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種々の温度で高エネルギー鉄イオン照射したタングステンの重水素滞留挙動

Deuterium retention behavior of W irradiated with a high-energy Fe ion at various temperatures.

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Tungsten (W) is a primary candidate as plasma-facing materials because of its physical merits, like high melting point, low hydrogen solubility and high thermal conductivity. It is reported that neutron irradiation to W drastically enhances its hydrogen retention and make the hydrogen desorption temperatures higher compared to non-irradiated W [1]. In order to understand the mechanisms of retention behavior in n-irradiated W, the investigation on the effects of irradiation damages caused by high-energy ion implantation on hydrogen retention would be helpful. In the present study, deuterium (D) retention behavior in W irradiated with a 6 MeV Fe ion was investigated.

The sample temperatures during Fe ion irradiation and irradiation damages were 573-1173 K and 0.1-0.3 dpa, respectively. D plasma exposures to these samples were performed with tritium plasma experiment (TPE) apparatus in INL. Incident energy of D ion and sample temperature during exposures were ~100eV and 673 K, respectively. The plasma flux was［0.9-1.2］x10^{22} D $m^{-2}s^{-1}$, and D fluence was 5x10^{25} D m^{-2}. After the plasma exposures, desorption behavior of the retained D was investigated with thermal desorption spectroscopy (TDS). In the TDS analysis, samples were heated from a room temperature to 1173 K with a heating rate of 0.167 K/s (10 K/min).

TDS spectra of D_2 for W irradiated with Fe ion at 573-1173 K is shown in Fig.1. The damage level was the same at 0.3 displacements per atom (dpa) for all samples. Although the desorption temperatures of D_2 were similar to each other, the desorption rate at the peak for W irradiated at 573 K was approximately twice as high compared to other samples. TDS spectra of D_2 for W with 0.1 and 0.3 dpa are shown in Fig.2. Only the spectrum for W irradiated at 1173 K had a different shape than other spectra. Hydrogen retention, in general, tends to be increased by irradiation damage. However, in this study, D retention in some of Fe-irradiated W were almost the same as undamaged W. One of the possible reasons for this is the annihilation of irradiation defects during Fe ion irradiation at high irradiation temperatures. Another possible reason is plastic deformation due to deuterium super saturation [2,3]. During exposure to low-energy, high-flux D plasma, the D concentration in the implantation zone greatly exceeds the solubility limit and stresses the matrix lattice until plastic deformation occurs to alleviate these tensions [2,3]. If these effects became dominant for hydrogen retention, the effects of Fe irradiation could be negligible. The results indicate that the effects of irradiation damage caused by high energy ion on hydrogen retention can be diminished depending on irradiation and plasma exposure conditions.

[1] Y.Hatano et al. Materials Transactions, 54 (2013) 437-441.
[2] J.B. Condon, T. Schober, J. Nucl. Mater., 207 (1993) 1.
[3] V.Kh. Alimov et al., J. Nucl. Mater., 420 (2012) 519–524

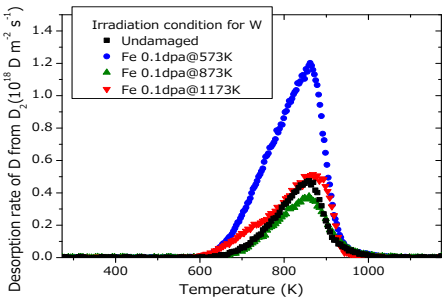

Figure 1　TDS spectra of D_2 for W irradiated Fe at various temperatures.

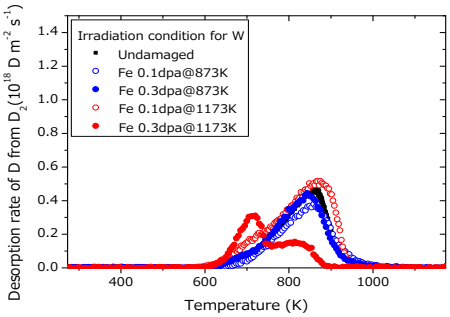

Figure 2　TDS spectra of D_2 for Fe-irradiated W with different dpa.