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高エネルギーイオン照射により照射損傷を導入したタングステンにおける水素同位体透過挙動

Hydrogen isotope permeation behavior for tungsten damaged by energetic ion irradiation

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Usage of tungsten (W) is considered as a plasma facing material (PFM) in fusion reactors. During operation, irradiation damages will be introduced in the PFM by implantation of various energetic particles such as hydrogen isotopes from plasma. It is expected that dissolution, diffusion, and permeation behaviors of hydrogen isotopes for damaged tungsten should be different from those for undamaged tungsten. Elucidation of hydrogen isotope permeation behavior for the damaged tungsten is important from a view point of safety evaluation. In this study, deuterium gas-driven permeation behaviors for tungsten damaged by energetic ions were studied at the temperature of. ....K. The role of the irradiation damages on the hydrogen permeation was discussed.

Tungsten foil (10 mm× 10 mm× 0.05 mm^{t}) purchased from Nilaco Co. Ltd was used. The sample was preheated at 1173 K for 30 minutes under ultrahigh vacuum (<10^{-6} Pa) to remove the impurities. After preheating, 1.0 keV or 3.0 keV D_2^+ implantation was performed to introduce the damage with fluence of 1.0 × 10^{22} D^+ m^{-2}. The deuterium implantation side of sample was placed at the downstream side. These samples were introduced into permeation chamber and sealed with silver coated gaskets. The deuterium permeation experiments were performed at the pressure of 3.00 - 45.00 kPa and temperature of 423 - 1173 K.

Figure shows the deuterium permeabilities for the unirradiated and D_2^+ irradiated samples. The permeation behavior for the unirradiated sample was changed at the temperature of 773 K, indicating two different permeation process existed. The permeation coefficient was determined to be P = (1.52 ± 0.15) × 10^{-10} exp (0.24 ± 0.01 eV / kT) [mol m^{-1} s^{-1} $Pa^{-0.5}$] at 423 K – 773 K and P = (3.39 ± 0.48) × 10^{-7} exp (0.76 ± 0.04 eV / kT) [mol m^{-1} s^{-1} $Pa^{-0.5}$] at 773 K – 1173 K. It is known that the activation energy of deuterium permeation for crystal grain boundary in poly-crystalline W is 0.23 eV. On the other hand, that for crystal lattice in poly-crystalline W is 0.58 eV. These values were good agreement with the present results, suggesting two permeation processes controlled the deuterium permeation and the deuterium diffusion in crystal boundary controlled at lower temperature and deuterium diffusion in the crystal lattice, at higher temperatures. The obtained permeability for the D_2^+ irradiated sample was similar to the unirradiated sample. However, the permeation coefficient was significantly reduced at the lower temperature side for the 3 keV D_2^+-irradiated sample. This suggests that the hydrogen permeation behavior was affected by the formation of the irradiation defects. The deuterium permeability for 3 keV D_2^+-irradiated sample was estimated to be P_{3keV}=(7.11 ± 2.16) × 10^{-5} exp(1.33 ± 0.03 eV / kT) [mol m^{-1} s^{-1} $Pa^{-0.5}$]. It was reported that the activation energy for deuterium de-trapping from vacancies is 1.41 eV [1], indicating that rate determination step for 3 keV D_2^+ irradiated sample was deuterium detrapping from vacancies, which reduced the deuterium permeation rate.

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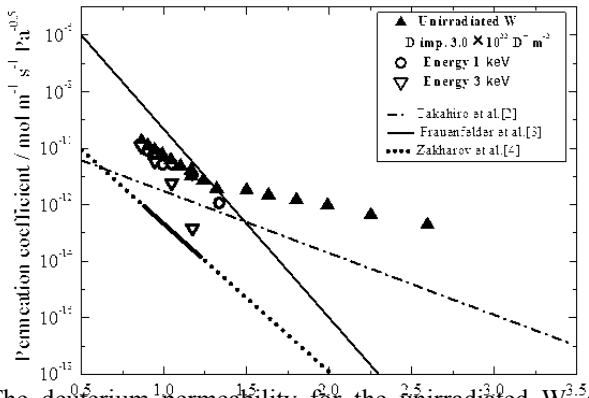

Fig. The deuterium permeability for the unirradiated W, and 1keV or 3 keV D_2^+ irradiated W with reference.