

§21. Hydrogen Isotope Retention Behavior on the Surface of Metal-carbon Mixture Layer under Carbon, Hydrogen Isotopes and Helium Simultaneous Irradiation Circumstance

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i) Introduction

On the D-T fusion reactor, it is important to elucidate dynamics of hydrogen isotopes behaviors under simultaneous ions, such as carbon (C^+), deuterium (D_2^+) and helium (He^+) ions irradiation circumstance on the surface of plasma facing components. Therefore, clarification of hydrogen isotope retention behaviors with formation of carbon-metal mixed layer was required to simulate actual fusion environment. In this study, C^+ , D_2^+ and He^+ were implanted into tungsten to clarify hydrogen isotopes retention behaviors on the mixed layer under triple ions simultaneous irradiation circumstance. The deuterium retention behaviors and the dynamics of irradiation defects were investigated by thermal desorption spectroscopy (TDS) and transmission electron microscopy (TEM).

ii) Experimental procedures

In this study, C^+ energy dependence of simultaneous and sequential $C^+-D_2^+$ implantation and $C^+-D_2^+-He^+$ implantation on D retention were studied for the stress relieved tungsten. The 3 keV D^+ was implanted with the ion flux of $1.0 \times 10^{18} D^+ m^{-2} s^{-1}$ up to the ion fluence of $1.0 \times 10^{22} D^+ m^{-2}$. The C^+ energies were changed to be 5, 7, 10 keV for C^+ energy dependence experiment. In $C^+-D_2^+-He^+$ implantation, both flux ratio of C^+/D^+ and He^+/D^+ were fixed to be 0.2. The ion energies of C^+ and He^+ were, respectively, set to be 10 keV C^+ , and 3 keV He^+ to keep same implantation depth. TDS measurements were performed to elucidate D retention behavior affected by C^+ and/or He^+ simultaneous implantation effect and mixed layer formation, at a heating rate of $0.5 K s^{-1}$, from R.T. up to 1173 K. TEM observations were also performed to

understand the formation processes of irradiation defects and the correlation between irradiation defects and D retention.

iii) Results and discussion

Figure 1 shows D_2 TDS spectra for the 5 keV $C^+-3 keV D_2^+$ sequential and simultaneous implanted samples. These spectra consisted of three D_2 desorption stages at around 400, 550 and 650 K, which were attributed to the desorption stages of D adsorbed on the surface and/or trapped by dislocation loops (Peak 1), trapped by vacancies (Peak 2) and D retained in the bulk (Peak 3), respectively.^{1,2)} It was found that D retentions as Peak 1 were almost the same among these samples although C concentration during D_2^+ implantation on the sample surface is lower than that in the simultaneous implantation case, indicating that release of CDx by chemical sputtering³⁾ was occurred not only by D_2^+ implantation but also by C^+ implantation. Only in the case of $C^+-D_2^+$ simultaneous implantation, D retention for Peak 1 increased with increasing of C^+ energy, showing that the chemical sputtering cross-section of CDx would be affected by C^+ energy and release of CDx decreased with increasing C^+ energy.

The D_2 TDS spectra for various simultaneous ion implantation cases were compared in Fig. 2. It was found that the D retentions for $C^+-D_2^+$, $D_2^+-He^+$ and $C^+-D_2^+-He^+$ implanted samples were higher than that for D_2^+ implanted one. In TEM observation, showing that the large amounts of irradiation defects for $C^+-D_2^+$, $D_2^+-He^+$ and $C^+-D_2^+-He^+$ implanted samples were formed and He bubble formation for $D_2^+-He^+$ and $C^+-D_2^+-He^+$ implanted samples was also found, suggesting that the desorption of D at around 400 and 500 K were attributed to that of D trapped by irradiation defects and that at around 600 K was thought to be the desorption of D trapped by He bubble for $C^+-D_2^+-He^+$ implantation sample. In $C^+-D_2^+-He^+$ implanted sample, formation of defects and He bubble was remarkable even if the ion fluence was low, while D retentions were decreased compared to that in $D_2^+-He^+$ implanted one. It was suggested that enhancement of He bubble density and sputtering of W by C^+ implantation would cause the reduction of D retention.

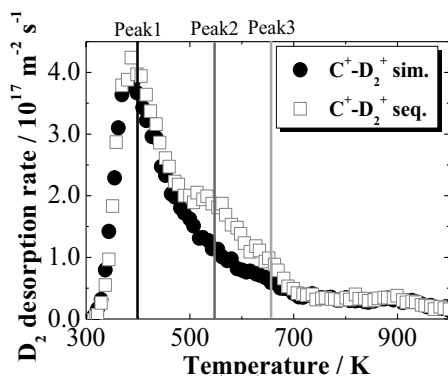


Fig. 1 TDS spectra for $C^+-D_2^+$ implantation with 5 keV C^+

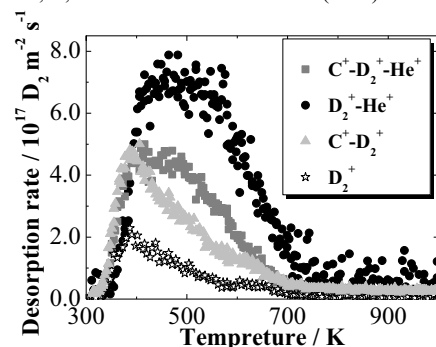


Fig. 2 TDS spectra for various simultaneous ion

- 1) Ogorodnikova, V, O. et al. : J. Nucl. Mater. 373 (2008) 254-258.
- 2) Eleveld, H. et al. : J. Nucl. Mater. 191 (1992) 433.
- 3) Bizyukov, A, I. et al. : J. Nucl. Mater. 390 (2009) 925