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Microgravity Sciences on board ISS and beyond (6)

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DYNAMICS OF SOLIDIFICATION MICROSTRUCTURE FORMATION IN DECLIC-DSI ONBOARD ISS

Abstract

The study of solidification microstructure is of utmost importance for materials design, as solid-liquid interface patterns largely govern mechanical 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 interface an invaluable tool to gain knowledge on the time-evolution of the interface pattern. Transparent organic analogs, which solidify like metallic alloys, allow direct visualization of interface dynamics. Extensive ground-based studies of bulk samples have established the presence of significant convection during solidification processes that alters the formation of interfacial microstructures. A reduced-gravity environment is therefore mandatory for fluid flow elimination.

In the framework of the CNES project MISOL3D (MIcrostrutures de SOLidification 3D) and the NASA project SPADES (SPAtiotemporal Evolution of three-dimensional DEndritic array Structures), we participated in the development of the Directional Solidification Insert (DSI) of the DEvice for the study of Critical Liquids and Crystallization (DECLIC). The DECLIC-DSI is dedicated to in situ and real-time characterization of solid-liquid interface patterns during directional solidification of transparent alloys in diffusive transport regime onboard ISS. Between 2010 and 2011, the first space campaign (DSI) explored the entire range of microstructures resulting in unprecedented observations essentially related to cellular patterns. A second campaign (DSI-R), performed between 2017 and 2018, expanded the benchmark database, particularly in the dendritic regime. In DSI-R, the alloy solute concentration was increased, leading to the formation of well-developed dendritic patterns. The microstructure resulting from dendritic growth has large consequences for material properties in metallurgy. Additional DSI-R experiments will be performed during 2022, to obtain interferometric images that provide precise, quantitative measurement of dendrite tip characteristics.

A review of the most outstanding observations will be presented, especially regarding the spatiotemporal evolution of the primary spacing, the main characteristic of a microstructures pattern: the effects of pulling velocity, concentration, misorientation, or interface curvature will be discussed. The analysis and interpretation of the experiments performed onboard ISS are considerably enhanced by experiments performed on the ground using thin-samples (Pr. Trivedi's group) and phase-field simulations (Pr. Karma's group).