§27. Effect of Neutron Irradiation on Tritium Behaviors in Fusion Materials

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Tungsten (W) is recognized as a primary candidate of a plasma facing material. Control of tritium (T) inventory in neutron-irradiated W is an important issue because W activated by neutron-irradiation may release a large amount of T under the conditions of loss-of-coolant accident through the generation of decay heat. From these viewpoints, the retention of hydrogen isotopes in neutron-irradiated W was examined in the Japan–US joint research project TITAN, and significant increase by neutron-irradiation due to the trapping effects of radiation defects was observed[1-3]. However, the release of T from neutron-irradiated W has not been evaluated. In FY2012, the release of T from neutron-irradiated W was simulated with the program TMAP4 (Tritium Migration Analysis Program ver. 4)[4].

In previous studies[1-3], disk-type W specimens were irradiated to 0.025 dpa with neutrons in the High Flux Isotope Reactor at Oak Ridge National Laboratory and then exposed to high flux deuterium (D) plasma in a linear plasma machine called Tritium Plasma Experiment (TPE) at Idaho National Laboratory. Then, D retention and release were examined by nuclear reaction analysis (NRA) and thermal desorption spectroscopy (TDS), respectively. NRA measurements showed that the density of traps induced by neutron irradiation to 0.025 dpa was ~0.2 at.%.

First, the TDS spectrum obtained after the plasma exposure at 773 K was analyzed with the TMAP4 program. A uniform distribution of traps at 0.2 at.% was assumed in the simulation. The initial occupancy of traps was assumed to be unity (full occupancy of traps). The diffusion coefficient of D in a normal bcc lattice of W was set to the value reported by Frauenfelder[5]. The rates of surface reactions of D were assumed to be sufficiently large in comparison with the diffusion rate in the bulk under the trapping effects. The thickness of W layer was set to 0.6 mm as the typical value for armor layers of first walls. Fig. 1 shows the thermal desorption spectrum and the result of simulation. The simulation roughly reproduced the measured spectrum by setting the activation energy of detrapping, E_{det}, to 1.83 eV. Although the peak position of simulated spectrum agreed with the experimental data, the former had a shoulder in a high temperature side. This shoulder appeared by the release of D from the opposite side (unexposed side) surface. Such disagreement in a high temperature region can be attributed to, at least in part, recovery of defects during TDS measurement. Note that the above-mentioned value of E_{det} (1.83 eV) has uncertainty due to such annealing effects of defects. In addition, this value should be considered as an average value of E_{det} for several different types of defects.

Fig. 2 shows the results of simulation of T release during heating in vacuum. E_{det} was set to 1.8 eV. No significant reduction in the average T concentration was observed at 673 K even after heating for 10 h. On the other hand, at 973 K, the T concentration clearly decreased. These observations indicate that the removal of T by baking under a vacuum at moderate temperatures ($\leq$ 673 K) is not very effective for n-irradiated W with a realistic thickness, while T release takes place if W is heated to high temperature by decay heat under the accidental conditions. The development of a T removal technique at moderate temperatures is necessary.

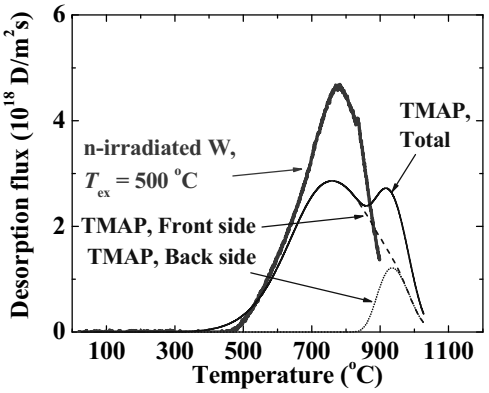

Fig. 1 TDS spectrum of D from neutron-irradiated W (0.025 dpa)[1-3] and the result of simulation with the TMAP4 program. The activation energy for detrapping, E_{det}, was set to 1.83 eV in the simulation.

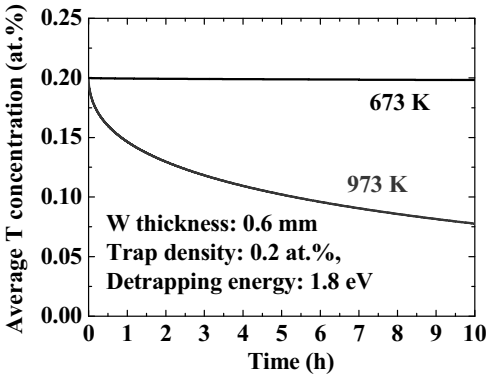

Fig. 2 Results of T release simulation with the TMAP4 program.

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3) Hatano Y. et al.: J. Nucl. Mater., in press, doi:10.1016/j.jnucmat.2013.01.018.
4) Longhurst G. R. et al.: TMAP4 User's Manual, EGG-FSP-10315, doi: 10.2172/7205576.
5) Frauenfelder R.: J. Vac. Sci. Technol. **6** (1969) 388.