§97. Advanced Evaluation of Radiation Effects on Fusion Materials

Nagai, Y., Toyama, T., Nagata, T., Yamasaki, M., Watanabe, M., Chou, M., Hasegawa, A. (Tohoku Univ.),
Muroga, T., Nishimura, R., Yajima, M.,
Takagi, I., Kimura, A. (Kyoto Univ.),
Nishitani, T. (JAEA),
Tsuchiya, B. (Meijiyou Univ.),
Hatano, Y. (Univ. Toyama),
Atsumi, H. (Kindai Univ.),
Watanabe, H. (Kyushu Univ.),
Oda, T., Terai, T. (Univ. Tokyo),
Sato, K. (Kagoshima Univ.),
Oya, Y. (Shizuoka Univ.),
Ohnuki, S., Nobuta, Y. (Hokkaido Univ.),
Ueda, Y. (Osaka Univ.),
Takagi, M., Ohno, N., Kuwabara, T. (Nagoya Univ.)

This project aimed to develop experimental apparatus and systems to investigate plasma-materials interaction (PMI) of fusion materials, as the fundamental project for all the other nine projects in the collaborative studies of NIFS and International Research Center for Nuclear Materials Science, Tohoku Univ. (IMR-Oarai).

In the fusion plasma environment, hydrogen isotopes and helium are introduced to plasma-facing materials, such as tungsten, via plasma-exposure and nuclear transmutation. Simultaneously, neutron-irradiation with high energy (14 MeV) occurs. It is therefore indispensable to clarify the effects of neutron irradiation on the behavior of hydrogen isotopes and helium atoms to assess in the materials the feasibility of their use in fusion reactors.

For that purpose, in 2010, thermal desorption spectrometry apparatus, TDS, was installed in a radiation controlled laboratory at IMR-Oarai. The apparatus enables us to make quantitative analysis of hydrogen isotopes and helium atoms contained in radioactive materials following neutron- and ion-irradiations. In addition, an ion gun was equipped with the TDS apparatus in 2011, called IG-TDS, to inject hydrogen isotopes or helium into specimen, followed by TDS analysis in the same vacuum chamber. The main specification of the ion gun is as follows; acceleration voltage of (0.1 – 3) keV, gas species of hydrogen, deuterium, helium and argon, beam scanning range of ± 20 mm, beam radius of ~1 mm, ion current of 3 mA. During 2012 – 2014, several improvements have been made for specimen tilting, installations of a Faraday cup and an evacuation system, suppression of out gassing and so on.

By using the IG-TDS, the emission and retention behavior of deuterium in tungsten irradiated with neutron or iron-ion were investigated, as reported in the NIFS annual report in 2012. It is revealed that both neutron and iron-ion irradiation induce the trapping sites for hydrogen isotopes. The flux effects on the formation of the trapping sites is also studied. For neutron-irradiated specimen, microstructural analysis by using positron annihilation were performed and it is indicated that such trapping sites are vacancy-clusters with size of around V_{10}.

In addition, in 2015, the compact diverter plasma simulator, C-DPS, was installed to the IG-TDS apparatus with collaboration with LHD project (leader: prof. Ohno, Nagoya University) as shown in Fig. 1. This combination enables us to perform TDS analysis after plasma irradiation without exposure to the air. This system, C-DPS/IG-TDS located in radio-isotope controlled area, is a unique system in the world which can analyze radio-active specimen. C-DPS/IG-TDS is expected to provide valuable information for plasma-materials interaction especially for neutron-irradiated specimen.

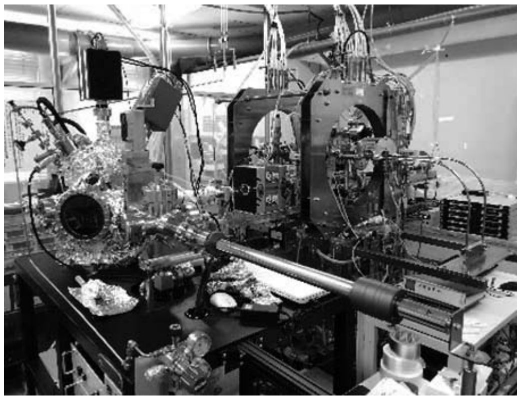

Fig. 1: Overview of Thermal Desorption Spectrometry with Ion-Gun and Compact Diverter Plasma Simulator, C-DPS/IG-TDS, in radio-isotope controlled area in IMR-Oarai. Fusion-plasma irradiation to neutron-irradiated specimen followed by TDS measurement without air-exposure is available.

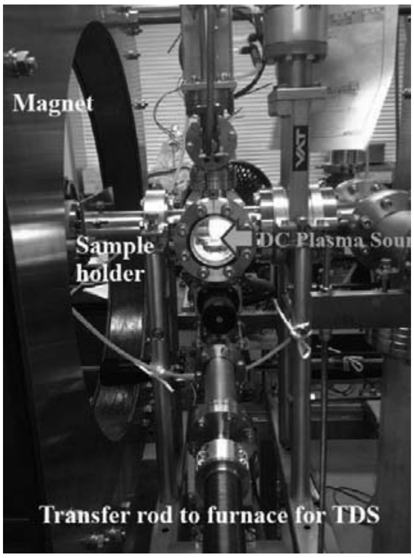

Fig. 2: Deuterium plasma generated in C-DPS system. After plasma irradiation, specimen will be transferred to an infrared-furnace without exposure to air and then TDS analysis will be performed.