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Temperature dependent surface modification of tungsten exposed to high-flux low-energy helium ion irradiation

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ABSTRACT

Nuclear fusion is a great potential energy source that can provide a relatively safe and clean limitless supply of energy using hydrogen isotopes as fuel material. ITER (international thermonuclear experimental reactor) is the world first fusion reactor currently being built in France. Tungsten (W) is a prime candidate material as plasma facing component (PFC) due to its excellent mechanical properties, high melting point, and low erosion rate. However, W undergoes a severe surface morphology change when exposed to helium ion (He^+) bombardment under fusion conditions. It forms nanoscopic fiber-form structures, i.e., fuzz on the surface. Fuzz is brittle and can easily contaminate the plasma, and therefore preventing the fusion chain reaction. In this study, we report on the effect of temperature on the surface morphology evolution of W coatings under low energy He^+ ion irradiation, relevant to fusion conditions. Submicron thickness W films have been deposited on Si (100) at room temperature using RF sputtering deposition technique. Several samples were cut from the same wafer and exposed to 100 eV He^+ ions having a constant flux of 1.2×10^{21} ions m^{-2} s^{-1} (total fluence of 4.3×10^{24} ions m^{-2}) at several temperatures in the range of 1073 – 1273 K. During each ion irradiation experiments the applied sample temperature were constant throughout that experiment. Post ion-irradiation samples (including pristine) were characterized using field emission scanning electron microscopy (FE-SEM), X-ray photoelectric spectroscopy (XPS), and optical reflectivity measurements for monitoring the changes in surface morphology, chemical composition, and surface roughness/optical properties, respectively. Our analysis shows a sequential enhancement in W fuzz density, sharpness, and protrusions from the film surface, with increasing sample temperature, during helium ion irradiation. *Ex-situ* XPS study shows the evidence of W_2O_3 phase formation due to natural oxidation of W fuzz in the open atmosphere, for all irradiated samples. The study is significant in the understanding processes of fuzz formation on high-Z refractory metals for fusion applications. In addition, the observed W_2O_3 fuzz structure may have potential applications in solar power concentration technology and in water splitting for hydrogen production.

KEYWORDS

Nuclear Fusion, Ion Irradiation, Tungsten, Scanning Electron Microscopy (SEM), X-ray Photoelectron Spectroscopy (XPS), Optical Reflectivity.