

The Mechanism of Solute-Drag and Catalyzed Grain Growth in Alumina

Grain boundary mobility in ceramics can be extremely sensitive to segregating dopants or impurities. Using α -Al₂O₃ as a model system, we examined how Ca²⁺ and Fe dopants (with mixed Fe³⁺/Fe²⁺ valencies) influence GB mobility. In Al₂O₃ doped with Ca below the solubility limit, Ca segregates to grain boundaries and increases the GB mobility, likely through charge-compensating oxygen vacancies. Dense Fe-doped Al₂O₃ (0.18–2.93 wt.% Fe), well below the solubility limit at 1600 °C (8.9 wt.%), was annealed in air or Ar. In air, grain growth was suppressed by solute drag: the GB mobility decreased with increasing Fe content, consistent with Fe³⁺ segregation at grain boundaries. In contrast, annealing in Ar increased the GB mobility and produced anisotropic grain growth, similar to Ca-doped Al₂O₃. X-ray photoelectron spectroscopy (bulk) and electron energy-loss spectroscopy (grain boundaries) show that lowering the oxygen partial pressure shifts Fe toward Fe²⁺ and increases the oxygen-vacancy concentration. White-line ratio analysis of the Fe L_{2,3} edges indicates that anisotropy arises from selective segregation of Fe³⁺/Fe²⁺ to specific GBs, which alters their mobility and promotes elongated grains. Fast-moving GBs are enriched in Fe²⁺ relative to slow-moving boundaries. These results demonstrate control of alumina grain size and morphology by tailoring dopant valence states and oxygen-vacancy concentrations.

Professional Status of the Speaker

Senior Scientist

Interest in submitting a paper in a special issue of

No interest

Invitation letter for visa

No

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Session Classification: Microstructure evolution during sintering and Microstructure-property relationships

Track Classification: Group 1: Microstructure evolution during sintering and Microstructure-property relationships