Helium bubble super-lattice formation, grain boundary agglomeration, and surface blistering of tungsten under combined helium implantation and self-ion irradiation

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Tungsten is an important identified candidate material for fusion applications. Numerous studies have been performed to understand swelling and blistering of tungsten under helium ion implantation. However, very limited data are available for dual-beam irradiation with helium under adjustable helium appm/dpa ratios. In the present study, a dual beam irradiation was conducted using 100 keV helium ion irradiation to introduce helium at the ~200 nm depth region and 3.5 MeV W ion irradiation to introduce damage cascades at the same depth as a way to simulate fusion neutron environment damage. The He and W fluences were adjusted to achieve a ratio of one order of magnitude difference.

We found that at low and intermediate dose levels, tungsten develops helium bubble super-lattices. With increasing dose, bubbles grow larger and become randomly distributed. In the presence of ordered super-lattice structures, the defect sink strength of grain boundaries becomes rather limited. At a later stage with larger and random bubbles, bubble agglomeration at grain boundary becomes significant, leading to intergranular cracking. At the peak helium region, micro-cracking develops due to bubble linkage. With increasing damage from W self ion irradiation, structural failure starts at much lower helium doses. Furthermore, we compare the blistering phenomena in several tungsten variants having different grain boundary densities and sizes, prepared using several deformation techniques. This study shows that resistance to swelling and blistering can be tuned using such boundary engineering.

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