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Deuterium Retention Behavior in Tungsten After Plasma Exposure at Varying Temperatures

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Temperature plays a critical role in the behavior of deuterium (D) in tungsten (W), a key material for plasma-facing components in fusion reactors. This study investigates the effects of temperature variation on D retention, surface blistering, and defect evolution in W. Two sets of temperature rising (TR) and temperature declining (TD) irradiation experiments were conducted in the temperature ranges of 420 K–590 K and 320 K–720 K.

The deuterium-induced surface blistering behavior was markedly different between the two temperature ranges. In the 420 K–590 K range, the TD exposure resulted in more severe surface blistering, while the TR exposure reduced the formation of intragranular blisters. For the 320 K–720 K irradiation, both TR and TD exposures led to dense blister formation on the tungsten surface, including both intragranular and intergranular blisters, though with different blister densities and average sizes. Statistical analysis of the surface blisters showed that the TD exposure favored the formation of smaller intergranular and intragranular blisters, whereas TR exposure promoted the growth of larger blisters.

In the 320 K–720 K irradiation experiment, both pristine and pre-damaged tungsten were compared to evaluate the influence of temperature variation on the pre-damage effect. The results showed that pre-damage suppressed intragranular blister formation, accelerated intergranular blister growth, and enhanced D retention in both TR and TD exposures, in agreement with previous studies. However, the exacerbating effect on intergranular blisters was more pronounced in the TR exposure, while the suppressive effect on intragranular blisters was reduced under the TD exposure.

Thermal desorption spectra revealed that D retention was significantly higher in the TD exposures compared to the TR exposures. The analysis of deuterium desorption peaks suggests that intrinsic defects in tungsten could evolve and cluster into larger ones in the TR exposure, which acted as higher-energy D traps. The evolution of pre-damaged defects in TR exposure was even more pronounced.

These studies highlight the significant impact of temperature variation during plasma exposure on D behavior and defect evolution in tungsten. Understanding these effects is crucial for optimizing the performance of plasma-facing materials in fusion reactors, where temperature fluctuations during exposure are inevitable.

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