}-10^{24}$ m$^{-2}$ and for low impact energies around the He sputtering energy threshold in the range 70-220 eV. Bombardments were carried out using a high-flux deceleration module and beam flux monitor at the ORNL MIRF, the linear plasma device PSI-2 and an RF plasma laboratory. Surface analyses were performed at the PIIM laboratory using electron microscopy techniques - scanning (SEM), transmission (TEM) on laminae cut by focused ion beam (FIB) and electron backscatter diffraction (EBSD) - and atomic force microscopy (AFM) if needed. At surface temperatures and beam fluences below the nanofuzz growth threshold, nano-wavy structures and pinholes are observed on individual grains, together with sub-surface bubbles. Those different topography structures were found to be strongly dependent on the pristine surface orientation W(100), W(111) or W(101). He bubble sizes and observed shapes were also found to be strongly dependent on the surface orientation after annealing of the exposed W. We discuss the correlation of the topography structure with the surface orientation and compare to the previous published results with the aim to deepen elementary processes of bubble formation and to uncover the dominant effects in the nanostructuring of exposed surfaces. For example, the dependence of He impact effects on crystal orientation or the diffusion of W atoms on surface following weak erosion should be addressed.