§11. Trapping Behavior of Deuterium in F82H Ferritic/martensitic Steel

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For the development of fusion reactor materials, the characterization of trapping and releasing behavior of hydrogen and its isotopes is one of the key issues considering the influences on plasma parameters and tritium inventory.

Low activated F82H ferritic/martensitic steel 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 under low energy helium irradiation was studied by means of thermal desorption spectrometry (TDS) and TEM in order to characterize the trapping behavior of deuterium on irradiated materials.

The reduced activated F82H ferritic/martensitic steel used in this study was IEA-heat 4-20 prepared for Japanese fusion reactor material program. The samples with a dimension of 6×10mm were mechanically cut to the thickness of around 2mm. Then the surfaces of the samples were mechanically polished up to buff polishing with 0.03μm colloidal silica for low energy ion irradiations. Some samples were prepared from a tempered material at 790 ºC for 30 minutes in order to reduce the influence of deuterium trapping by dislocations for comparison with the normalized materials. The tempering condition was estimated form former studies.

Low energy helium and deuteron irradiations were performed at Research Institute for Applied Mechanics, Kyushu University. The specimens were first irradiated with 5keV He^+ ions at 600ºC followed by the additional irradiations with 0.5keV D_2^+ ions at RT. The deuteron irradiation energy of 0.5keV is that without any introduction of displacement damage into Fe-based alloys.

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. This high resolution spectrometer enables to distinguish slight differences in the mass between He (m=4.0026) atom and D_2 (m=4.0282) gas. The desorption rates of He and D_2 were quantitatively calibrated by using standard He leak with specific relative ionization efficiency. At the same time, the samples for the microstructural study by TEM were prepared using focused ion beam system (FIB) from the same specimens.

Thermal desorption spectra of deuterium from tempered and normalized specimens are given in fig.1. Note that the deuterium ion irradiation was carried out with very low energy of 0.5keV, where no displacement damage will be introduced in Fe-based alloys. The microstructures for these specimens are shown in fig.2. There were two desorption stages for deuterium observed for F82H. One appears between the temperatures from 350K to 500K and the other from around 800K to 1000K. These stages were seen on both tempered and normalized specimens. Desorption stage at lower temperature is typical for Fe-Cr based alloy. This stage is assumed to be a release of deuterium mainly trapped on dislocations, since the stage also appears on the cold worked Fe-9Cr alloy though it disappears after annealing. On the other hand, the stage at higher temperature is unique to F82H. From the microstructural observations, growth of the grins and reduction in dislocation density was observed after tempering at 790ºC for 30 minutes. In addition, the density of carbides decreased rapidly after tempering. Since the stage at higher temperature appears on both tempered and normalized specimens and total desorption decreased to about half on tempered specimens, this stage at higher temperature is mainly attributed to the deuterium trapped by the carbides.

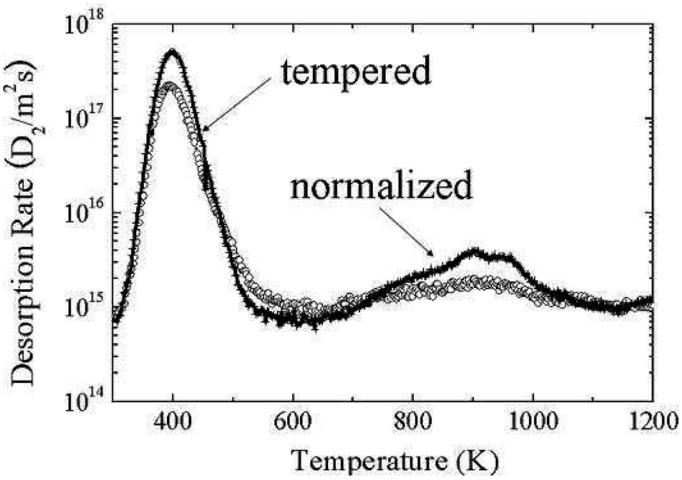

Fig.1. Comparison of the D_2 desorption spectra between normalized specimen and tempered specimen without He^+ irradiations.

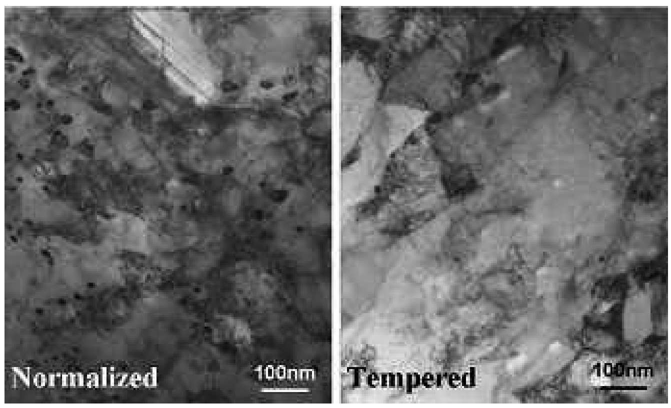

Fig.2. Microstructures of the normalized and tempered F82H.