§32. Study on Hydrogen Isotope Exchange in Deposition Layer of Plasma Facing Material

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It is necessary to understand isotope exchange reaction for the evaluations of tritium inventory and permeation because the flux of hydrogen isotopes from plasma is changed by fuel control. Deposition layers, which will grow on the surface of plasma facing components may affect hydrogen isotope behavior because the structure of deposition layers will be different from that of original materials. Some reports have shown that metal deposition layers formed under hydrogen isotope plasma can trap a certain amount of hydrogen isotopes in the deposition process[1,2]. However, basic behaviors such as dissolution, diffusion and surface recombination of hydrogen isotopes on tungsten (W) deposition layers have not been understood quantitatively so far. In this work, W deposition layers, which were formed on nickel substrate by hydrogen plasma sputtering, were exposed to hydrogen or deuterium gas and the permeation behavior was observed.

By hydrogen plasma sputtering at 100 W RF power, 10 Pa H_2 pressure and 307 hours deposition time, tungsten deposition layer was formed on circular substrates of nickel, 20 μm in thickness and on square substrates of quartz, 1 mm in thickness. From SEM observation of the cross-section of the W deposition layer formed on the quartz substrate, thickness of the deposition layers were measured to be 970 nm. From the deposition weight and the volume, the porosity was estimated to be 0.37. By EDX analysis, the layer contained oxygen at 20~30 at%. The permeation experimental device was shown in Fig.1. The sample substrate separates a hydrogen supply side (primary side) and a hydrogen permeation side (secondary side). The secondary side connecting to a pressure gauge was closed in a vacuum before pure hydrogen gas or pure deuterium gas was supplied to the primary side. The permeation flux was obtained from the pressure rise in the secondary side.

Fig.2 shows the pressure rise by hydrogen permeation at 244 °C through the nickel substrate with and without W deposition layer. This result implies that the rate-controlling step of hydrogen permeation through the nickel substrate with the W deposition layer is hydrogen transfer in the W deposition layer. Therefore the permeability of hydrogen and deuterium through the W deposition layer was obtained ignoring the permeation in the nickel substrate. As shown in Fig.3, hydrogen permeability and deuterium permeability in the W deposition layer corresponded and were higher than that in bulk tungsten[3,4]. From the analysis of the permeation curve by Time-Lag method, it was found that the diffusivity of hydrogen isotopes in W deposition layer is considerably smaller than that in bulk tungsten.

1) Katayama, K., et al., J. Nucl. Mater., **438** (2013) 1010.
2) Temmerman, G.De, et al., J. Nucl. Mater., **389** (2009) 479.
3) Frauenfelder, R.J., Chem. Phys., **48** (1968) 3955.
4) Zakharov, A.P., et al., Sov. Mater. Sci., **9** (1973) 149.

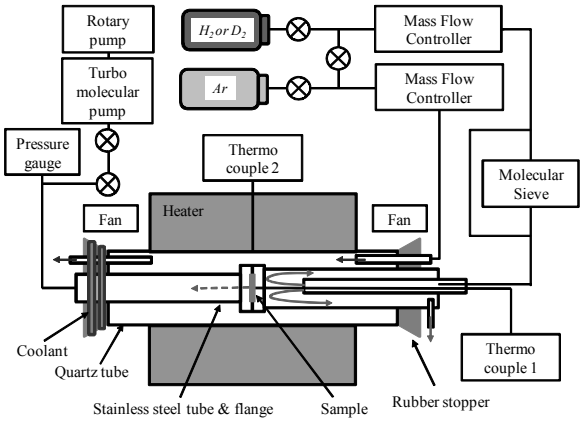

Fig.1 The schematic diagram of the experimental apparatus.

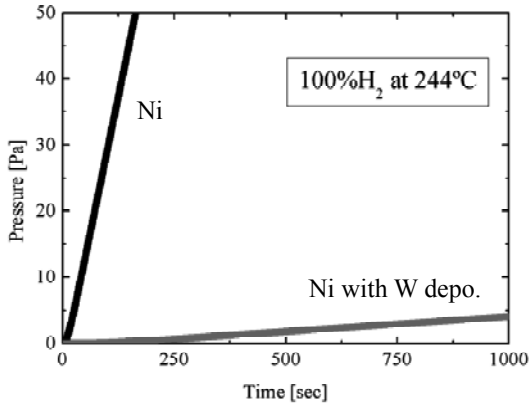

Fig.2 The pressure rise by hydrogen permeation.

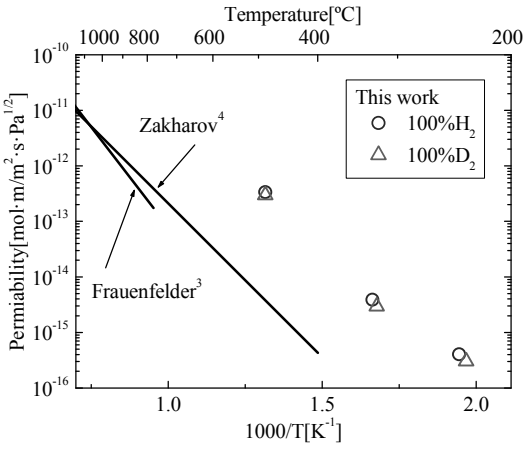

Fig.3 Hydrogen and deuterium permeability.