§28. Study on Hydrogen Isotope and Helium Behavior in Reduced Activation Ferritic/martensitic Steel during Mixed Plasma Irradiations

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Understanding of hydrogen retention/desorption behavior of plasma facing materials is one of the urgent issue from the point of view of tritium safety and fuel hydrogen recycling. In fusion devices, not only hydrogen particle but also helium particles are implanted into the plasma-facing materials. Therefore, the effect of helium implantation on hydrogen retention/desorption behavior is needed to be investigated. Reduced activation ferritic-martensitic steel, F82H, is a candidate for plasma-facing material. In this study, F82H were irradiated by a mixed plasma of hydrogen and helium using the Vehicle-1 device in NIFS and the retention/desorption behavior of hydrogen were investigated with thermal desorption spectroscopy (TDS).

Before the plasma irradiation, the F82H samples were degassed in a vacuum at 873 K for 45 min. The size of the samples was 10 mm x10 mm x 1 mm. Three types of plasma irradiation were conducted: only hydrogen irradiation, hydrogen plasma irradiation following helium ion irradiation and irradiation of mixture plasma of hydrogen and helium. Table 1 shows the plasma ion fluence and a partial pressure during the irradiation. A bias voltage of minus 100 V was applied to the samples to attract plasma ions and the irradiation was conducted for 30 min. During the plasma irradiation, the sample temperature was in the range from 540 K to 580 K. After the irradiation, the amount of retained hydrogen and hydrogen desorption behavior were studied with TDS. During the TDS analysis, the samples were heated up to 873 K with a heating rate of 0.5 K/s. The microstructure of the irradiated F82H samples was observed by TEM.

Figure 1 shows the amount of retained hydrogen after each plasma exposure. In the case of hydrogen plasma exposure following helium plasma irradiation, irradiation defects and helium bubbles would be formed at the surface after the helium plasma irradiation, which can act as a trap site for hydrogen implanted after the helium plasma irradiation. This would be a reason for the increase in hydrogen retention.

The amount of retained hydrogen was largest in the case of a mixture plasma irradiation. In this case, a part of hydrogen retained in the material could be knocked on deep into the bulk by the collision with the succeeding implanted helium ions. This result indicates that helium ions simultaneously implanted with hydrogen greatly affects the hydrogen retention behavior.

In the TEM observation, the F82H samples irradiated with a mixture of hydrogen and helium shows as many helium bubbles as the samples irradiated only with helium plasma, although the fluence of helium in the mixture plasma case was much smaller than that of only helium irradiation case, as shown in table.1.

These results show that a little amount of helium ion contained in hydrogen plasma significantly affects the hydrogen retention behavior and micro structure in F82H.

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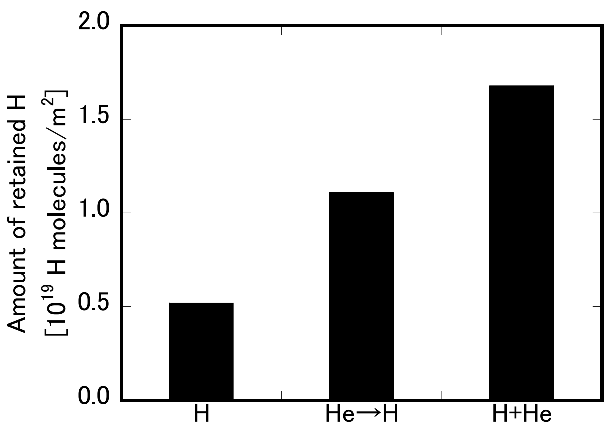

Figure 1 Amount of retained hydrogen after each exposure case.

Table.1 Fluences of hydrogen and helium ions and partial gas pressure during plasma exposure for each irradiation case.

	Hydrogen fluence [10^{23} m^{-2}]	Helium fluence [10^{22} m^{-2}]	Partial pressure during plasma exposure (Hydrogen/Helium)
Hydrogen plasma exposure	3.0	-	0.3
Hydrogen plasma exposure followed by helium plasma exposure	2.3	9.9	0.3/0.3
Exposure to mixture of hydrogen and helium ions	2.3	0.1	0.15/0.15