Coupled Crystal Plasticity/Vertex Dynamics Modeling of Static Recrystallization in Iron

Jaime Marian

University of California, Los Angeles

ABSTRACT

Recrystallization of metallic materials is an important metallurgical treatment to bring cold-worked alloys to a usable state. Static recrystallization (SRX) occurs after deformation, once the material has built up sufficient plastic strain energy to trigger grain boundary motion. However, we have very limited knowledge about the combined effects on recrystallization kinetics of temperature, amount of cold working, triple junction mobility, and level of recovery in the deformed microstructure. In particular, little is still known about the microstructural factors that control the onset of SRX. Here we present a comprehensive physical model based on coupling crystal plasticity and grain boundary kinetics that utilizes curvature and differential plastic strain energy as driving forces for SRX in polycrystalline iron. The model links finite-element polycrystal plasticity simulations with a two-dimensional vertex dynamics approach, and is used to probe the large parameter space influencing static recrystallization. Our main finding is that the initial texture (defined by the polycrystal's grain orientation and size distribution) is the dominant feature triggering and controlling SRX kinetics. We find a direct correlation between the degree of dislocation density buildup and the relative grain orientation across a grain boundary at the beginning of the deformation phase. Indeed, analysis of our results points to the maximum Schmid factor of a grain as the best predictor for activation of its grain boundaries during the recrystallization phase. We also find that the amount of post-deformation recovery only has a limited effect on the evolution of the recrystallized microstructure. Finally, using a definition based on the rate of transformation of the material, we find a recrystallization temperature of 600C, consistent with experimental observations in high-purity iron specimens.