§39. Synergistic Effects between Helium and Deuterium on Gas Detrapping in F82H

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Radiation damage in metals by helium ions is remarkable due its interaction with lattice defects. It is expected, therefore, that co-bombardment of helium with hydrogen isotope in fusion environment may affect not only material properties but also the behavior of hydrogen isotopes in the plasma facing materials.

Reduced activation ferritic/martensitic steel F82H is one of a candidate alloys for the first wall of fusion reactors as well as for the beam window of spallation target for ADS. In this study, trapping behavior of deuterium in F82H was studied following helium and/or deuterium irradiations by means of thermal desorption spectrometry (TDS) and microstructural observation by TEM.

F82H ferritic/martensitic steel used in this study was IEA-heat 4-20 prepared for Japanese fusion reactor material program. The specimens with a dimension of 6×10 mm were mechanically cut to the thickness of around 2mm. Then the surfaces of the specimens were mechanically polished up to buff polishing with 0.03μm colloidal silica for low energy ion irradiations.

Low energy helium irradiations and following deuterium irradiations were performed at Research Institute for Applied Mechanics (RIAM), Kyushu University. After the irradiations, thermal desorption of D_2 and He under heating with a ramping rate of 1 K/s were measured with high resolution quadruple mass spectrometer. At the same time, the samples for the microstructural study by TEM were prepared using focused ion beam system (FIB) from the same specimens.

Fig. 1 shows the microstructures of as-received and re-tempered specimens irradiated with 5keV He^+ at 600 ºC. Helium bubbles are densely formed near the surface of the specimens. If all implanted deuterium was trapped inside of these helium bubbles, deuterium desorption peak should appeared in the higher temperature region which corresponds to that of the helium desorption peak, which is above 1000K where stagnant helium bubbles at lower temperature become mobile. Therefore, the result indicates that the implanted deuterium was trapped in some other weaker trapping sites, which expected to be the surrounding of highly pressurized helium bubbles.

These types of peak shift on hydrogen gas release behavior for high energy proton irradiated F82H alloy was also seen on the former studies on gas release measurement and microstructural investigation of STIP irradiated materials. According to these studies, the desorption stage which should be attributed to the release of hydrogen gases from helium babbles appears more clearly on the specimens irradiated to 20.3dpa at around 400ºC where formation of high-density small helium bubbles occurs, compared to that irradiated to the lower dose of 10dpa at around 100ºC where no visible helium bubble formation was observed, which consequently appears as a peak shift. In addition, the same types of deuterium release behavior are also observed on helium irradiated specimens at relatively higher energy in the present work.

Fig.2 shows the deuterium desorption spectra from the specimen irradiated with 1MeV He^+ at 400ºC followed by D_2^+ irradiation at RT with the energy of 650keV. The deuterium desorption spectrum from the specimen with only deuterium irradiation is also shown for comparison. The peak shift of about 50K and the peak broadening to higher temperature is clearly observed for this case. The peak shift can also be explained by the release of deuterium trapped by the surroundings of helium bubbles, and the broadening is the result of migration from deeper region of the specimen, since the peak region for helium bubble formation in this case is about 1μm deep from the surface according to microstructural observations.

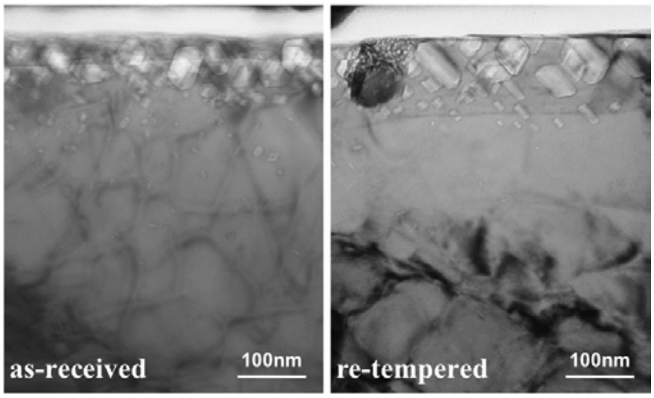

Fig. 1. The microstructures of as-received and re-tempered specimens irradiated with 5keV He^+ at 600 ºC.

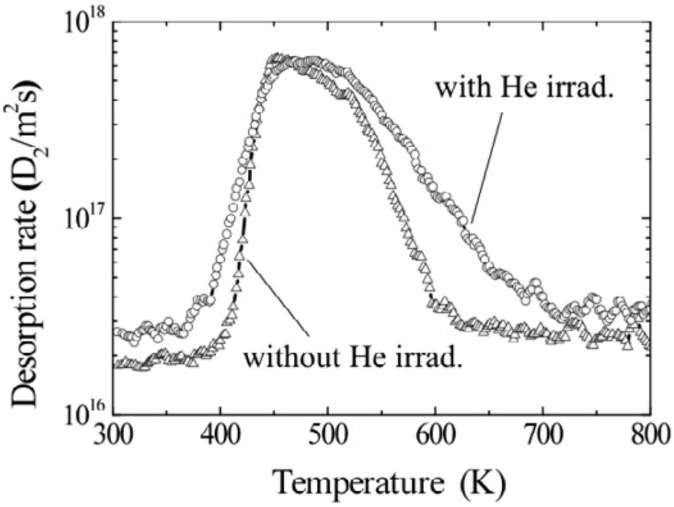

Fig. 2. Thermal desorption spectra of D_2 and He from as-received specimen irradiated with 1MeV He^+ and 650keV D_2^+.