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Microgravity Sciences Onboard the International Space Station and Beyond - Part 1 (6)

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PRIMARY SPACING EVOLUTION DURING MICROSTRUCTURE FORMATION IN 3D DIRECTIONAL SOLIDIFICATION: MICROGRAVITY EXPERIMENTS CONDUCTED IN THE DECLIC-DSI

Abstract

The study of solidification microstructure formation is of utmost importance for the design and processing of materials, as solid-liquid interface patterns largely govern mechanical and physical properties. Pattern selection occurs under dynamic conditions of growth in which the initial morphological instability evolves nonlinearly and undergoes a reorganization process. This dynamic and nonlinear nature renders in situ observation of the solid-liquid interface an invaluable tool to gain knowledge on the time-evolution of the interface pattern. In this framework, the materials of choice for direct visualization of interface dynamics are transparent organic analogs that solidify like metallic alloys. Extensive ground-based studies of both metallic and organic bulk samples have established the presence of significant convection during solidification processes that alters the formation of cellular and dendritic microstructures. The reduced-gravity environment of Space is therefore mandatory for fluid flow elimination in bulk samples.

Over a hundred days of experiments were carried out in the Directional Solidification Insert (DSI) of the Device for the Study of Critical Liquids and Crystallization (DECLIC), developed by the French Space Agency (CNES) in collaboration with NASA and installed onboard the International Space Station. The DSI offered the unique opportunity to observe in situ and characterize the entire development of the microstructure in extended 3D patterns under diffusive growth conditions, using bulk samples of transparent organic alloys. Analysis and interpretation of our experiments is considerably enhanced by

corresponding phase-field computational modelling.

A selection of some of our most striking results will be presented. These focus on crystal grain competition and the dynamics of primary spacing selection, highlighting the effects of crystal orientation, grain boundary configurations, solidification front velocity, and macroscopic interface curvature. We will also discuss selected quantitative comparisons of the experiments with phase-field simulations that shed light on fundamental mechanisms of interface pattern selection.

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