§70. Correlation between Crystal Structure Change and Tritium Retention on Mixed-layer of First Wall

Okuno, K., Oya, Y., Kobayashi, M., Osuo, J., Suzuki, M., Hamada, A., Matsuoka, K., Kawasaki, K., Fujishima, T., Miyahara, Y. (Shizuoka Univ.), Matsuyama, M., Hatano, Y., Hara, M. (Toyama Univ.), Sagara, A.

i) Introduction

Tungsten is considered to be a candidate for plasma facing materials (PFM) in future fusion devices. During the plasma operations, carbon will be implanted into the surface of tungsten, and a tungsten-carbon (W-C) mixed layer will be formed on the surface of tungsten. It is well known that the W-C mixed layer induces higher hydrogen isotope retention, indicating that the elucidation of hydrogen isotope retention behaviors under energetic hydrogen isotope implantation in the carbon pre-implanted tungsten is quite important to estimate the fuel behaviors in PFM during the fusion reactor operation. In this study, the deuterium ion was implanted with various ion fluences into the carbon pre-implanted tungsten and correlation between recovery of irradiation damages and deuterium desorption behavior was studied.

ii) Experimental

Polycrystalline tungsten (10 mm $^{\varphi}$×0.5 mm^{t}) purchased from Allied material Co. was used. The samples were heated at 1173 K for 10 minutes under ultrahigh vacuum to remove the surface impurities and damages introduced during the polishing processes. After preheating, the 10 keV C^+ was implanted into tungsten with flux of 1.0×10^{17} C^+ m^{-2} s^{-1} and fluence of 1.0×10^{21} C^+ m^{-2}. Thereafter, the 3.0 keV D_2^+ implantation was performed with flux of 1.0×10^{18} D^+ m^{-2} s^{-1} and fluence of $(0.03\text{-}1.8) \times 10^{22}$ D^+ m^{-2}.

Thermal desorption spectroscopy (TDS) measurements were performed to evaluate deuterium retention after D_2^+ implantation. The chemical states of carbon and tungsten on the surface was evaluated by X-ray photoelectron spectroscopy (XPS). The Transmission Electron Microscopy (TEM) observation with Focused Ion Beam (FIB) was done at Kyushu University to understand depth profiles of microstructure and irradiation defects in tungsten. The Glow Discharge Optical Emission Spectroscopy (GD-OES) measurements were carried out at University of Toyama to obtain the depth profiles of deuterium in tungsten.

iii) Results and discussion

D_2 TDS spectra for C^+ pre-implanted tungsten consisted of three deuterium desorption stages, located at around 400 (Peak 1), 550 (Peak 2) and 650 K (Peak 3), which were attributed to the desorptions of deuterium adsorbed on the surface and trapped by dislocation loops (Peak 1), trapped by vacancies (Peak 2) and retained in the bulk of tungsten (Peak 3).

The retentions of deuterium adsorbed on the surface, trapped by dislocation loops and trapped by vacancies, namely Peaks 1 and 2, were increased with increasing the deuterium fluence. On the other hand, the retention of deuterium migrated into the bulk of tungsten was hardly found in lower deuterium fluence region less than 0.3×10^{22} D^+ m^{-2}. Figure shows the depth profiles of deuterium observed by GD-OES and chemical states of carbon by XPS for C^+ - D_2^+ sequential implanted tungsten. The TEM image of sample cross-section was also shown in this figure. It was found that deuterium was accumulated within the depth of 10 nm, where W-C bond was the major chemical state of carbon. The condensed damage was introduced in the W-C mixed layer by C^+ pre-implantation. Most of deuterium was trapped in W-C mixed layers. It was reported that the WC mixed layer played a diffusion barrier for deuterium [1], considering that deuterium would be trapped by irradiation defects in condensed damage regions.

In the C^+ - D_2^+ simultaneous implantation, deuterium will be retained in tungsten with formation of irradiation defects. It was predicted that the amount of available trapping site in W-C mixed layers were different from that in the C^+ pre-implanted tungsten, because deuterium trapping will be occurred before formation of diffusion barrier. Therefore, the hydrogen isotope retention behavior in C^+ - D_2^+ simultaneous implanted tungsten will be elucidated in the future work.

[1] T. Shimada et al., *J. Nucl. Mater,* 313 (2003) 204.

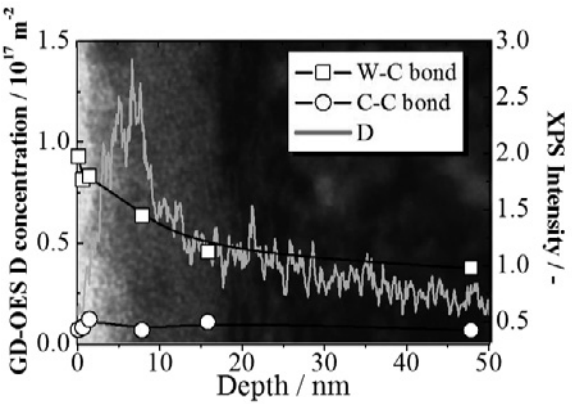

Fig Depth distributions of deuterium in D_2^+ fluence of 0.3×10^{22} D_2^+ m^{-2} and chemical states of C in C^+-D_2^+ sequential implantation, and TEM image in 5.0×10^{21} C^+ m^{-2}