Dynamics of Absorption/Emission of Hydrogen Isotope in Neutron-Irradiated Tungsten with the Compact Divertor Plasma Simulator

International Research Center for Nuclear Materials Science

A compact divertor plasma simulator combined with thermal absorption spectroscopy was developed in the radiation-controlled area of the IRCNMS. The dynamics of hydrogen isotope absorption/emission for neutron-irradiated tungsten are being investigated, which will be essential for ongoing studies on plasma-facing materials in fusion reactors.

Studies on fusion reactors are ongoing worldwide. These include the development of plasma-facing materials that requires an understanding of hydrogen isotope behavior in the materials. Systematic experiments on the absorption/emission of hydrogen isotopes in neutron-irradiated materials are of importance for this matter, but few are available worldwide.

Recently a compact divertor plasma simulator (CDPS), as shown in Fig. 1, was developed in the radiation-controlled area of the International Research Center for Nuclear Materials Science (IRCNMS), Tohoku University, as a result of collaborations with the National Institute for Fusion Science and other universities [1]. The CDPS produces steady-state deuterium (D) and/or helium plasmas with densities above 10^{18} m^{-3} at a well-controlled sample temperature of approximately 5 K. The CDPS has a sample-carrier system, which makes it possible to transfer a plasma-exposed sample from the sample holder to an infrared heater for analysis using thermal desorption spectroscopy, without exposing it to the air.

We performed neutron-irradiation for tungsten, which is the primary candidate for plasma-facing material. Then, we investigated the dynamics of D absorption and emission [2, 3]. The total D retention was found to be proportional to the square root of D fluence, as shown in Fig. 2. The results suggest that the implanted D atoms first occupied the defects near the surface, and then the defects located in deeper regions. The effects of post-plasma annealing on D emission was also studied. It was found that 30 h of annealing at 573 K caused D emissions, suggesting that the heat treatment of the plasma-facing component of a fusion reactor at moderately elevated temperatures can contribute to the removal of accumulated hydrogen isotopes. These results were obtained through international collaborations at the IRCNMS and will be essential for ongoing and future studies of plasma-facing materials in fusion reactors.

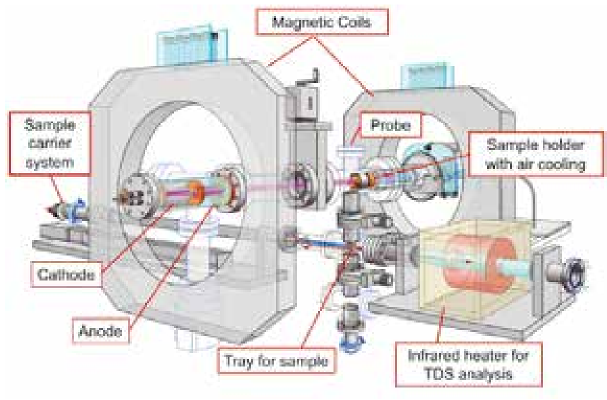

Fig. 1 Schematic view of the CDPS.

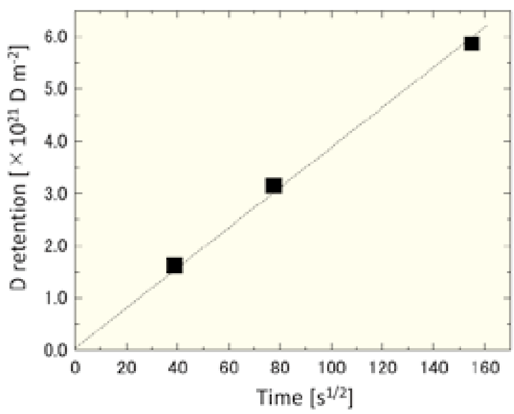

Fig. 2 Correlation between the plasma exposure time and D retention in neutron-irradiated pure tungsten.

References

[1] N. Ohno, T. Kuwabara, M. Takagi, R. Nishimura, M. Yajima, A. Sagara, T. Toyama, K. Suzuki, H. Kurishita, T. Shikama, Y. Hatano, and N. Yoshida, Plasma Fusion Res. **12**, 1405040 (2017).

[2] V. Kh. Alimov, Y. Hatano, T. Kuwabara, T. Toyama, S. Someya, and A. V. Spitsyn, Nucl. Fusion **60**, 096025 (2020).

[3] T. Toyama, M. Yajima, N. Ohno, T. Kuwabara, V. Kh. Alimov, and Y. Hatano, Plasma Fusion Res. **15**, 1505081 (2020).

Keywords: nuclear materials, radiation effects, hydrogen

Takeshi Toyama (Corresponding Author, International Research Center for Nuclear Materials Science)
E-mail: ttoyama@imr.tohoku.ac.jp
Yasuyoshi Nagai (Head of International Research Center for Nuclear Materials Science)
E-mail: nagai@imr.tohoku.ac.jp
URL: http://www.imr-oarai.jp/en/