Application of tritium tracer technique for determination of hydrogen diffusion and permeation coefficients near room temperature

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Data for hydrogen diffusion and permeation coefficients in fusion reactor materials at lower temperatures is urgently needed for reliable estimation of tritium retention and permeation. At lower temperatures, it is very hard to observe hydrogen diffusion and permeation in materials, because of their very low solubility and diffusivity. Since tritium (T) is so easy to detect owing to its radio activity comparing with hydrogen (H), we have applied a tritium tracer technique for gaseous hydrogen permeation measurements to determine hydrogen diffusion and permeation coefficients in candidate for fusion reactor materials at a temperature ranging from 298 to 353 K.

Hydrogen permeation measurements were conducted with a membrane specimen, one side of which was exposed to hydrogen gas containing tritium with 1.25×10^{-4} in T/H ratio. And the permeated tritium was directly collected to liquid scintillation cocktail filled at the other side, and quantified by a liquid scintillation counter.

The first measurement has been done for pure nickel (Ni) of which both coefficients are well established. Diffusion coefficients (D) were determined by the time-lag method, and permeation coefficients (Φ) was determined from the total amount of permeated tritium divided by the dilution rate of T. Temperature dependences for both coefficients are

$$D_{Ni} = (9.77 \pm 5.9) \times 10^{-4} \exp((-60.3 \pm 2.1)\ (\mathrm{kJ/mol})/RT)\ ,\ \mathrm{m^2 s^{-1}}$$

and

$$\Phi_{Ni} = (7.02 \pm 4.2) \times 10^{-7} \exp((-52.8 \pm 2.4)\ (\mathrm{kJ/mol})/RT)\ ,\ \mathrm{molm^{-1} s^{-1} Pa^{-1/2}}.$$

Both are in nearly perfect agreement with reliable literature data. This assures the reliability of the present method, and then we have applied the method to tungsten (W). Permeation thorough W was detected even at such a low temperature i.e. room temperature, and preliminary results were given by

$$D_W = (3.42 \pm 0.68) \times 10^{-9} \exp((-37.8 \pm 1.2)\ (\mathrm{kJ/mol})/RT)\ ,\ \mathrm{m^2 s^{-1}}$$

and

$$\Phi_W = (1.21 \pm 0.24) \times 10^{-5} \exp((-57.8 \pm 0.9)\ (\mathrm{kJ/mol})/RT)\ ,\ \mathrm{molm^{-1} s^{-1} Pa^{-1/2}}.$$

The temperature range measured was still too narrow to claim the reliability of activation energies, and measurements will be continued and extended to other candidates of fusion reactor material.