§28. Tritium Trapping in Radiation Defects in Fusion Materials

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Tungsten (W) is recognized as a primary candidate of a plasma facing material (PFM). Control of tritium inventory in neutron-irradiated W is an important issue because W activated by neutron-irradiation may release a large amount of tritium under the conditions of loss-of-coolant accident through the generation of decay heat. From these viewpoints, retention of hydrogen isotopes in neutron-irradiated W has been examined in the Japan-US joint research project TITAN[1-4] and found to increase significantly by irradiation due to the trapping effects of radiation defects. However, neutron-irradiation has been carried out only under limited conditions, and hence the mechanisms underlying the trapping effects have not been clarified. The objective of this work is to gain an understanding of trapping mechanisms through ion-irradiation experiments under much wider conditions than neutron irradiation and simulation. In 2011, the thermal stability of defects created by ion-irradiation was examined to gain information on types of defects playing dominant roles in trapping effects.

Plates of recrystallized W were irradiated with 20 MeV W ions to 0.5 dpa at room temperature through the courtesy of Max-Planck Institute für Plasmaphysik, Germany and Japan Atomic Energy Agency. After annealing at a given temperature for 6 hours, the specimens were exposed to D_2 gas at 673 K for 10 hours. We used D_2 gas instead of plasma and ions because gas exposure is better in controlling chemical potential of D in the specimens. Then, the retention of D was evaluated using techniques of nuclear reaction analysis (NRA) and thermal desorption spectroscopy (TDS).

The results of nuclear reaction analysis showed that D was accumulated only in the damaged zones extended to a depth of ca. 2 μm. The thermal desorption spectrum of deuterium is shown in Fig. 1. A sharp desorption peak was observed in a temperature region above 850 K. Desorption at such high temperatures indicates that the activation energy for detrapping (detrapping energy) was ca. 2 eV or even higher. Fig. 2 shows the correlation between concentration of D trapped in radiation defects and annealing temperature. The D concentration showed no significant change after annealing at 973 K, and started to decrease at 1073 K. In other words, the defects playing dominant roles in trapping effects was stable even at 973 K. Futagami et al.[5] observed the microstructure of W irradiated with 2.4 MeV Cu ions at room temperature using a transmission electron microscope. They found that the nanosize voids are formed even at room temperature through cascade collisions, and these nanosize voids are stable at least up to 973 K. In addition, according to Van Veen et al.[6], the above mentioned value of detrapping energy corresponds to that for hydrogen isotopes chemisorbed on inner surfaces of voids. Therefore, the defects playing dominant roles are most probably nanosize voids under the conditions of this study.

1) Shimada M. et al.: J. Nucl. Mater. **415** (2011) S667.
2) Oya Y. et al.: Phys. Scr. **T145** (2011) 014050.
3) Shimada M. et al.: Phys. Scr. **T145** (2011) 014051.
4) Shimada M. et al.: Fusion Eng. Design, in press, doi:10.1016/j.fusengdes.2012.02.103.
5) N. Futagami et al.: Plasma Conference 2011, November 22-25, 2011, Kanazawa, Japan.
6) A. Van Veen et al.: J. Nucl. Mater. **155-157** (1988) 1113.

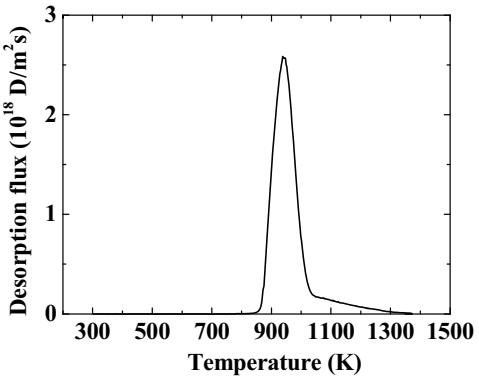

Fig. 1 TDS spectra of D from recrystallized W irradiated with 20 MeV W ions to 0.5 dpa and exposed to D_2 gas at 673 K and 0.1 MPa.

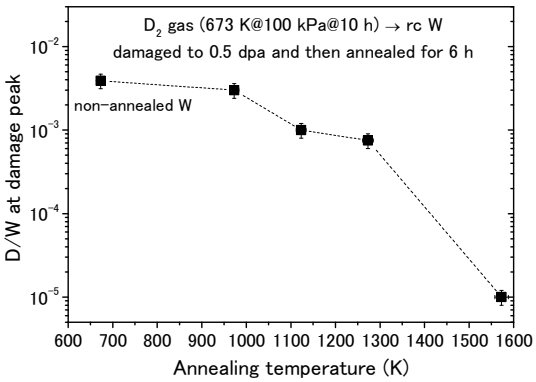

Fig. 2 Correlation between concentration of D trapped in radiation defects and annealing temperature.