§10. Synergistic Effects between Helium and Deuterium on Gas De-trapping in Plasma Facing Material

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Low activation ferritic steel, which has been developed as the structure material of the blanket in the demo reactor, has superior properties such as low activation, good heat conductivity and good mechanical and size stabilities as fusion materials. In the present work, synergistic effect of both helium and deuterium in model alloy of ferritic steel (Fe-9Cr) were studied by thermal desorption spectrometry (TDS).

Fe-9Cr specimens used in the present work were prepared by arc melting method. The specimens were pre-irradiated with 8keV-He^+ at room temperature, and then irradiated with 8keV-D_2^+. After implantation, thermal desorption of D_2 and He under heating with a ramping rate of 1 K/s was measured with high resolution quadruple mass spectrometer (HR-QMS).

Fig. 1 shows thermal desorption spectra of deuterium injected in the specimens with the pre-irradiations of 8keV-He^+ at room temperature for doses ranging from 1.0×10^{20} He^+/m^2 to 1.0×10^{22} He^+/m^2. Deuterium ion irradiation was performed subsequently at room temperature up to 1×10^{21} D_2^+/m^2. Desorption of deuterium from the sample without pre-irradiation of helium is also shown in the figure for comparison. Majority of deuterium is desorbed between 350 K and 450 K for the non pre-irradiation case, while desorption stage for helium pre-irradiated specimens were formed between 350 K and 550 K. The amount of desorbed deuterium increase with increasing helium dose, and it saturates above 1.0×10^{21} He^+/m^2.

Fig. 2 shows thermal desorption spectra of helium from Fe-9Cr pre-irradiated with 8keV-He^+ to doses of 1.0×10^{20} He^+/m^2 with or without 8keV-D_2^+ irradiation to dose of 1.0×10^{21} D_2^+/m^2. For the deuterium irradiated specimen, the helium desorption peak were shifted to higher temperature side and the retention of helium decreased about 30%.

Pre-irradiation with helium ions caused remarkable effects on the trapping of injected deuterium. Most of the injected deuterium is desorbed between 350K and 450K for the case without helium pre-irradiation, while additional large desorption occurs above 450K for the helium pre-irradiation case. Amount of deuterium trapped at the sites increases with increasing dose of helium and deuterium. For example, total amount of the trapped deuterium for irradiations of $1.0\text{x}10^{21}He/m^2$ and $1.0\text{x}10^{21}D_2/m^2$ is $5.4\text{x}10^{19}D_2/m^2$, which is more than eight times higher than that of no helium pre-irradiation case. According to the TEM observation, dense small He bubbles are formed by the He pre-irradiation. One of the possible trapping site for the desorption above 450K is the stress field around the high-pressure helium bubbles.

Desorption property of trapped helium is also affected by the deuterium irradiation. As shown in Fig. 2, about 30% of the retained helium was reduced by the deuterium irradiation to dose of 1×10^{21} D_2^+/m^2. Since erosion of sputtering is about 1nm, this phenomenon cannot be attributed to the sputtering. Therefore, it is thought that the helium atoms were flipped to the deuterium directly, and dissociated from the surface. The remainders of the helium atoms are probably contained in more stable bubbles that desorption peak were shifted to higher temperature side.

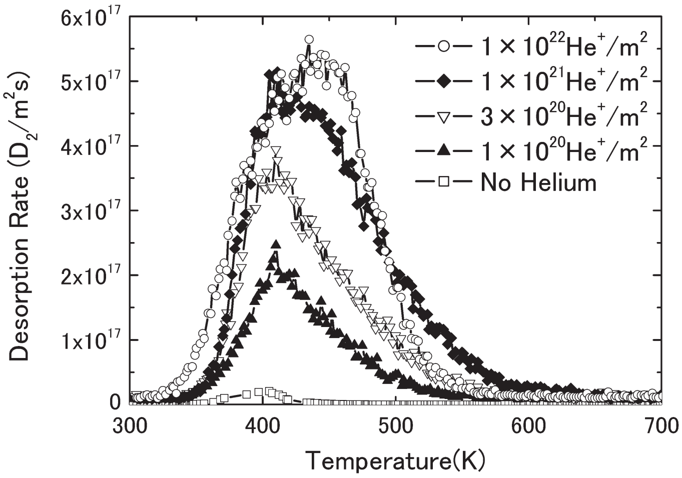

Fig.1 Thermal desorption spectra of deuterium injected in the Fe-9Cr with the pre-irradiations of 8keV-He^+ at room temperature for doses ranging from 1.0×10^{20} He^+/m^2 to 1.0×10^{22} He^+/m^2.

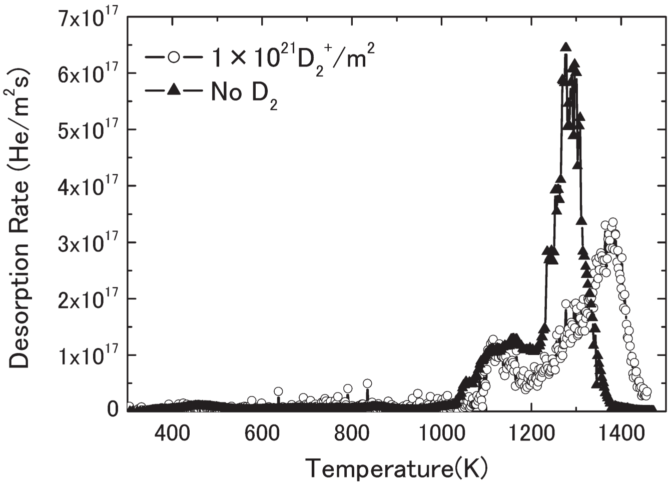

Fig.2 Thermal desorption spectra of helium from Fe-9Cr pre-irradiated with 8keV-He^+ to doses of 1.0×10^{20} He^+/m^2 with or without 8keV-D_2^+ irradiation to dose of 1×10^{21} D_2^+/m^2.