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ABSTRACT

Deuterium transport and trapping in self-ion irradiated tungsten: influence of irradiation temperature, damage dose, and alloying elements

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Tungsten (W) is a prime candidate material for plasma-facing components (PFCs) in magnetic confinement fusion devices. PFCs will be subjected to high fluxes of 14 MeV neutrons. This will result in creation of lattice defects and production of transmutation elements, particularly rhenium (Re). Lattice defects are trapping sites for hydrogen (H) isotopes, resulting in retarded H transport and increased H inventory in W.

To simulate the neutron-induced displacement damage, W samples were irradiated by 20 MeV W-ions at 290 K, 800 K, and 1350 K to peak damage doses in the range of 0.001–2.3 dpa. To study the effect of Re transmutation products, W samples containing 0, 1, 3, and 5 at.% Re were irradiated to 0.5 dpa at 290 K and 1350 K. The irradiated samples were exposed to a low-flux deuterium (D) plasma at 370 K. Trapped D concentration profiles were measured using D(^{3}He, p)^{4}He nuclear reaction analysis.

In the cases of irradiation of pure W at 290 K and 800 K, the trapped D concentration increases with increasing damage dose up to 0.1 dpa, where it reaches a saturation value (1.8 at.% at 290 K and 0.45 at.% at 800 K). In the case of irradiation at 1350 K, no clear trend towards saturation is visible: at 2.3 dpa the D concentration reaches 1.7 at.%. Thermal desorption spectra (TDS) from the samples irradiated at 1350 K differed significantly from the spectra of the samples irradiated at 290 K and 800 K. This is attributed to the change of the D trapping mechanism, related with the formation of nm-sized irradiation-induced voids at 1350 K. Re addition has little effect on the trapped D concentration and the nature of trapping sites in the case of irradiation at 290 K. In the case of irradiation at 1350 K, the trapped D concentration monotonically decreases with increasing Re concentration: in W-5%Re it is 50 times smaller than in pure W. This is attributed to the reduction of void growth caused by the presence of Re.