Séminaire LIONS

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Complex multiphased solidification patterns: zigzags, labyrinths and spirals.

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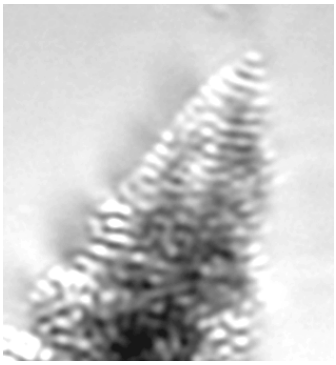

The formation of solidification microstructures in multicomponent alloys results from a nonequilibrium self-organization of the solid-liquid interface. By crystallizing the melt at constant speed in a fixed thermal gradient (directional solidification), one imposes an axial symmetry to the system. In steady state, the solid-liquid interface remains on average parallel to a planar isotherm, but develops regular structures on typical scales ranging from 1 (or even less) to 100 microns, depending on alloy characteristics and control parameters. In non-faceted growth, this morphogenesis is governed by the (destabilizing) diffusion of chemical species in the liquid, and the stabilizing effect of surface tension and thermal gradient. These microstructures are associated with branches of periodic solutions of the (non-linear) equations of the solidification, and are observed over a continuum of the spatial period, but undergo symmetry breaking instabilities and a complex spatio-temporal phenomenology, upon slight variations of the environment, outside the stability limits. The experimental key to fundamental studies of these phenomena is the implementation of in situ observation facilities, in 2D (thin samples) and 3D geometry, using transparent or metallic model alloys, combined with time-resolved numerical simulations (phase-field).

We will discuss three questions of increasing complexity in the context of multiphase solidification of eutectic alloys (used industrially as natural composites): What do we learn from the quantitative analysis of the uniformization dynamics of modulated structures? What are the mechanisms that lead to a morphological selection of lamellar and fibrous patterns in binary eutectics? What are the effects of the addition of a third component on the stability of eutectic growth? We will present in particular the recently discovered "spiral two-phased dendrite", namely, a two-scale crystal growth shape of a "needle-crystal" type with selected morphological features, which exhibits a two-phased substructure growing from a spiral pattern.