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

Okuno, K., Oya, Y., Kobayashi, M., Kawasaki, K., Fujishima, T., Miyahara, Y., Uchimura, H., Taguchi, T., Toda, K., Miura, R. (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 (C) 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. Therefore, the elucidation of deuterium (D) behaviors under energetic D implantation in the carbon (C) pre-implanted tungsten is quite important to estimate the fuel behaviors in PFM during the fusion reactor operation. In this study, C^+ - D_2^+ sequential implantations with various C^+ implantation temperatures were performed to clarify the effect of W-C mixed layer formation on D retention behavior.

ii) Experimental

Polycrystalline tungsten (10 mm^{φ} × 0.5 mm^{t}) purchased from Allied material Co. was used. The samples were heated at 1173 K for 30 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} at room temperature and 673 K. 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 1.0×10^{22} D^+ m^{-2} at R.T. for both samples.

Thermal desorption spectroscopy (TDS) measurements were performed to evaluate the deuterium retention in samples after D_2^+ implantations. The chemical states of carbon and tungsten on the surface of samples were evaluated by X-ray photoelectron spectroscopy (XPS). The Transmission Electron Microscopy (TEM) observations were performed at Kyushu University to understand the microstructure and irradiation damages in tungsten.

iii) Results and discussion

Figure shows the D_2-TDS spectra for C^+ implanted samples at room temperature and 673 K. The D_2 desorption was observed at 300 - 700 K. These spectra were consisted of three D desorption stages, characterized by Peaks 1, 2 and 3, respectively. Peaks 1, 2 and 3 were attributed to desorption of D trapped by dislocation loops, trapped by vacancies and trapped by voids or vacancy clusters, respectively from previous studies [1,2]. Peaks 2 and 3 in the sample implanted with C^+ at 673 K were twice as large as that in the sample with C^+ implantation at R.T., although the D retention as Peak 1 was hardly increased. Void formations were observed in all samples and it was found that the large amount of void was formed by C^+ implantation at 673 K. In addition, the amount of carbon was decreased in the sample implanted with C^+ at 673 K compared to that in the sample implanted at R.T. It was considered that the carbon implanted into tungsten was retained in vacancy and the diffusion of vacancy and retention of hydrogen in vacancy were controlled by retention of carbon in vacancy. Therefore, the aggregation of vacancy and the deuterium trapping in vacancy and void were occurred significantly only in the sample implanted C^+ at 673 K due to decrease of the amount of carbon retained in the sample.

In the collaborative research in three years, it is considered that hydrogen isotope irradiated for tungsten is diffused into the bulk after saturation of trapping on surface. In addition, it is indicated that the W-C mixed layer formed by carbon irradiation controls hydrogen isotope diffusion to the bulk region of tungsten. The aggregation of vacancy and the deuterium trappings in vacancy and void are also controlled by carbon, indicating that the structure and chemical state of W-C mixed layer is affected on the hydrogen isotope retention behavior.

[1] H. Iwakiri *et al., J. Nucl Mater.,* 307 (2002) 135.
[2] O.V. Ogorodnikova *et al., J. Nucl Mater.,* 415 (2011) S661.

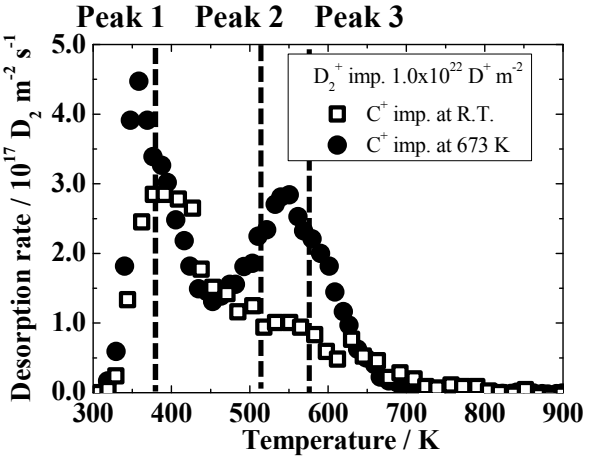

Fig. D_2-TDS spectra for C^+ implanted sample at room temperature and 673 K