Radiation damage in gallium-stabilized δ-plutonium with helium bubbles

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Abstract

Plutonium serves as a key fissile component for both nuclear weapons and the uranium plutonium mixed oxide fuel. The continuous self-irradiation events result in the accumulation of lattice defects and helium bubbles, which dominants the aging process and threatens the effective applications of related materials. Molecular dynamics simulations are conducted on gallium-stabilized δ-plutonium with pre-existing helium bubbles to find out the role of helium on microstructure evolutions. It is found that bubble promoting effect dominates the production of point defects, resulting in increasing number of Frenkel pairs. Further investigation reveals an energy transfer discrepancy and altered spatial morphology of point defects induced by mass effect. The formation of stacking faults surrounding the disordered core is studied and their binding effect on the propagation of point defects is intuitively observed. Moreover, the helium behaviors driven by internal pressure during the cascade is presented. The two initial helium bubbles coalesce first and are then completely resolved in the hot spike, followed by the subsequent re-nucleation and shrinkage of the newly formed bubble. Understanding the role of helium is an important issue in the studies of self-irradiation effects in δ-plutonium, which contributes to the aging mechanisms of plutonium-based materials.

Keywords: Radiation damage; Plutonium; Helium bubbles; Molecular dynamics