Numerical study of tungsten fuzz tendril behaviour during rapid heating

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Fuzzy nanostructures form on tungsten surfaces under helium plasma exposure, relevant to conditions in fusion devices [1]. The growth of such helium-filled nanostructures can raise the probability of unipolar arc ignition [2], thereby enhancing the erosion of plasma-facing materials. Herein, we use molecular dynamics simulations to investigate the atomistic behaviour of individual fuzz tendrils under rapid heating. The heating rates considered in the simulations are based on theoretical estimations of the fuzz thermal balance [2], which account for Joule heating and reduced thermal conductivity [3]. The simulation results identify a critical heating rate of ∼100 K/ps order. Exceeding this rate leads to the explosive destruction of a nanowire. At lower heating rates, a more gradual structural change via bubble rupture and sublimation is observed. Furthermore, by modelling the interaction between an exploding nanowire and a neighbouring stable structure, we demonstrate that the high-energy flux of ejected material from the primary structure transfers sufficient kinetic energy to the adjacent nanowire to destabilize its internal helium bubbles, initiating a secondary release event. These findings reveal a detailed atomistic mechanism for the initiation and potential cascade propagation of explosive thermal damage within tungsten fuzz layers. The work was supported by the Russian Science Foundation (grant No. 22-12-00274-P).

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