INSTITUT JEAN LAMOUR
cnrs UNIVERSITÉ DE LORRAINE

Séminaire présenté par Mehdi Medjkoune

Institut Jean Lamour, Nancy

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3D dendritic array dynamics in purely diffusive solidification: experiments aboard the International Space Station (ISS) with the DECLIC instrument

Controlling microstructure formation during solidification requires understanding the dynamics of cellular and dendritic arrays as they develop, reorganise, and order progressively. A major difficulty in studying these dynamics on Earth is the coupling between morphological instability and thermosolutal convection in the liquid, which alters both temperature and solute fields. Working in microgravity removes this coupling and gives access to purely diffusive transport conditions, necessary to characterise network dynamics on extended 3D samples.

Within the MISOL3D project (CNES/IM2NP), the DECLIC-DSI instrument aboard the International Space Station was used to study in situ the formation of 3D solidification microstructures on a transparent analogue — succinonitrile–0.46 wt% camphre. The DSI-R campaign produced maps of microstructure as a function of control parameters, with primary spacing as the key observable.

Three phenomena are addressed. During growth at constant velocity, the primary spacing λ is not uniquely selected but lies within a stability band. To map the boundaries of this band, corresponding to dendrite elimination at small spacings and tertiary branching at large spacings, velocity-jump experiments were performed. This approach provides reference data on how initial conditions and velocity changes affect array structure and order.

The morphology of dendrite tips was also characterised using interferometric images acquired in situ, which allow 3D reconstruction of the tip region during growth and direct measurement of tip curvature radii. Several measurement methods were developed and applied to build a quantitative dataset.

Finally, grain competition during columnar growth was investigated. At high velocities ($V > 3\mu m/s$), the concave curvature of the interface triggers the appearance of parasitic grains at the sample edges, misoriented with respect to the growth axis, which progressively invade the sample centre. This behaviour questions the classical picture in which better-aligned grains systematically eliminate their neighbours.

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