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Dendritic zircon formation by deterministic volume-filling fractal growth: Implications for the mechanisms of branch formation in dendrites

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Abstract

In this paper, I demonstrate that the complex structure observed in natural dendritic zircon, which crystallized from a mafic magma, can be approximated by a simple model of deterministic volume-filling fractal growth. The model comprises a novel dendritic growth process that reveals a previously unrecognized underlying structure to complex dendritic crystals, and provides an ideal way of maximizing surface area at the crystal-melt interface during dendritic crystal growth. This addresses the important kinetic effect of creating interfacial area. In turn, this relates to dissipation of the latent heat of fusion from the moving crystal-melt interface, which, in addition to chemical diffusion, is known to be a fundamental rate-controlling process in dendritic crystal growth.

A new mechanism of tip-splitting branch formation in dendritic crystals is proposed. Although both types of branch formation seem to occur simultaneously, the newly proposed mechanism operates at larger length scales and independently of classical side-branching linked with periodic perturbations caused by thermal noise. It is shown that this type of modeling potentially has applications in metallurgical engineering; and in predicting the relative lengths, orientations, and spacings of branches in mathematical modeling studies of natural and experimentally grown dendritic crystals.

Keywords: Dendrite, zircon, fractal, alloy casting, crystal growth