§26. Accumulation of Impurity Carbon and Quantitative Evaluation of Sputtering Particles on PFMs

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1) Introduction

Tungsten (W) has been considered as a plasma facing material (PFM) in D-T fusion reactors due to its higher melting point and lower sputtering yield. During the plasma operation, W will be exposed to energetic particles including hydrogen isotopes, neutron and impurities like carbon (C), and various irradiation damages will be introduced, where large amount of hydrogen isotopes will be trapped. In addition, formation of W-C mixed layer which produced by energetic C suppresses the deuterium (D) diffusion. These facts indicate that hydrogen isotope behavior for such energetic particles irradiated W will be clearly different from that for un-damaged W. Therefore, it is important to evaluate the synergetic effect on D retention behavior for W under various damage profiles for the elucidation of the hydrogen isotope dynamics in PFMs. In this study, hydrogen isotope retention behavior in damaged W by energetic iron ion (Fe^{2+}) and C^+ implantation was evaluated.

2. Experimental

Polycrystalline W disk type samples (10 $mm^{\varphi} \times 0.5$ mm^{t}) purchased from A.L.M.T. Corp. Ltd were used. To remove impurities, these samples were preheated at 1173 K for 30 minutes under ultrahigh vacuum ($<10^{-6}$ Pa). 6 MeV Fe^{2+} implantation with the damage concentration of 0.01, 0.1, and 1 dpa (displacement per atom) was performed for these samples. Then, 10 keV C^+ implantation for these damaged samples and un-damaged W was performed with the ion fluence of 1.0×10^{20} - 1.0×10^{22} C^+ m^{-2}. Thereafter, 3 keV D_2^+ was implanted with the ion fluence of 1.0×10^{22} D^+ m^{-2}, and the D_2 desorption behaviors were evaluated by thermal desorption spectroscopy (TDS) measurements from room temperature up to 1173 K, with a heating rate of 0.5 K s^{-1}. In addition, to evaluate D_2 depth concentration for all sample, the Hydrogen Isotope Diffusion and Trapping (HIDT) simulation [1] was performed.

3. Results and Discussion

Fig. 1 shows the D_2 TDS spectra for Fe^{2+} - C^+ implantation and only C^+ implantation sample, and their simulation results. TDS spectra have consisted of three desorption peaks located at 400 K (Peak 1), 600 K (Peak 2) and 780 K (Peak 3) attributing to desorption of D adsorbed on the surface and trapped by dislocation loops, vacancies and voids, respectively [2, 3]. The D retentions for Fe^{2+} - C^+ implantation samples and only C^+ implantation sample as Peak 1 were almost same. On the other hands, the D retention as Peak 3 were increased as Fe^{2+} damage concentration was increased. Fig.2 shows the simulation results of D_2 depth distribution after D_2^+ implantation. These experimental and simulation results indicated that D was trapped by the dense dislocation loops introduced by C^+ implantation, and D retention behavior adsorbed from the surface was not controlled by Fe^{2+} implantation damage level. However, it was found that D was diffused toward the bulk, and the retention of D trapped by vacancies and voids in the bulk was increased as Fe^{2+} implantation damage concentration was increased.

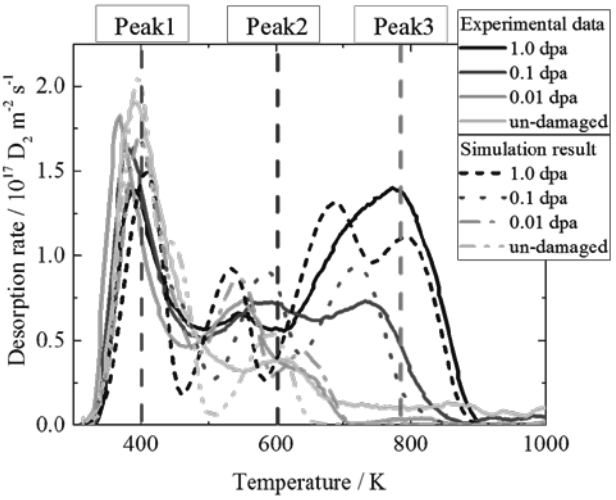

Fig. 1. The D_2 TDS spectra for Fe^{2+} - C^+ implantation samples, and the simulation results.

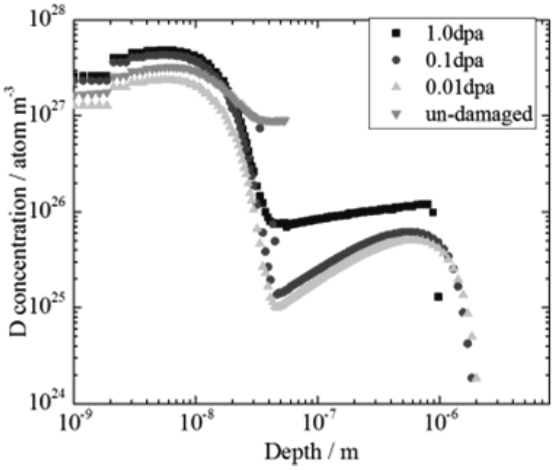

Fig. 2. The simulation results of D_2 depth concentration for each sample after D_2^+ implantation.

1) Y. Oya et al.: J. Nucl. Mater. **461** (2015) 336.
2) O. V. Ogorodnikova, et al.: J. Nucl. Mater. **469** (2003) 313.
3) G. N. Luo et al.: Fusion Eng. Des. **81** (2006) 975