§96. Effects of Plasma Exposure on Hydrogen Isotope Retention by 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 the 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 the present work, tritium exposure experiments have been carried out for long term installed samples on first wall in spherical tokamak QUEST, which is an all metallic first wall device.

Samples have been installed on vacuum chamber of spherical tokamak QUEST at Kyushu University. The vacuum vessel, and an armor of divertor and center stack of QUEST are made of SUS316L and tungsten, respectively. After the plasma discharge experiments, the samples have been examined using XPS, RBS and ERD. In addition, tritium exposure experiments have been carried out using a tritium (T) exposure device at University of Toyama. Pressure of the T gas was 1.3 kPa and T exposure was kept for 4 h in all examinations. T concentration in the gas was about 5 %. After thermal exposure to T gas, T amount retained in surface layers of the sample was evaluated by β-ray-induced X-ray spectrometry (BIXS) and imaging plate (IP) measurements. In this fiscal year, T exposure experiments on sample which was exposed by 9th cycle (from 2012/11 to 2013/3) under the condition which temperatures of pre-heating and T exposures were 400 ºC and 350 ºC, respectively have been also performed.

XPS analyses showed that the re-deposited layer was formed on SUS316L and and main composition was Fe, O, W and Cr. Fe and Cr are considered to be sputtered on the vacuum vessel made by SUS316L. On the other hand, W is considered to be emitted from the divertor armor, the center stack and W protector. In addition, O, which is residual gas, was co-deposited in the re-deposited layer. H is also detected on the W surface by ERD analyses and is considered to be also co- deposited in the re-deposited layer. The thickness of the re-deposited layer is thinner than that of the 3rd cycle which main composition was C, and 6 times thicker than that of the 7th cycle, which main composition was Fe. These composition and thickness of the re-deposited layers are considered to be reflected the plasma parameter and the surface condition of the plasma facing components and the vacuum vessel.

Figure 1 shows the result of IP measurement of the SUS316L and W which were installed in the 9th cycle under the condition which temperatures of pre-heating and T exposures were 400 ºC and 350 ºC, respectively. IP measurement after the T exposure indicated that amount of T on SUS316L and W was 7 and 11.3 times higher than that of non-exposure sample, respectively. On the other hand, T in the area of SUS316L and W which was sputtered by Ar for XPS analyses was 2.1 and 3.7 times higher than that of non-exposure sample, respectively. These results indicate that the formation of the re-deposited layer enhances T retention on the surface area, and radiation damage and surface modification by Ar sputtering on SUS316L and W surfaces also increases T retention.

In addition, IP measurement after 7 days from the T exposure indicated that amount of T on SUS316L and W was 1.0 and 0.77 times higher than that of after the T exposure, respectively. On the other hand, T in the area of SUS316L and W which was sputtered by Ar for XPS analyses after 7 days from the T exposure was 0.91 and 0.73 times higher than that of after the T exposure, respectively. These T decreases are considered to be due to the isotope exchange reaction and be influenced by property, microstructure and composition of the re-deposited layer.

BIXS measurement of SUS316 and W after the exposure of the plasma which temperatures of pre-heating and T exposures were 400 ºC and 350 ºC, respectively showed that character X-rays peaks from Fe and Cr in SUS316L and W, in addition to Ar(Kα) peak, originated from β ray on T near the surfaces detected. In addition, bremsstrahlung X ray originated from T which exists in deeper area of SUS316 and W was also detected. These results mean that T diffused to the deeper area from the re-deposited area to deeper area of the samples.

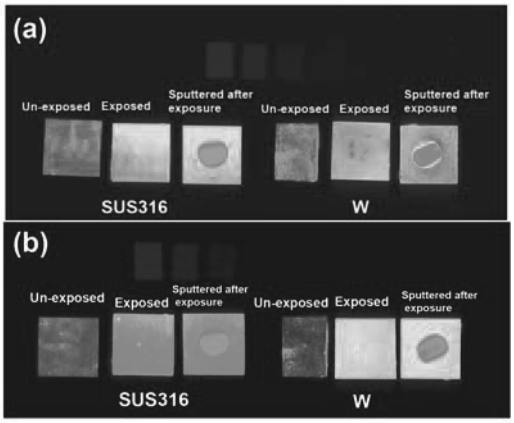

Fig. 1. Tritium images of SUS316L and W samples exposed to T gas which temperatures of pre-heating and T exposures were 400 ºC and 350 ºC, respectively. (a)After the T exposure and (b) After 7 days from T exposure