§21. Study on Hydrogen Retention and Hydrogen Recycling in Radiation Damaged Tungsten

Watanabe, H. (RIAM, Kyushu Univ.),
Sakamoto, M. (Univ. Tsukuba),
Tokitani, M.

Understanding of plasma-wall interaction is one of the most important issues for stable steady state operation of fusion plasma. From the view point of particle control and safety (i.e. tritium inventory), especially, study of hydrogen isotope retention in the plasma facing materials is indispensable. In this study, we have focused on a tungsten material which has excellent properties such as high melting temperature, high thermal conductivity, low sputtering yield and low hydrogen isotope retention as a plasma facing material. However, such properties should change during the steady state operation due to the plasma-wall interaction. As for the hydrogen isotope retention, it is well known that the retention increases due to the neutron irradiation, but there is less database of neutron irradiation effects on the hydrogen isotope retention. In this study, heavy ion (2.4 MeV Cu^{2+}) irradiation to the recrystallized tungsten (RC-W) is done as a surrogate irradiation of neutron.

Before the heavy ion irradiation to the RC-W sample, we investigated retention properties of the RC-W without the irradiation compared to those of ITER grade tungsten (IG-W). Each sample was exposed to low energy and high flux deuterium plasma in the compact PWI simulator APSEDAS. The ion energy was 33 eV, the flux was ~1.6 x 10^{21} D/m^{2}s and the fluence was ~9 x 10^{24} D/m^2. After the plasma exposure, the tungsten sample was transferred in a thermal desorption spectroscopy (TDS) apparatus and then thermal desorption spectra were measured. Figure 1 shows thermal desorption spectra of RC-W and IG-W. Noted that the HD (m/e=3) desorption signal which is observed above 900 K is attributed to influence of large increase in H_2 (m/e=2) desorption from vacuum components, indicating that the signal above 900 K does not mean the actual HD desorption. The desorption rate of D_2 from the RC-W sample is one order magnitude larger than that of the IG-W. The deuterium retention in RC-W and IG-W samples are ~3 x 10^{19} D/m^2 and ~3 x 10^{20} D/m^2, respectively, indicating that the residual strain in the RC-W is considerably low.

Figure 2 shows estimated depth profiles of displacement damage and implanted ion range distribution in W calculated using the SRIM code. The peak damage region of 400 nm and the displacement damage distribution up to approximately 600 nm were calculated using the SRIM code with displacement energy of 55 eV. In another W sample with 2.4 MeV Cu^{2+} ion irradiation, high density of small interstitial typed dislocation loops and also nano-voids due to cascade collisions were detected by TEM observation [1]. The RC-W sample with 2.4 MeV Cu^{2+} ion irradiation (2 dpa) was also exposed to the deuterium plasma in APSEDAS and the deuterium retention property was measured by TDS. In this plasma exposure, ion energy was ~27 eV, the flux was ~1.5 x 10^{21} D/m^{2}s and the fluence was ~1 x 10^{25} D/m^2. The D retention in the RC-W sample with heavy ion irradiation was 6 x 10^{20} m^{-2}, which is about 20 times higher than that of the RC-W sample without the ion irradiation, indicating a significant effect of the radiation damage in the tungsten surface on the retention property.

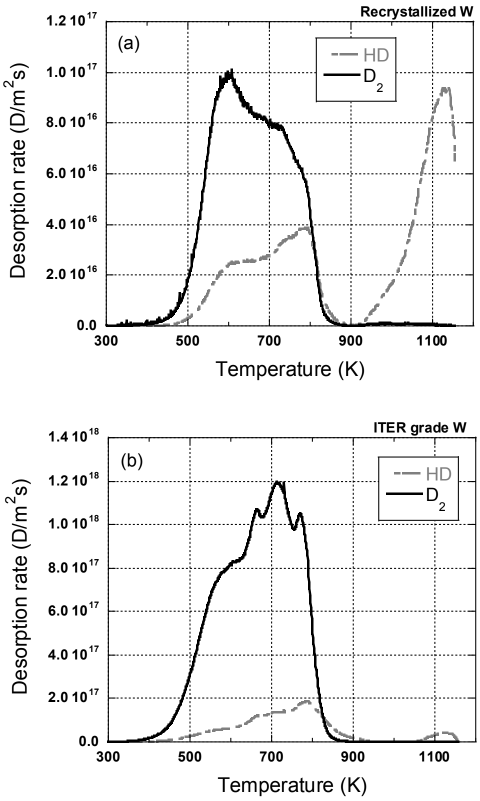

Fig. 1 Thermal desorption spectra of (a) recrystallized W and (b) ITER grade W.

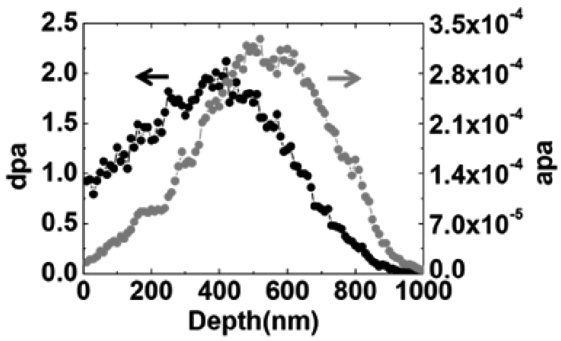

Fig. 2 Estimated depth profiles of displacement damage and implanted ion range distribution in W calculated using the SRIM code. [1]

1) H. Watanabe, N. Futagami, S.Naitou, N.Yoshida: J. Nucl. Materials **455** (2014) 51-55.