§38. Influence of Deposition Layer on Hydrogen Isotope Permeation in Plasma Facing Wall

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In a fusion reactor, the plasma facing wall is eroded by energetic particle incidents and sputtered atoms deposit on the wall during plasma operation. Formation of deposition layers on the plasma facing wall may influence tritium permeation behavior from the plasma facing wall to the coolant. Quantitative evaluation of hydrogen permeation rate through the deposition layer is an important issue from a viewpoint of fuel particle control and tritium safety management. It has been found that metal deposition layers formed under hydrogen isotope plasma retain a certain amount of hydrogen isotopes in the deposition process[1,2]. However, hydrogen permeation rate through metal deposition layer has not been quantitatively evaluated to date. In this work, hydrogen permeation rates through W deposition layers in different porosity formed on nickel substrate by hydrogen plasma sputtering were measured.

The nickel plate on which W deposition layer was formed was clamped between a copper gasket and a stainless steel flange. The flange connected to stainless steel tubes was inserted in a quartz tube and set at a center position of an electric furnace. The permeation cell was heated to the preset temperature by the furnace. The temperature of the furnace was controlled by thermocouple contacting to the outer surface of the quartz tube. The sample temperature was measured by another thermocouple contacting to the sample surface from the primary side. Just after the secondary side was closed under vacuum condition, hydrogen gas or mixed gas of hydrogen with argon was introduced into the primary side. From a pressure rise in the secondary side, hydrogen permeation flux was obtained. W deposition layer was formed on quartz substrates in addition to Ni substrate. The quartz substrate was broken to half after the deposition process and the cross section was observed by SEM to estimate the thickness. It was assumed that the thickness on Ni was same as that on quartz. The porosity was estimated from deposition weight, thickness and plasma facing surface area. Estimated thickness and porosity of W deposition layer used in this work were shown in Table 1.

The hydrogen permeation flux was obtained for each samples. The obtained permeation fluxes through W deposition layer on Ni substrate are compared to that through bare Ni substrate with 20μm and W bulk with 0.409μm. It was found that the hydrogen permeation flux through W deposition layer is two orders of magnitude larger than that through W bulk. In spite of difference in thickness and porosity, the permeation fluxes for all samples were plotted approximately linearly to the inverse of temperature.

The numerical calculation of one dimensional diffusion of hydrogen and the simulated pressure rise in the secondary volume was fit to the experimental one by varying diffusivity and solubility as parameters. The obtained diffusivity was compared to the diffusivity in W bulk in Fig.2. It was revealed that diffusivity in W deposition layer was smaller than that in W bulk. This implies that hydrogen solubility in W deposition layer is much larger than W bulk. The tendency that the diffusivity becomes large with increasing the porosity was observed.

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1) Katayama, K., et al., J. Nucl. Mater., **438** (2013) 1010.
2) Temmerman, G.De, et al., J. Nucl. Mater., **389** (2009) 479.

Table 1 Thickness and porosity

Thickness [μm]	0.409	0.711	0.934	2.18	2.42
Porosity [-]	0.37	0.29	0.32	0.54	0.59

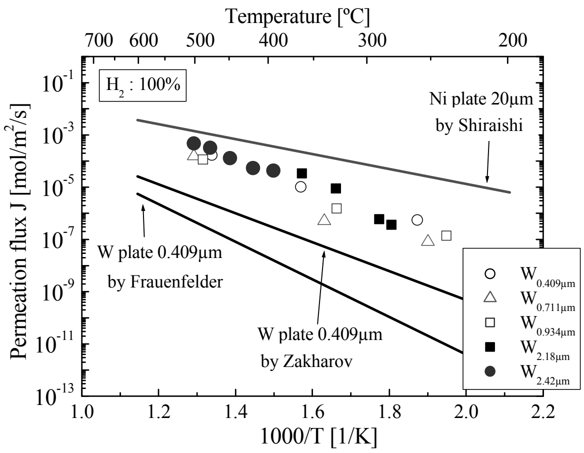

Fig.1 Hydrogen permeation flux through W deposition layers on Ni substrate, bare Ni substrate and W bulk.

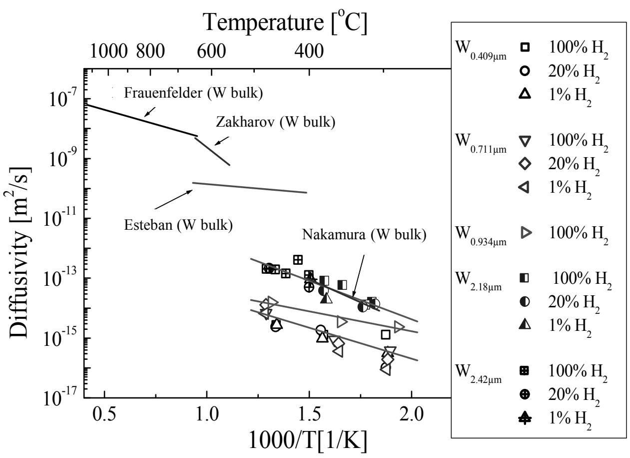

Fig.2 Hydrogen diffusivity in W deposition layers compared with that in W bulk.