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Deterministic Capillary-Mediated Branching

We analyzed the Gibbs-Thomson potential distribution along an arbitrary interface and found that it acts as a weak interfacial field, by imposing tangential potential gradients and interfacial energy fluxes. Energy conservation along a slender interface shows varying deposition and removal rates of capillary-mediated energy. Locally, this energy excess (or deficit) departs from (or returns to) the interface. If excess energy is directed toward the melt, the local growth rate is enhanced slightly, whereas if energy is withdrawn from the melt and directed toward the solid the local rate of growth is retarded slightly. These opposing dynamic responses balance at points along an advancing interface where the surface Laplacian of the capillary-mediated potential vanishes, initiating deterministic rotation of the interface. Interfacial rotations with favorable chirality couple with the normal transport field and eventually form a branch. A precision, noise-free, Greens f unction solver confirms that predicted interface rotations and subsequent branching arise dynamically at locations predicted analytically for various 2-D starting shapes. Rotations develop episodically as the interface shape and rotation points co-evolve. This mechanism of branching morphogenesis leads to dendritic growth for crystalline materials, or to deterministic chaos ('seaweed')for fluid-fluid systems.