§78. Mechanism Underlying Trapping of Hydrogen Isotopes in Neutron-irradiated Plasma Facing Materials

Hatano, Y., Alimov, V.Kh., Nozaki, T. (Univ. Toyama), Kurishita, H., Nagai, Y., Toyama, T., Hatakeyama, M., Hasegawa, A., Nogami, S., Fukuda, M. (Tohoku Univ.), Oya, Y. (Shizuoka Univ.), Sato, K. (Kyoto Univ.), Ueda, Y. (Osaka Univ.), Atsumi, H. (Kinki Univ.), Muroga, T., Nagasaka, T., Kato, D.

Understanding of tritium (T) behavior (diffusion, trapping, desorption, etc.) in neutron-irradiated plasma facing materials (PFMs) is indispensable for evaluation of tritium mass balance and assessing safety margins of fusion reactors. Tungsten (W) has been recognized as a primary candidate of PFMs, and the effects of neutron irradiation on T behaviors have been examined in the Japan–US joint research project TITAN.[1–3] In this project, W specimens are irradiated with neutrons in the High Flux Isotope Reactor at Oak Ridge National Laboratory, and the retention of hydrogen isotopes is examined in Idaho National Laboratory using a linear plasma machine called Tritium Plasma Experiment (TPE).[1-3] The objective of this work is to get better understating of the mechanisms underlying hydrogen isotope trapping in irradiated W through characterizations of defects in the W specimens prepared in the TITAN project, ion-irradiation experiments, and computer simulation. In FY2012, the effects of Re on deuterium (D) retention was examined because neutron irradiation results in not only formation of radiation defects but also that of transmutation elements such as Re and Os. The irradiation effects of neutrons were simulated by 20 MeV W ions.

Specimens used were plates of W–Re alloy, in which the concentration of Re was 4.6 mass%. This specimen is hereafter denoted as W–5Re alloy. For comparison, plates of ITER-grade W and recrystallized W (RX-W) were also used as specimens. These specimens were irradiated with 20 MeV W ions to 0.5 dpa at room temperature and 873 K. Damage profiles were evaluated using the SRIM2008 program. The displacement threshold energy of W was set to 90 eV.The irradiated specimens were exposed to D_2 gas at 100 kPa and 673–973 K. Duration of exposure was 36 ks (10 h) at 673 K, and 10.8 ks (3 h) at 773 and 873 K. The concentration of trapped D was examined by nuclear reaction analysis (NRA).

Fig. 1 shows depth profiles of D and damage profile in the W-5Re alloy irradiated at room temperature. The damage level took the maximum value at the depth of 1.4 μm, and the damaged zone extended up to ~2 μm. Deuterium was clearly enriched in the damaged zone due to the trapping effects of radiation damages. The D concentration in the damaged zone decreased with increase in the temperature of exposure to D_2 gas. Such reduction in D concentration was ascribed to decrease in occupation probability of traps with increase in temperature. Similar enrichment of D in the damaged zone and reduction of D concentration with increase in temperature were observed for all specimens examined in the present study.

The D concentration at the damage peak is plotted in Fig. 2 as a function of the temperature of exposure to D_2 gas. Since no significant difference was observed between ITER-grade W and RX-W, only the results of W–5Re alloy and ITER-grade W are shown. The D concentration in the specimens irradiated at 873 K was lower than the values for the specimens damaged at room temperature. This observation indicated that a part of radiation damages was recovered during the irradiation at 873 K. At the same irradiation temperature, D concentration in W–5Re alloy was lower than that in ITER-grade W. In other words, Re has preferable effects from the viewpoints of T inventory. Further investigation is required to understand the mechanisms underlying the reduction in D retention by Re.

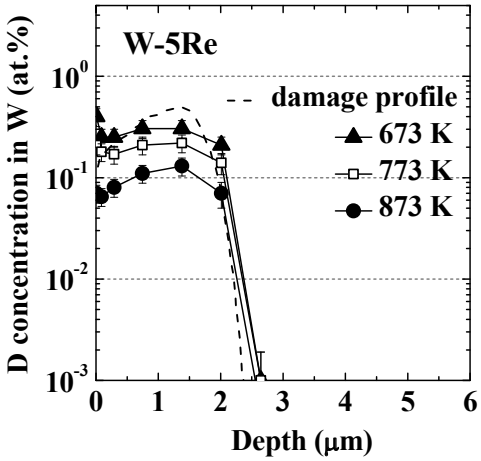

Fig. 1 Depth profiles of D and damage profile in W–5Re alloy irradiated with W ions at room temperature and exposed to D_2 gas at temperatures indicated in the figure.

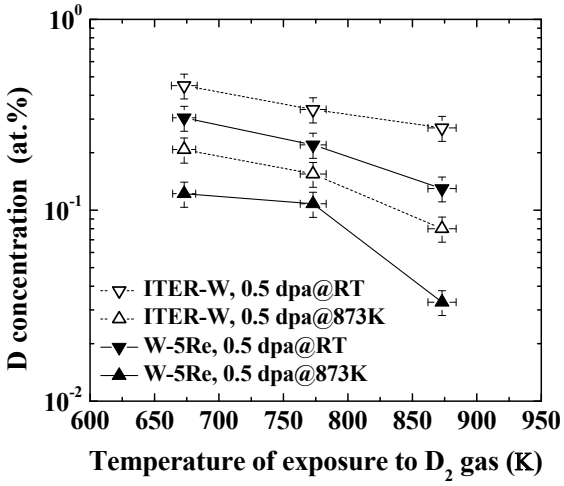

Fig. 2 Deuterium concentration at the damage peak in W–5Re alloy and ITER-grade W.

1) Hatano Y. et al.: Mater. Trans. **54** (2013) 437.
2) Hatano Y. et al.: Nucl. Fusion **53** (2013) 073006.
3) Hatano Y. et al.: J. Nucl. Mater., in press, doi:10.1016/j.jnucmat.2013.01.018.