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The influence of neon or argon impurities on deuterium permeation in tungsten
重水素・ネオン/アルゴン同時照射がタングステン中の重水素透過挙動に与える影響

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Mixed D+Ne or D+Ar ion driven permeation experiments were performed to investigate the influence of Ne or Ar impurities on D transport. The D permeation flux for mixed irradiation was lower in comparison to D-only irradiation at T > 500 K, opposite to trends observed for nitrogen. The reason for the observed decrease in permeation flux was interpreted to arise from combined effects of sputtering and possible precipitation. The lag times for D+Ne case was slower than D-only case, while D+Ar was faster.

1. Introduction

In order to reduce the local power load onto tungsten (W) divertor plates and to protect them against melting, impurity seeding has been proposed as method to distribute the power over the entire divertor by radiation. Presently, nitrogen (N) and neon (Ne) are candidate species for use in the divertor region, while argon (Ar) has been proposed for the first wall region [1, 2]. With the introduction of such impurities, the impurities and hydrogen isotopes will irradiate the W surface simultaneously. The resulting interaction can sputter and modify the surface state of W, affecting both hydrogen release and transport in W. Such changes may impact tritium (T) safety due to changes in T retention and permeation rates. Changes in hydrogen transport can be directly studied by ion driven permeation experiments. In our previous study, we have examined the effects of helium (He) [3] or nitrogen [4] impurities, which resulted in a decrease or an increase in permeation flux compared to D-only irradiation, respectively.

The introduction of N, Ne, or Ar can also lead to increased erosion of W by sputtering depending on the local plasma conditions. Ne or Ar are different from N in that it does not chemically bind with W, thus the dominant process should be limited to implantation and physical sputtering only. However, the synergistic effect of surface erosion or its effect on H transport has only rarely been studied experimentally and by modeling [5]. Therefore, in this study we performed mixed D+Ne or D+Ar ion driven permeation experiments to examine the effects of such impurities on D transport and examine for any synergistic effects.

2. Experimental

Permeation experiments were performed using a high flux ion beam test device (HiFIT) coupled with a permeation device at Osaka University [3]. D ions from a microwave-heated plasma discharge was extracted and focused by triode spherical electrodes, forming a D^+, D_2^+, and D_3^+ ion beam. Ne or Ar impurity was introduced into the beam by introducing Ne or Ar gas into the source. The resulting ion beam composition was determined by mass analyzing the extracted beam with a bending magnet. The source gas flow was regulated until Ne or Ar ion fraction with respect to the D ion fraction in the beam was 3.5 ± 0.5 %. The extraction voltage was 1 keV in all experiments.

The specimens used in this study were stress-relieved 99.99 % pure polycrystalline W with a diameter of 34.8 mm and thickness of 31 μm and 61 μm. The specimen temperature range was 500 – 1000 K.

3. Results

In Fig. 1, steady state D permeation flux is plotted as function of temperature for D+Ne and D+Ar irradiation. Also plotted for comparison are values for D-only case. In the case of D+Ne irradiation, steady state permeation flux was almost constant over the entire temperature range. In comparison to D-only irradiation case, permeation flux was lower over the entire temperature range. In the case of D+Ar irradiation, steady state permeation flux was nearly constant at $500 \leq T \leq 800$ K. In comparison to D-only case, permeation flux was lower at $650 \leq T \leq 800$ K, similar at T =

600 K, and higher at 500 ≤ T ≤ 550 K. At T > 800 K, permeation flux decreased with increasing temperature.

To investigate the relationship for D transport and sputtering yield, the lag times were determined from the transient permeation curves. Fig. 2 plots the calculated sputtering yield versus lag time in the temperature range, 550 K < T < 700 K for mixed D+Ne, D+Ar, and D-only irradiation. In all cases, the lag times increase as temperature decreases. The lag time for D+Ar irradiation is shorter in comparison to D-only irradiation, in contrast, the lag time for D+Ne irradiation is much longer than D-only irradiation.

In this presentation, we discuss the influence of Ne or Ar impurities on D transport. We also discuss the implications of using Ne or Ar as impurity species for radiative cooling in a full W-divertor.

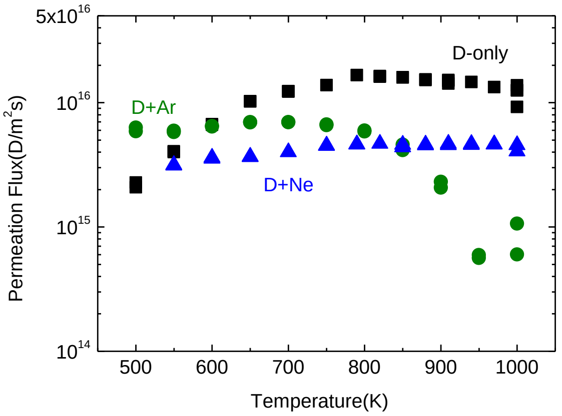

Fig. 1. Steady state D permeation flux for the case of D-only, D+Ne and D+Ar irradiation as function of temperature.

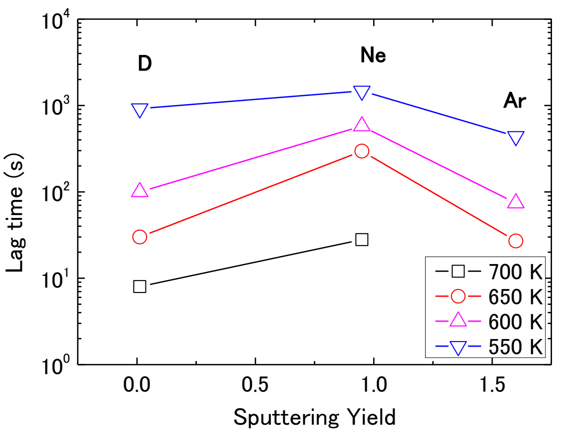

Fig. 2. Calculated sputtering yield versus lag time at T = 700 K, 650 K, 600 K, and 550 K for mixed D+Ne, D+Ar, and D-only irradiation.

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