§75. Advanced Evaluation of Radiation Effects on Fusion Materials

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Eight research proposals have been accepted after reviews at NIFS and International Research Center for Nuclear Materials Science, IMR, Tohoku University (the IMR-Oarai Center). The following is the report on "(98) 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 isotopes are produced by nuclear transmutation and the transport and retention of hydrogen isotopes and helium originated 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 the radiation restricted area at the IMR-Oarai Center. In 2011, an ion gun was equipped with the apparatus to implant hydrogen isotopes or helium into neutron irradiated specimens without additionally introducing radiation induced lattice defects that likely act as trapping centers for hydrogen isotopes or helium. This year, improvements in the vacuum system and mass number identification of elements have been made for completion.

Figure 1 shows the entire view of the TDS apparatus equipped with an ion gun and two Q mass (high and standard resolutions) detectors. The apparatus allows us to obtain thermal desorption spectra against temperature for hydrogen isotopes or helium implanted by the ion gun, thereby enabling assessments of their retention and trapping energy by lattice defects induced by reactor or accelerator irradiation in structural and functional radioactive materials.

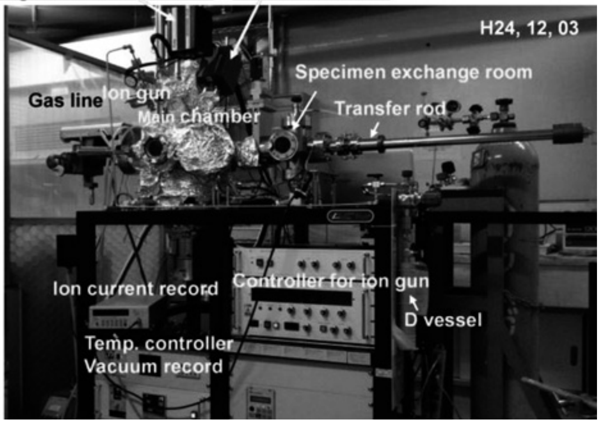

Fig. 1 Entire view of TDS apparatus equipped with an ion gun installed in the restricted area at the IMR-Oarai Center.

The IMR-Oarai Center, the joint-use research center for materials irradiation with reactors and PIEs (Post Irradiation Examinations), has kept a number of neutron irradiated specimens in stock. Before bringing the valuable neutron irradiated specimens to TDS it is needed to establish fundamental techniques to obtain reliable, reproducible results by using the TDS apparatus because such results are very sensitive to the surface layer condition of the specimen immediately before and during ion irradiation and TDS measurements. Therefore, we have at first examined the effects of degassing conditions of mechanically polished specimens and the TDS chamber by heating the specimen in a vacuum up to 1173K on the absorption behavior of deuterium implanted by the ion gun into tungsten (W) materials with well controlled microstructures: W materials are the leading candidate for use as plasma facing materials and components in the future fusion reactors and planned to be employed as the full W divertor in ITER (International Thermonuclear Experimental Reactor).

Two kinds of commercially available pure W materials, fully recrystallized W and ITER grade W (stress relieved W), were surface mirror polished and set to the TDS followed by degassing at 1123K for 3 hours. The degassed specimens were irradiated with deuterium ion with 2 keV at room temperature and 573K to fluences of 1 x 10^{22} and 3.3 x 10^{22} D^{2+}, then subjected to TDS measurements up to 1273K at a ramp rate of 1K/sec in a vacuum of 3 x 10^{-7} Pa. It has been found that even in the fully recrystallized W that is known to exhibit the lowest retention among the W materials, distinct peaks of desorption of D_2 and D-H occur at around 330K and 473K, respectively, and each peak intensity significantly increases with fluence of D^{2+}. The ITER grade W that contains substructures of dislocations acting as trapping sites for D exhibits an appreciable higher desorption rate than recrystallized W. The results indicate that the present TDS system works well to clarify the effects of neutron irradiation on the behavior of hydrogen isotopes and helium in W materials with various microstructures.