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Deuterium trapping and release from high-temperature ion irradiated tungsten: experiments and reaction-diffusion simulations

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Tungsten (W) is considered as a promising plasma-facing material for future fusion reactors. W components will be subjected to an intense flux of 14 MeV neutrons. This will result in the production of displacement damage and material transmutation. W components will operate at elevated temperatures (673-1300 K), which will favor the formation of irradiation-induced voids. These voids will act as trapping sites for the hydrogen (H) isotopes. So far, little is known about their H trapping characteristics.

In order to simulate the neutron-induced displacement damage, recrystallized W samples were irradiated by 20 MeV self-ions at 1350 K to peak damage doses ranging from 0.001 to 2.3 dpa. To decorate the introduced defects with deuterium (D), the samples were exposed to a low-temperature D plasma at 370 K. Concentration profiles of trapped D in the samples were measured using D(3He,p)4He nuclear reaction analysis.

In contrast to the irradiations near room temperature, where the trapped D concentration reaches saturation at damage doses above 0.1 dpa, no clear trend towards saturation is visible at 1350 K. The D concentrations in the samples irradiated at 1350 K to 0.1-2.3 dpa are considerably higher compared with the extrapolation of the existing data on ion-irradiated tungsten at different temperatures (up to 1243 K).

Thermal desorption spectra (TDS) from the samples irradiated at 1350 K differed significantly from the spectra of the samples irradiated near room temperature, demonstrating the change of the D trapping mechanism. Transmission electron microscopy (TEM) investigations of the samples irradiated to 0.1, 0.5, and 2.3 dpa revealed the presence of nm-sized irradiation-induced voids. The damage dose dependence of the void swelling correlated with the damage dose dependence of the trapped D concentration in these samples.

Reaction-diffusion simulations assuming that all trapped D is located in the voids as D2 gas in the volume and as D atoms at the surface were performed. Void number densities and average sizes derived from the TEM observations were used in the simulations. The model could reasonably reproduce the kinetics of D uptake in the samples during the D plasma exposure and the TDS spectra.

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