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

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THREE-DIMENSIONAL CELLULAR AND DENDRITIC PATTERNS UNDER DIFFUSION TRANSPORT: IN SITU CHARACTERISATION OF GROWTH DYNAMICS IN DECLIC-DIRECTIONAL SOLIDIFICATION INSERT ONBOARD ISS

Abstract

Because the microstructures and concomitant segregation of chemical components formed in the solid in the solidification step largely govern the properties in use of materials, it is of uppermost importance to control the dynamical pattern formation at the solid-liquid interface in solidification processing of advanced materials. Directional solidification in which all experimental parameters are precisely and separately controlled has become the method of choice to clarify the correlations between the typical microstructures, among which cells and dendrites are at the forefront, and the processing conditions. For getting unambiguously understanding of the basic physical mechanisms, the dynamics of formation and the stability of spatially extended three-dimensional (3D) arrays of cells and dendrites under diffusive transport of heat and species was characterised in series of experiments carried out under low gravity on the International Space Station using the Directional Solidification Insert in the DECLIC facility of CNES. As the microgravity environment of space allowed working in the limit of hydrodynamic quietness, homogeneous values of control parameters were achieved over the whole solid-liquid interface, which enabled extended 3D-patterns and quantitative benchmark data to be obtained. In experiment, the dynamics of 3D-interface pattern evolution under different growth conditions were monitored in a succinonitrile-0.24 wt% camphor alloy, a transparent model system that freezes like metals, by in situ and real-time visualisation through two cameras (bright field) and laser interferometry. Following a brief presentation

of the experimental procedure and methods of image analysis, the evolution with time of the spatial arrangement (primary spacing, topological array disorder) in the dynamical evolution of 3D-patterns will be detailed, and new evidences on secondary instability in cellular growth at low velocity will be described. In particular, the DECLIC-DSI microgravity experiments unveiled the formation of multiplets in three-dimensions and novel oscillating modes, mostly incoherent but showing splitting into three groups of cells, each oscillating in phase when the cellular array is locally hexagonal. These observations compare well with results of quantitative phase-field numerical simulation. Finally, differences between experimental benchmark data under diffusion transport from microgravity experiments and in situ observation data from experiments conducted on the same sample back on ground, where fluid flow driven by gravity was interacting with solidification, will be exemplified.