Suppression of vacancy formation and hydrogen isotope retention in irradiated W-Cr alloy

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Alloying is one of promising ways to minimize the hydrogen isotopes retention in irradiated W, which is a key issue for safe operation of future fusion devices. Hatano et al. [1] have examined the D retention and the positron lifetime in W and W-5 at.% Re alloy irradiated with 6.4 MeV Fe ions at elevated temperatures. They observed a significant suppression effects of Re on the formation of vacancy-type defects and the D retention at temperatures ≥ 773 K. On the other hand, Wang et al. have reported that Ta and Mo showed no significant alloying effects [2]. According to Suzudo et al. [3, 4], the Re atom reduces the effective mobility of the W self-interstitial atom (SIA) by forming a mixed dumbbell and enhances recombination with a vacancy. The binding energy of the Mo atom with the SIA is far lower than that of Re, while Ta do not form stable mixed-dumbbells. They predicted that Cr has the larger binding energy with W SIA than Re [4]. However, the alloying effects of Cr have not been examined by experiment.

Plates of W-0.3 at.% Cr alloy were irradiated at 523–1273 K with 6.4 MeV Fe ions to 0.5 dpa at the damage peak. The irradiated samples and non-irradiated ones were exposed to D_2 gas at 100 kPa and 673 K for 10 h. D retention was measured by thermal desorption spectrometry in which a sample was heated up to 1273 K at the ramp rate of 0.5 K/s. The positron lifetimes of non-irradiated and irradiated samples were also measured.

The D retention in the W-0.3 at.% Cr alloy was substantially smaller than that in W and comparable to or even lower than that in W-5 at.% Re alloy. The mitigation effects by Cr addition increased with increasing irradiation temperature. No noticeable increase in positron lifetime was observed for W-0.3 at.% Cr alloy after the irradiation, while the lifetime in W showed a clear increase. The results led to the conclusion that the addition of 0.3 at.% Cr is effective to mitigate the formation of vacancy type defects under high temperature irradiation and the increase in D retention by trapping effects. This conclusion is consistent with the predictions by Suzudo et al. [4] based on first principles calculations about the binding energy between a solute atom and a W-SIA.

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