Hydrogen Trapping in Stainless Steel Irradiated by H and He Ions

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As structural materials of fusion reactors can be heavily damaged by irradiation of fast neutron and charged with a large amount of tritium, hydrogen traps induced by radiation damages would significantly affect the tritium inventory. In the present work, an experimental study on stainless steel was conducted to investigate some properties of hydrogen trapping by use of a nuclear reaction analysis (NRA) and plasma-exposure method.

A sample was a membrane of type 304 stainless steel with thickness of 0.2 mm. One side of the sample was exposed to deuterium plasma and a deuterium permeation flux to the other side was monitored. The plasma-exposing side was irradiated by 0.3-MeV H or 0.8-MeV ^{4}He ions to introduce radiation damages. After and before the irradiation, depth profiles of deuterium concentration in the sample were observed by the NRA with a 1.7-MeV ^{3}He beam. During the NRA analysis, the sample was continuously exposed to the plasma.

Due to the He irradiation with a dose of 1.5×10^{21} m^{-2}, the deuterium concentration significantly increased, for example, to 50 times higher. The concentration profile was similar to a distribution of atomic displacement. A large amount of deuterium was trapped in radiation-induced traps. In case of H irradiation, the deuterium concentration also increased.

Assuming a quasi-equilibrium between trapping and solution sites, temperature dependence of the data was analyzed. A trapping energy, an enthalpy difference between the two sites, was found to be 0.27 eV for both the cases of the He and H irradiation. A production rate, a ratio of number of the traps to the displaced atoms, for the He irradiation is 0.0047 and about ten times larger than that for the H irradiation. The trap was not annihilated below 700 K in the He irradiated sample while it was annihilated around 500 K in the H irradiated sample. The above results and the recovery behaviour of defects in stainless steel indicated that the trap was a vacancy cluster, which can be stabilized by He atom.