

§30. Development of Hydrogen Isotope Separation Technologies for DEMO Fuel Cycle

Sugiyama, T., Takada, A., Morita, Y. (Nagoya Univ.), Kotoh, K., Moriyama, S., Funakoshi, H. (Kyushu Univ.), Munakata, K., Wada, K. (Akita Univ.), Taguchi, A. (Univ. Toyama), Kawano, T., Tanaka, M., Akata, N.

Detritiation of huge amount of tritiated water and safety improvement by reducing the tritium inventory are still important developing challenges for DEMO fuel cycle. In the present study, we adopted water-hydrogen chemical exchange and cryogenic pressure swing adsorption (PSA) as technologies of hydrogen isotope separation. The purposes of study are development of high-efficient adsorbent and catalyst applied to the above technologies, and development of devices for hydrogen isotope separation with its high-efficient operating procedures.

i) Water-hydrogen chemical exchange

A water detritiation system, which consisted of two liquid phase chemical exchange columns operated under the different temperature and pressure each other, was newly proposed. We call this system 'Dual-Temperature Dual-Pressure Catalytic Exchange (DTDP-CE)' hereinafter. An experiment device was built as shown in the left hand side of Fig. 1 in order to demonstrate DTDP-CE. The chemical exchange columns were both 55 mm in I.D. and 1 m in height. Kogel catalysts and Dixon gauze rings were mixed and randomly filled in the columns. The catalyst packing rate was set as 30 % in volume. The temperature and pressure can be controlled at constant values in the ranges 30-70 °C and 0.03-0.1 MPa, respectively, for the low-temperature low-pressure column, and in the ranges 70-140 °C and 0.1-0.5 MPa, respectively, for the high-temperature high-pressure column. Flow rates of hydrogen gas and feed water can be set at a maximum as 30 NL/min and 30 g/min, respectively. Experiments were started and the results will be reported in the near future.

ii) Catalyst for DTDP-CE

Developing targets of a Pt-catalyst for DTDP-CE are improvement in heat resistance and lasting hydrophobicity under pressurized condition. A porous silica beads (Fuji silysia chemical Ltd., CARiACT Q-50 hydrophobic prototype) was used as a carrier. Its average pore diameter was 50 nm. The pore volume and specific surface area were measured as 1.0 cm³/g and 73 m²/g, respectively. The catalyst was prepared by impregnating the carrier with chloroplatinic acid followed by reduction with hydrogen. The catalyst performance for hydrogen atom exchange between water vapor and hydrogen gas was measured with tritiated water of 1 MBq/kg, and the overall mass transfer coefficient was obtained as 1.8 cm/s. The experimental and theoretical results obtained for the developments of high-efficient adsorbent and catalyst were reported in the literatures.¹⁻⁶⁾

iii) Cryogenic pressure swing adsorption

For the hydrogen isotope separation system in the deuterium-tritium fuel cycle protium removal is one of the most important issues, but complete separation of deuterium and tritium is not necessary required. Based on this point of view, we have been developed a cryogenic PSA process and its high-efficient operating procedure. An experiment device of a cryogenic pressure swing adsorption process with three adsorption columns was built as shown in the right hand side of Fig. 1. We call this device 'Pressure Swing Multi-packed-column Adsorption Process (PSMAP) system' hereinafter. The U-shaped adsorption columns were made of stainless steel, and those inner diameter and effective length of the adsorption bed were 23 mm and 92.4 cm, respectively. The synthetic zeolite of SZ-13X was chosen as an adsorbent according to the results of previous research. The device was controlled automatically and the three adsorption columns worked cyclically processes of evacuating desorption, priming carrier H₂ replenishment and isotopic replacement adsorption, like a merry-go-round way. Experiments were started and the results will be reported in the near future. A preliminary experimental and theoretical results for the present study was reported in the literature.⁷⁾



Fig. 1. Snapshots of devices for hydrogen isotope separation: DTDP-CE (left), PSMAP (right).

- 1) K. Munakata, Surface Science, 616, pp. 1-11 (2013).
- 2) K. Munakata, K. Hara, T. Sugiyama *et al.*, Fusion Engineering and Design, 88(9-10), pp. 2408-2412 (2013).
- 3) K. Munakata, Journal of Chemical Engineering of Japan, 46(7), pp. 444-449 (2013).
- 4) Y. Kawamura, Y. Iwai, K. Munakata *et al.*, Journal of Nuclear Materials, 442, pp. S455-S460 (2013).
- 5) A. Taguchi, Y. Kato, Y. Torikai *et al.*, Microporous and Mesoporous Materials, 179, pp. 217-223 (2013).
- 6) K. Kotoh, S. Moriyama, S. Takashima *et al.*, Fusion Engineering and Design, 88, pp. 2223-2227 (2013).
- 7) S. Takashima, K. Kotoh, Fusion Engineering and Design, 88, pp. 2366-2368 (2013).