

Boundary-Layer Analysis of Chimney Structures in Mushy Layers

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When a multicomponent fluid solidifies against a cooled boundary, morphological instability can lead to growth of dendritic crystals of one component that form a porous medium, with interstitial liquid that is rich in the other components. Convection driven by compositional buoyancy can subsequently dissolve the solid crystals in narrow channels, which are called chimneys. We study the structure of a steady-state chimney theoretically. This requires analysis of coupled nonlinear partial differential equations characterizing the solute concentration, temperature, solid fraction and the flow field. We use boundary-layer analysis and find similarity solutions that are valid in the vicinity of the chimney. As well as obtaining a prediction for the variation in the heat and solute concentration fields and the flow, we predict the mass and solute flux through the chimney and its width.

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