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PROCEEDINGS

Dislocation Climb Driven by Lattice Diffusion and Core Diffusion

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ABSTRACT

Diffusion of material has a crucial influence on dislocation motion, particularly at elevated temperatures. It is generally believed that, in a single crystal, lattice diffusion prevails when the temperature is high and core diffusion dominates at relatively low temperatures. Due to the complexity of modelling the coupling between core and lattice diffusion, a given physical problem is often simplified into two extremes where only one of the two diffusion regimes is considered. However, a quantitative definition of the condition under which each of the diffusion mechanisms is dominant is still lacking. In the present work, we employ a variational principle for the analysis of microstructure evolution; we demonstrated how finite element (FE) based analysis can be developed from it, in which the competition and synergy between core diffusion and lattice diffusion can be naturally taken into consideration. A dislocation climb model is further developed by incorporating the FE analysis into the nodal-based three-dimensional dislocation dynamics framework, which also considers glide and cross-slip processes. A systematic study of the coalescence of prismatic dislocation loops (PDLs) at various conditions is conducted based on the proposed method; together with the analytical solutions of the motion of a circular PDL controlled by core and lattice diffusion, a diffusion mechanism map is constructed, which provides useful guidance on determining the dominant diffusion mechanism for given loop sizes, spacing, and temperature. The results show that, in a practical loop coarsening process, core diffusion provides a fast short circuit for local atomic rearrangement, so that it is dominant when loop size or the distance between loops is small, particularly at temperatures lower than 0.5Tm (Tm is the melting point of a given material). While, at high temperatures, when the distance between loops is large or when the loop size is large, lattice diffusion becomes more efficient. The present findings indicate that simultaneous consideration of both core and lattice diffusion is necessary to quantitatively understand the microstructure evolution for dislocation climb-related physical processes, such as creep and post-irradiation annealing.

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