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Enhancement of solid-state reaction rates by non-hydrostatic stress effects on polycrystalline diffusion kinetics

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Abstract

Reaction layer growth between two chemically different solids may be controlled by polycrystalline diffusion kinetics in the growing phase. The kinetics depend on the interplay between volume and grain boundary diffusion. Using spinel formation between single crystals of periclase and sapphire as an example, we quantify the effects of an applied mechanical stress on the bulk-transport properties of the reaction layer. The rate of spinel growth increases fourfold when stress normal to the reaction interface increases from 3 to 30 MPa due to stress-induced changes in grain boundary structure. At low applied stress, low-index (i.e., Σ3) "coincidence site lattice" grain boundaries with slow diffusion coefficients dominate, related to epitactic growth of spinel on sapphire. Increasing stress triggers epitactic growth of spinel on periclase, and causes sapphire-grown spinel grains to rotate out of epitaxy, and grain boundaries with fast diffusion coefficients dominate. This effect outweighs the hitherto emphasized influence of grain size on the bulk transport properties of polycrystals.

Keywords: Spinel, mineral reaction, reaction kinetics, epitaxy, non-hydrostatic stress