Phase-Field Simulations of Solidification Microstructures

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The phase-field method, based on the phenomenological equations of out-of-equilibrium thermodynamics, has become the method of choice for numerical simulations of pattern formation during solidification. Recent progress, both in mathematical analysis and numerical algorithms, makes it now possible to perform quantitative three-dimensional simulations on the scale of the individual microstructures. This will be illustrated by several examples: (i) dendritic crystallization of a pure substance, where the shape and velocity of the dendrites can be directly compared to experimental results for both low-speed and high-speed growth regimes, controlled respectively by capillarity and interface kinetics; (ii) directional solidification of binary alloys, where the stability and dynamics of cellular and eutectic microstructural patterns are investigated.