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Influence of the Presence of Deuterium on Damage Evolution in Tungsten

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The influence of the presence of deuterium (D) on damage evolution at elevated temperatures was studied for self-ion irradiated tungsten (W). W samples were irradiated by 20.3 MeV W ions at room temperature to the peak damage dose of 0.23 dpa and loaded with a low-temperature D plasma at 370 K to decorate the created defects. Low energy (< 5 eV/D) and low flux (5.6x1019 D m-2s-1) was used to make sure plasma exposure does not create additional defects. Afterward, samples were heated during plasma loading at four different temperatures, ranging from 470 K to 770 K. The appropriate annealing time was calculated applying the rate equation modelling code TESSIM-X. For accurate quantitative comparison, annealing experiments at each temperature were carried out also in vacuum. Nuclear reaction analysis (NRA) with 3He was used to determine the D depth profile and thermal desorption spectroscopy (TDS) was used to measure the total retention and de-trapping energy of D.

Both vacuum annealing and plasma annealing exhibit a decrease in D retention with increasing annealing temperature. Decorating all samples after annealing again with the same D plasma allows to differentiate between the effects caused by thermal de-trapping and defect evolution. Combined with results from plasma-annealed samples without D reloading, it is found that most of the decrease in D retention during annealing is due to thermal de-trapping, and only a small portion is due to defect evolution. The presence of D during annealing has a small stabilizing effect on the defects. The results differ from the plasma annealing results reported in [1] but align with the vacuum annealing results in [2]. All TDS spectra can be described consistently with six different traps with energies of 1.05-1.10 eV, 1.25-1.28 eV, 1.39-1.46 eV, 1.72-1.74 eV, 1.94 eV for the defects created by the W irradiation within the first 2 µm, and 1.18 eV for the intrinsic defects. The fitting results show that defects with a lower de-trapping energy for D are more prone to thermal annealing, while those with a higher de-trapping energy for D remain more stable. Consistent with [2] the trap with the highest de-trapping energy for D is not affected up to 770 K. The trap with the lowest de-trapping energy for D starts to decrease in density already above 470 K.

[1] M.J. Simmonds et al., Nucl. Fusion 62 036012 (2022)
[2] M. Pečovnik et al., Nucl. Fusion 60 106028 (2020)