Effect of Re addition on hydrogen isotope permeation behaviour

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Tungsten (W) is a promising candidate for plasma facing materials (PMFs) in fusion reactors due to its higher melting point and lower sputtering yield. W will be exposed to high fluxes of deuterium (D) and tritium (T), as well as helium (He) ash. In addition, 14 MeV neutrons produced by D+T fusion reactions will be irradiated the W PFMs, leading to the transmutation to rhenium (Re) in W matrix. For steady-state operation in a fusion reactor, it is crucial to understand the dynamics of hydrogen isotopes, including desorption, dissolution, trapping/de-trapping and permeation in W-Re alloys. However, knowledge of these dynamics in W-Re is currently limited.

In this study, dynamics of hydrogen isotopes through W-10%Re alloy was studied by plasma driven permeation experiments. Positron annihilation spectroscopy (PAS) using ^{22}Na as a positron source and BaF_2 scintillation detectors, was used to evaluate the size and density of irradiation defects. The specimens were installed in the plasma driven permeation (PDP) device at Shizuoka University, where permeation behaviour was studied at the temperature between 723 K and 823 K. A 13.56 MHz RF power supply with a maximum output of 3 kW was used to generate a 550 W plasma discharge with a neutral pressure of 1.0 Pa. The plasma flux was calculated from the current-voltage (I-V) characteristics measured by a double Langmuir probe, yielding an ion flux of 1.0×10^{21} D m^{-2} s^{-1}. The permeating H_2, HD, and D_2 fluxes were measured using a mass spectrometer calibrated with a deuterium standard leak. Thermal desorption spectroscopy (TDS) was performed to evaluate the desorption behaviour from room temperature up to 1173 K with the heating rate of 0.5 K s^{-1}.

The permeation flux of W-10%Re was higher than W. From permeation flux and diffusion coefficient, recombination constant was calculated by using Pick equation [1]. The recombination constant was decreased by adding Re. Therefore, the D concentration at the sample surface increased, and the permeation flux increased. The D desorption behaviour for both undamaged W and W-10%Re were evaluated after D plasma exposure with the ion fluence of 1.0×10^{25} D m^{-2}. The major D desorption temperatures were found to be in the same temperature range for both samples. Total D retentions for W and W-10%Re were calculated to be 3.47×10^{20} D m^{-2} and 1.18×10^{20} D m^{-2}, respectively. Re migrates between the W lattice and recombines with vacancies, which reduces the number of trap sites [2]. Therefore, the D trapping sites of W-Re was reduced and D retention of W-10%Re was decreased. In this presentation, we will discuss diffusion and release of hydrogen isotopes from these materials based on the results of the permeation and TDS experiment discussed above.

[1] M. A. Pick and K. Sonnenberg, J. Nucl. Mater 131, 208-220 (1985)
[2] X.P.Tian, Y. Xu, et al., Fusion Eng. Des. 211, 114822 (2025)
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