Hydrogen and helium interaction with bcc metals and alloys

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Body-centred cubic (bcc) refractory metals and alloys are key candidates for plasma-facing and structural components in future fusion devices. Tungsten is the reference material for divertor applications because of its high melting point, low sputtering yield and favourable thermal properties. However, energetic-particle exposure produces defects that modify the interaction of the material with hydrogen isotopes and helium.

This contribution investigates irradiation-induced defect evolution in bcc metals, using tungsten as a model system, and explores how these defects influence the trapping, transport, and retention of light elements. Heavy-ion irradiation was used as a non-activating proxy for neutron-induced damage. Polycrystalline tungsten reference samples were irradiated with W ions at 800 K and 1000 K, with damage doses ranging from 0.02 to 0.8 dpa. At these temperatures, vacancies become mobile and can cluster, making the competition between dislocation loop formation, void nucleation, and defect annealing a key factor controlling the resulting microstructure. The damaged samples were characterized by combining X-ray diffraction, transmission electron microscopy and deuterium retention analysis using ^{3}He nuclear reaction analysis. Such multi-scale approach correlates average lattice distortion with direct imaging of nanoscale defects and quantitative hydrogen-isotope trapping. At low damage dose, dense distributions of small dislocation loops dominate the microstructure, while higher doses promote the formation of nano-sized voids. The deuterium concentration increases with increasing damage dose, demonstrating a clear connection between irradiation damage and hydrogen-isotope retention.

The results provide a basis for understanding how light elements interact with radiation-induced defects in bcc metals and alloys under fusion-relevant conditions, and contribute to predicting fuel retention, swelling, embrittlement and long-term performance of plasma-facing materials.