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Bi-directional hydrogen isotopes permeation through a reduced activation ferritic steel alloy F82H

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In a number of recent DEMO reactor studies, including FFHR [1], the breeder serves as a coolant as well in the blanket structures. The first wall will be subjected to bi-directional hydrogen isotopes permeation [2]: in one direction by edge plasma-driven permeation (PDP) of deuterium as well as tritium into blankets, and in the other direction by bred tritium gas-driven permeation (GDP) into the edge plasma. It is important to note that deuterium PDP will hinder the recovery efficiency of tritium from the breeder and will probably necessitate isotopes separation as well. On the other hand, tritium GDP, acting as fueling, will lead to an unwanted increase of the particle recycling in the first wall region, which could even affect core confinement performance as well as isotopes mixture imbalance [3].

Reduced activation ferritic steel alloys such as F82H (Fe-8Cr-2W) are the candidate materials for the first wall of DEMO reactors [4]. In this work, hydrogen and deuterium transport parameters including permeability, diffusivity, solubility and surface recombination coefficient for F82H have been evaluated in the temperature range of 150-500 ℃ and the isotopic mass effect has been discussed. Bi-directional deuterium PDP and hydrogen GDP through F82H has been demonstrated for the first time under controlled experimental conditions.

Shown in Fig. 1 are the results of permeability and diffusivity of hydrogen isotopes for F82H from 150 to 500 ℃. It is commonly assumed that the ratio of diffusivity is equivalent to the inverse ratio of the square root of the masses of the isotopes [5], which relates diffusivity to atomic vibrational frequencies and these frequencies are inversely proportional to mass. The activation energy for diffusion is assumed to be independent of the mass of the isotope, which is supported by our present experimental results.

Shown in Fig. 2 is the result of bi-directional hydrogen isotopes permeation through a 0.5 mm thick F82H membrane at the temperature of ~500 ℃. The membrane is exposed to deuterium plasma at bombarding energy of 100 eV and plasma exposure is controlled by a pneumatic shutter. Recognize that the hydrogen gas partial pressure and D_α signal nicely keep track of each other in the duration period of shutter-on and off. A significant decrease of hydrogen partial pressure is observed when the deuterium plasma exposure is on and the hydrogen partial pressure increases when the plasma is shaded by shutter. Not presented here are similar data taken on hydrogen GDP that flows into the upstream helium plasma. These data indicate that upstream plasma exposure will hinder the hydrogen GDP flux from the opposite direction.

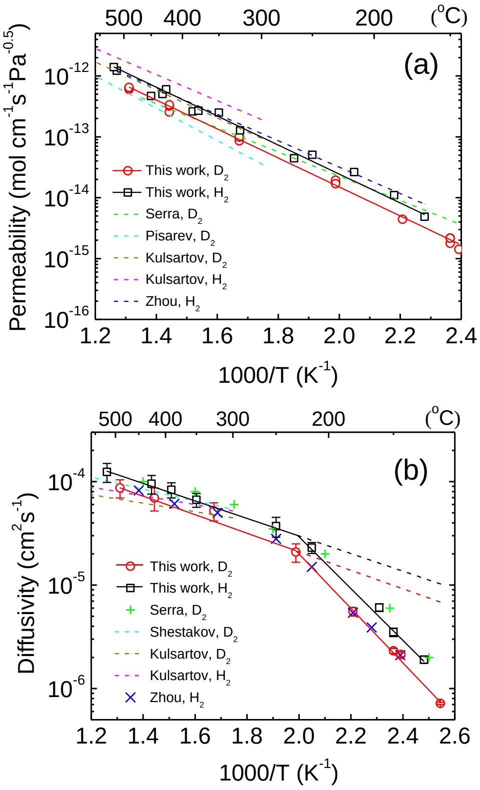

Fig. 1 Permeability (a) and diffusivity (b) of hydrogen isotopes for F82H.

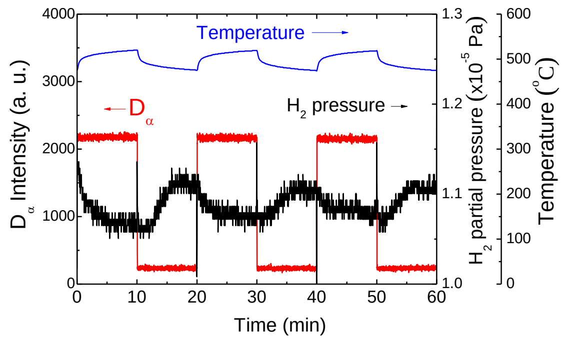

Fig. 2 Measured H_2 partial pressure and D_α-signal at the plasma-facing side. Plasma exposure is controlled by a pneumatic shutter.

References

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