## §74. Advanced Evaluation of Radiation Effects on Fusion Materials

Shikama, T., Kurishita, H., Yamazaki, M.,
Hatakeyama, M., Narui, M., Watanabe, M., Nagata, S.,
Chou, M., Nagai, Y., Hasegawa, A. (Tohoku Univ.),
Hatano, Y. (Univ. Toyama),
Atsumi, H. (Kinki Univ.),
Kimura, A., Takagi, I., Sato, K. (Kyoto Univ.),
Ohnuki, S. (Hokkaido Univ.),
Watanabe, H. (Kyushu Univ.),
Ueda, Y., Nishijima, S. (Osaka Univ.),
Terai, T., Oda, T. (Univ. Tokyo),
Oya, Y. (Shizuoka Univ.),
Tsuchiya, B. (Meijyou Univ.),
Nishitani, T. (JAEA),
Muroga, T., Nishimura, A.

Nine research proposals have been accepted after reviews at NIFS and International Research Center for Nuclear Materials Science, IMR, Tohoku University (the Center). The following is the report on "(96) Advanced evaluation of radiation effects on fusion materials (the principal investigator: T. Shikama, Tohoku University)" which is the fundamental project for all of the proposed studies.

The feature of the fusion reactor environments is that helium and hydrogen are produced by nuclear transmutation and the transport and retention of hydrogen isotopes and helium from the core plasma and tritium generated at the blanket occur under neutron irradiations. It is hence indispensable to clarify the effects of neutron irradiation on the behavior of hydrogen isotopes and helium in the candidate materials to assess the feasibility of their use in fusion reactors.

For this, in 2010 a TDS (Thermal Desorption Spectrometer) apparatus was installed in a radiation controlled laboratory at the Center. The apparatus allows us to obtain thermal desorption spectra, thereby enabling the identification and quantification of hydrogen isotopes and helium contained in radioactive materials following reactor or accelerator irradiations. In 2011, an ion gun was equipped with the TDS apparatus to inject hydrogen isotopes or helium into neutron irradiated specimens. The main specification of the ion gun is as follows: 1) Accelerating voltage: 0.1-3kV, 2) gas species: Ar, He, H, $D_2$, 3) beam scanning range: ±20mm (XY), beam radius: 1mm (at 3kV), 4) ion current: 3mA. In this set-up, several improvements have been made for specimen tilting, installations of a Faraday cup and an evacuation system, suppression of out gassing, etc.

By using this apparatus, the emission and retention behavior of D in recrystallized tungsten (W) specimens that were at first irradiated with 2.8MeV Fe ions to 3dpa (displacement per atom), followed by exposure to D atoms with very low energy and low flux (fluence: $6.2\times10^{22}$Dm$^{-2}$) was measured, and the result is shown in Fig.1. For comparison, the results for W specimens irradiated with neutrons or Fe ions and then exposed to TPE (Tritium Plasma Experiment: high energy, high fluence $10^{25}$D m$^{-2}$) are included.

In the case of TPE exposure, neutron irradiated specimens exhibit D desorption at relatively low temperatures to as high as above 1000K, whereas Fe-ion irradiated specimens exhibit the completion of D desorption at around 700K. In the case of specimens with Fe-ion irradiation and D atom exposure, D desorption starts at around 500K and continues even at above 1000K. The D desorption behavior suggests the existence of trapping sites for hydrogen isotopes as strong as those in neutron irradiated specimens (de-trapping energy : ~2eV). These results indicate that 2.8MeV Fe-ion irradiation can induce strong trapping sites (de-trapping energy: ~2eV) for hydrogen isotopes and that such strong trapping sites survive under low-flux D exposure, but disappear under high-flux D exposure. The de-trapping energy of ~2eV corresponds to chemisorption entrapment of hydrogen isotope atoms at the inner surface of voids in W.

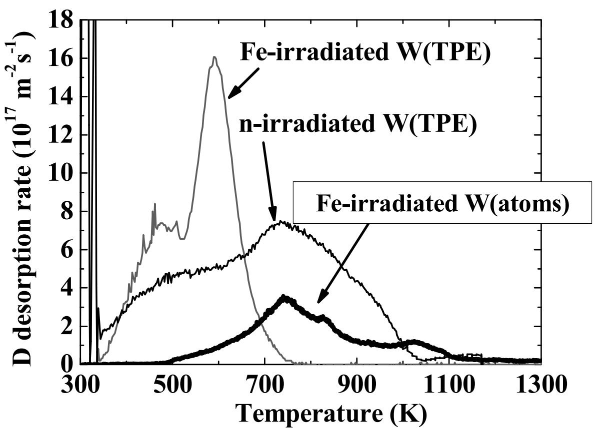


Fig. 1 TDS results on D desorption rate in recrystallized pure W with different irradiation (Fe-ions or neutrons) and D exposure (atoms or plasma (TPE) ).

The mechanism in which the strong trapping sites have disappeared is not yet clear, but the present results that low-flux D exposure enables the suppression of changes in radiation-induced microstructures, provide an important insight when neutron irradiation effects are simulated by ion irradiation. Since in neutron irradiated specimens radiation-induced defects are formed homogeneously, there exist two microstructurally distinctive regions: plasma affected region near the surface and unaffected region distant from the surface. In the neutron irradiated specimens, D de-trapping from both regions has occurred and yielded a broad detrapping spectrum.