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Possible defect stabilization due to simultaneous D plasma exposure during annealing in self-ion damaged W

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The typical defect recovery observed for vacuum annealed self-ion damaged tungsten (W) samples was significantly reduced for samples simultaneously exposed to deuterium (D) plasma during annealing. In these experiments, W samples were all polished, pre-annealed, and then damaged with 20 MeV W ions. Samples were divided into two groups to be annealed either with or without simultaneous D2 plasma exposure. The simultaneous annealed samples were first decorated by D2 plasma at 383 K prior to ramping up to an annealing temperature of 473, 573, 673, or 773 K and held for 1 h with concurrent plasma exposure. The exposure at low sample temperature ensured high D occupancy and simultaneous exposure/annealing maximized available D to populate the heavy-ion induced defects at elevated temperature. The vacuum annealed samples each had a corresponding temperature history but without D2 plasma treatment. Finally, all samples were exposed to D2 plasma at 383 K to decorate the remaining defects.

Nuclear reaction analysis (NRA) and thermal desorption spectroscopy (TDS) show that the simultaneous plasma exposed/annealed samples exhibited virtually no defect recovery at annealing temperatures of up to 673 K, and had higher D retention than found in the vacuum annealed samples. TDS results indicate that only the lowest detrapping energy defects recover at a 773 K anneal for the simultaneous plasma annealed samples. As seen in previous annealing studies, the vacuum annealed samples showed defect recovery at all anneal temperatures.

This experiment clearly demonstrates that D occupied defects can significantly reduce or eliminate defect annealing in W, and is consistent with the existence of synergistic plasma exposure/displacement damage effects in fusion-energy relevant plasma facing materials. In addition, previous work by Pečovnik et al. [1] demonstrates a similar result of reduced defect recovery for a sequential D2 plasma exposure followed by annealing. Though the effect is more evident for simultaneous plasma exposure that acts to increase the D occupation of defects. As such, it is likely that the observed reduced recovery is due to defect stabilization.

References:

[1] Pečovnik M., Markelj S., Kelemen M. and Schwarz-Selinger T. 2020 Effect of D on the evolution of radiation damage in W during high temperature annealing Nucl. Fusion 60 106028

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