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Growth of helium bubbles in tungsten under realistic rates

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The growth process of helium bubbles in tungsten is investigated using molecular dynamics and parallel replica dynamics for growth rates spanning six orders of magnitude (10^{12}–$2\times10^{6}\,\mathrm{He\,s^{-1}}$). Our results show clear differences in the evolution of bubbles as a function of the growth rate, a consequence of competing kinetics at the atomic scale. Fast and slow growth regimes are defined relative to typical diffusion hopping times of tungsten interstitials around the helium bubble. For a given number of helium atoms, slow (realistic) growth rates allow the diffusion of interstitials around the bubble. Due to the extended nature of the associated crowdions and their elastic interaction with the surface, this diffusion process favours the biased growth of the bubble towards the surface. In contrast, at fast growth rates interstitials do not have sufficient time to diffuse around the bubble. This leads to a more isotropic growth and allows the bubbles to grow larger before they burst, increasing the damage on the surface. Our results demonstrate the importance of capturing the correct relative rates of competing atomic-scale kinetic processes in describing larger scale phenomenon and have implications for the growth of fuzz, a detrimental phenomenon observed in plasma-irradiated tungsten.