§44. Study on Hydrogen Behavior and Surface Modification of Tungsten Plasma Facing Materials

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It is of importance to clarify phenomena of implantation, retention, diffusion and permeation of tritium on surface of the armor materials of the first wall/blanket and the divertor from a viewpoint of precise control of fuel particles, reduction of tritium inventory and safe waste management of materials contaminated with tritium. In addition, it is well known that re-deposited layer, which includes the first wall components emitted by sputtering and residual gases such as oxygen, is formed. On the other hand, tungsten would be used as armor material of the first wall and divetor in DEMO reactor. Therefore, clarification of behavior of tritium on surface exposed by plasma in all metallic first wall and divertor needs to be made. In addition, the first wall will be exposed by particles such as hydrogen isotopes, helium (He) and high energy electrons. In the present work, investigation of surface modification and material degradation by plasma exposure and electron/ion beam irradiation on plasma facing material such as W has been carried out to gain fundamental data for development of the blanket of the fusion device. In this fiscal year, tritium (T) exposure experiments on samples which were exposed by plasma discharges in QUEST, Kyushu University and 10 MeV electrons have been carried out using a T exposure device at Toyama university. In addition, Hydrogen (H) retention of W, which was irradiated by helium (He) ions, and the effect of stress on this have been investigated. In this manuscript, the result of the hydrogen (H) retention change of W by He irradiation and stress application will be reported [1].

W small specimens were fabricated from ITER grade W. Heat treatment for the specimens was conducted at 2073 K for 1 h. Grain size is about 50 μm. One side of central area were irradiated with 10 keV helium ions at RT up to the fluence of 5×10^{21} ions m^{-2} using an ion gun equipped with an ion selector. Tensile tests were performed at 1073 K at a strain rate of 2×10^{-4} s^{-1}. Specimens were tested to plastically strained to 2%, 5%, 10%, 20%. After the tensile test, surface modification before and after the tensile test plastically strained to 2%, 5%, 10% and 20% was examined with a field emission type scanning electron microscope (FE-SEM). Quantitative analyses of depth profiles of composition and the implanted He and H in W specimen before and after the tensile tests were carried out by means of Rutherford back-scattering spectrometry (RBS) and elastic recoil detection (ERD). Depth profile of He was also measured by using an $^{16}O^{4+}$ analyzing beam ERD technique with an energy of 4.0 MeV. The incident angle of the analyzing beam was 72° from the surface normal to the specimen. The scattered ^{16}O atoms were detected with the RBS detector placed at an angle of 170° to the incidence direction. The recoiled He and H atoms were detected by the ERD detector at an angle of 30° to the analyzing beam direction. An Al film 4 μm thick was placed in front of the ERD detector to absorb the O ions scattered from the specimen surface. Quantitative analyses using a standard sample have been carried to evaluate amount of He.

Figure 1 shows depth profiles of He and H before and after He irradiation. It can be seen that H adsorbed on the surface before the He irradiation. After the He irradiation, He is detected and amount of H on the surface increases. The increase of amount of H is considered to be caused by damage such as He bubble and defects formation due He irradiation. In addition, the figure shows that He diffuses deeper area than that of the range comparing with the depth profile of APA. After the stress was applied, the amount of He decreases with increasing plastic strain. This indicates that He releases by application of the tensile stress and plastic strain. Changes of the He retention by tensile stress is considered to be due to the formation and breaking of blisters, surface exfoliation, crack formation and movement of dislocations. On the other hand, the amount of hydrogen became to be half at plastic strain of 2%. After that, the amount of hydrogen was not changed up to plastic strain of 20% and existed on the near surface of W.

[1] K. Tokunaga, H. Osaki, H. Kurishita, S. Matsuo, S. Nagata, B. Tsuchiya, M. Tokitani,K. Araki, A. Kawaguchi, T. Fujiwara, M. Hasegawa, K. Nakamura, Effect of low energy helium irradiation on mechanical properties of tungsten, 17 th International Conference on Fusion reactor materials, October 11 th – 16 th, 2015, Eurogress Aahen, Germany

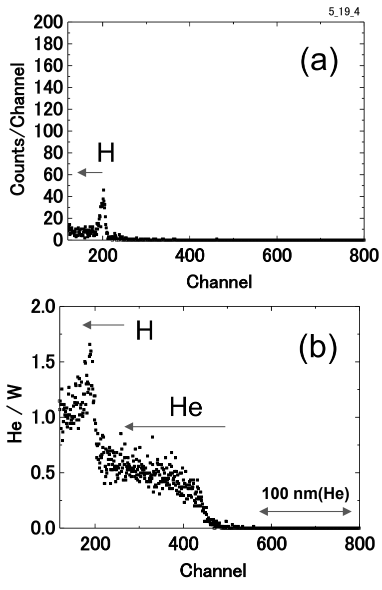

Fig.1 Depth profiles measured of Hydrogen (H) and helium (He) measured by RBS-ERD ((a):Before helium irradiation, (b)After helium irradiation). Scale of vertical axis of 200 in (a) is corresponding to 2.0 in (b).