§35. Construction of Measurement System for Examination of Irradiation Effects on Hydrogen Permeation Behaviors through Ceramic Materials

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Development of ceramic coatings has been conducted for suppression of hydrogen isotope permeation through high temperature coolant ducts in a reactor. Since the ceramic coatings are used in a high radiation environment, transient and permanent performance changes are issues to be examined by irradiation experiments. In the fiscal year of 2013, a hydrogen permeation measurement system has been constructed for examination of ^{60}Co gamma-ray irradiation effects on permeation behaviors through ceramic materials.

In our previous ^{60}Co gamma ray irradiation experiment, all required apparatuses such as a sample holder, heater, vacuum gauge, QMS (quadrupole mass spectrometer), vacuum chambers, vacuum pumps etc. have been installed in an irradiation room. While all the apparatuses were shielded by lead blocks, increase in the QMS signal levels was observed during irradiations. In the present experiment, the sample holder and heater were placed in the irradiation room and other apparatuses were placed outside for more precise measurements (Fig. 1). The sample holder and measurement system were connected with 1/2 inch diameter tubes through walls of the irradiation room. The length of each tube was ~5 m. It was confirmed that the pressure in the chambers can be kept at <~1 x 10^{-5} Pa.

The constructed system has been used in a deuterium permeation measurement through poly-crystalline SiC disc under a ^{60}Co gamma ray irradiation (Collaborative experiment with Prof. B. Tsuchiya (Meijyo Univ.), performed at a JAEA facility.). The dimensions of the SiC disc were 20 mmϕ x 0.78 mm thick. Both the surfaces were mirror-polished and fasten in the sample holder with vacuum seals. After evacuating the high-pressure and low-pressure chambers to <10^{-5} Pa, deuterium gas of ~80 kPa was introduced to the high-pressure chamber. Deuterium gas permeating through the disc was detected with the QMS at the low-pressure chamber.

As to the SiC disc sample, it has been confirmed that the magnitude of hydrogen permeability is almost 4 orders lower compared with that of ferritic steel discs at 700-800 °C without an irradiation. However, it is considered that thermal and irradiation effects might appear at simultaneously under an irradiation. To enhance irradiation effects, hydrogen permeation was measured at a relatively low temperature of 200 °C. The dose rate on the SiC disc was ~1.2 Gy/s.

Although the measurement of deuterium permeation was continued for 20 hours, responses of QMS were under the detection limit both with and without irradiations. Deuterium permeability was evaluated to be <~4 x 10^{-17} mol/m/s/Pa$^{0.5}$ at 200 °C and 1.2 Gy/s. Detection of deuterium permeation and examination of radiation effects are planned to be performed at higher temperatures by using a mixture gas of helium and deuterium and enhancing the safety.

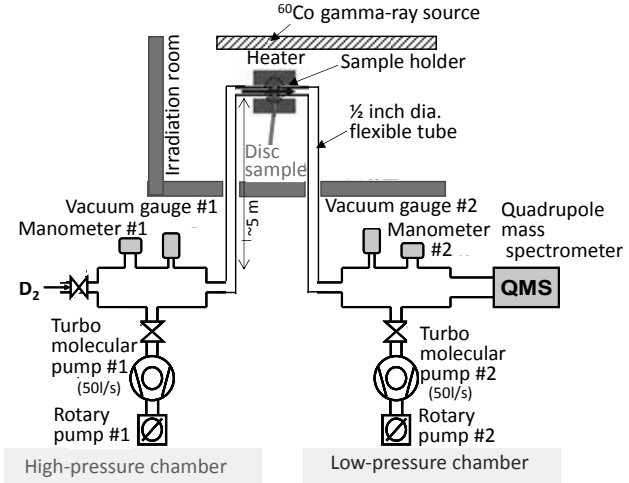

Fig. 1 Schematic drawing of measurement system for examination of ^{60}Co irradiation effects on hydrogen permeation behaviors.