DEUTERIUM GAS-DRIVEN PERMEATION AND RETENTION IN LA$_2$O$_3$, Y$_2$O$_3$, AND ZRO$_2$ DISPERSION-STRENGTHENED TUNGSTEN

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The addition of small amount of ultrafine oxide particles to tungsten (W) can effectively hinder dislocation and grain boundary migration, thereby improving its high-temperature mechanical properties and toughness, raising the recrystallization temperature, and enhancing its irradiation resistance [1, 2]. Oxide dispersion-strengthened W (ODS-W) are considered promising candidates for the first wall of future fusion reactors. For first-wall materials, the permeation and retention of hydrogen isotopes are closely related to key issues such as plasma steady-state operation, fuel cycling, and radiation safety [3]. However, research on the behavior of hydrogen isotopes in ODS-W has not been extensively conducted.

This study investigates three types of ODS-W: W with 2.0 wt.% La$_2$O$_3$ (WLaO), W with 2.0 wt.% Y$_2$O$_3$ (WYO), and W with 1.0 wt.% ZrO$_2$ (WZrO). The ODS-W used in this study were hot-rolled plates manufactured by AT&M Co. Ltd Inc., China. For the GDP experiments, samples were cut into discs with a diameter of 12.6 mm and a thickness of 1 mm, while for the TDS experiments, they were cut into 10 mm × 10 mm × 1 mm pieces. All samples were taken perpendicular to the rolling direction. They were mechanically polished to a mirror finish and annealed at 1223 K for 2 hours to remove residual gases. The deuterium (D) permeation and retention behavior in these materials were examined using gas-driven permeation (GDP) and thermal desorption spectroscopy (TDS). In the GDP experiments, the samples were clamped between two silver-plated gaskets to be sealed in 1/4-inch VCR couplings. After achieving high vacuum ($\sim 2 \times 10^{-5}$ Pa) on both the upstream and downstream sides, the samples were heated to the target temperature using a tube furnace. D$_2$ was then introduced from the upstream side to initiate permeation, while the downstream D signal was monitored using a quadrupole mass spectrometer. Measurements were performed at 50 K intervals within the temperature range of 973–1123 K. In the TDS experiments, the samples underwent static D$_2$ charging by being exposed to D$_2$ at 1×10^5 Pa and 1173 K for 2 hours. They were then rapidly cooled to room temperature and swiftly transferred into a quartz tube for thermal desorption. After achieving high vacuum ($\sim 2 \times 10^{-5}$ Pa) in the quartz tube, the samples were heated from room temperature to 1500 K at a heating rate of 0.5 K/s, while the desorbed D signal was monitored using a quadrupole mass spectrometer.

The results from the D GDP experiments show that the diffusion rates of D in WLaO and WYO are significantly higher than in pure W. Under the same temperature and driving pressure, the steady-state D permeation fluxes in WLaO and WYO are comparable and approximately twice that of pure W under identical conditions. The D permeability values calculated from the steady-state permeation fluxes are shown in Fig. 1. The gray dashed line represents the D permeability measured by L. Li *et al.* [4] for pure W as a comparison. It can be seen that the permeability of WLaO and WYO is slightly higher than that of pure W, but there is no significant order of magnitude difference. The GDP experiment for WZrO is currently in progress.

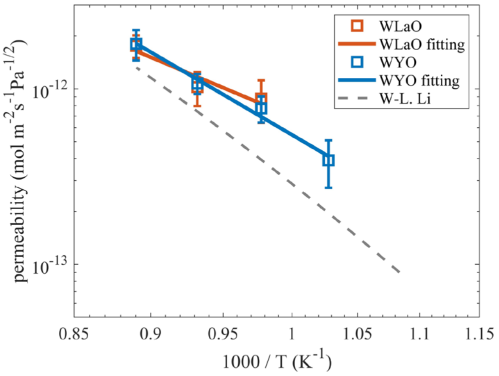

Figure 1 The deuterium permeability of WLaO and WYO compares with pure W [4].

The results of the TDS are shown in Fig. 2, where the gray line represents the data for pure W measured by L. Li *et al*. [4] as a comparison. It can be seen that the D retention in all three ODS-W materials is significantly higher than in pure W. The desorption peak for WLaO occurs at the highest temperature, with D still not completely desorbed even at 1500 K. WYO shows two distinct desorption peaks, indicating the presence of two types of D trapping defects in this material. WZrO exhibits the highest D retention, with the integrated D retention obtained from the TDS being approximately 1.6 × 10^{-3} mol·m^{-2}, which is three orders of magnitude higher than the D retention of 3.8 × 10^{-6} mol·m^{-2} in pure W.

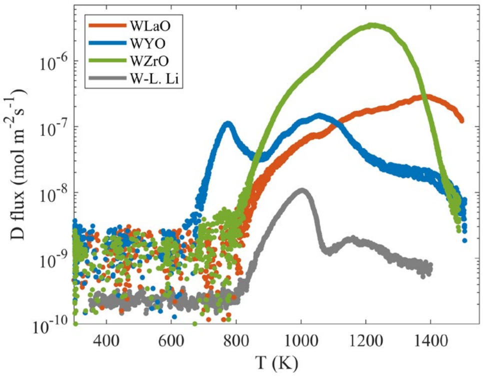

Figure 2 Thermal desorption spectroscopy of WLaO, WYO, and WZrO compares with pure W [4].

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