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ABSTRACT

The Hidden Relationships Between Grain Boundary Diffusion, Grain Boundary Segregation, and Grain Boundary Motion

This presentation examines the pivotal role of grain-boundary diffusion in stabilizing polycrystalline and, particularly, nanocrystalline materials against grain growth. Thermodynamic stabilization can be achieved by reducing the grain-boundary free energy through solute segregation. Because grain-boundary free energy and grain-boundary diffusion are closely linked, segregation not only lowers the thermodynamic driving force for grain growth but also influences the kinetics of grain-boundary transport. We critically reexamine the Borisov relation between grain-boundary diffusion and grain-boundary free energy, explicitly identifying the assumptions on which it is based and delineating the limits of its applicability to different grain-boundary diffusion mechanisms. Solute segregation also stabilizes microstructures by reducing grain-boundary mobility. Grain-boundary motion is suppressed through several mechanisms, including the classical solute-drag effect and a recently proposed self-pinning mechanism. The latter arises from phase separation within the segregation atmosphere surrounding a moving grain boundary, leading to the formation of pinning clusters. Both the phase separation process and the kinetics of cluster formation are controlled by grain-boundary diffusion. The presentation will highlight the interplay between thermodynamic and kinetic stabilization mechanisms and explore how controlling grain-boundary diffusion can offer new opportunities to enhance the thermal stability of polycrystalline microstructures.