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The influence of displacement damage on helium interaction with and retention in tungsten

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In a future nuclear fusion reactor, the inner wall components facing the deuterium-tritium-plasma will be subjected to a significant flux of helium (He) as a product of the fusion reaction. Tungsten (W) is considered as the most favorable plasma-facing material because of its good thermal properties, low solubility for hydrogen isotopes, and the high energy threshold for physical sputtering. However, He bombardment is known to degrade the mechanical and thermal properties of W and various studies have shown a complex influence of the presence of He on the retention of hydrogen isotopes in W. In order to make sound predictions for future nuclear fusion devices such as ITER, a fundamental understanding of the He-W interactions is necessary.
In this study, the influence of pre-existing displacement damage on the early stages of helium interaction with tungsten as well as the resulting defect creation through He clustering mechanisms was investigated experimentally. Samples were irradiated with 20.3 MeV W ions to different displacement-damage levels of 0.005, 0.01 and 0.1 displacements per atom (dpa). Displacement-damaged samples were exposed to a He plasma at room temperature at a He flux in the range of 10¹⁸ He/m²s to fluences of up to 10²² He/m² together with pristine W samples. He ion energy of 100 eV was used to remain well below the threshold for displacement damage creation in the bulk. Elastic recoil detection analysis (ERDA) shows that the He retention in the damaged samples is one order of magnitude larger than in the undamaged sample. Detailed He depth distributions were obtained by stepwise removal of near-surface layers (via anodic oxidation followed by the dissolution of the oxide) and subsequent ERDA measurements of the remaining He content. Pre-damaged samples show a significantly faster decrease in He concentration with depth than the undamaged sample, indicating that He is efficiently stopped from diffusing into deeper regions beyond 30 nm by pre-existing defects. The undamaged sample exhibits a lower He concentration in the near surface region and a flatter distribution of He up to a depth of 100 nm. Since our data shows the displacement damage level to be the determining factor of the on the He uptake and retention we conclude that He self-trapping mechanisms do not yet have a strong effect on the He diffusion depth in W at the low He fluxes used in this study.

Category

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