Growth of mushy layers with temperature modulations

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— Directional solidification of aqueous solutions produces a solid-melt coexisting zone whose growth rate can be predicted by the mushy-layer theory. We present measurements of mushy-layer growth when solidifying aqueous ammonium chloride with the cooling temperature modulated periodically \( T_B(t) = T_0 + A \cos(\omega t) \). The mush-liquid interface \( h(t) \) evolves as the square root of time for a constant \( T_B \), but exhibits periodical humps in the present of modulations. The growth rate \( \dot{h}(t) \) is best approximate to \( \dot{h}(t) = h_0 e^{-\gamma \omega t/2} \cos(\omega t + \pi + \phi(t)) \), with a decay rate \( \gamma = 0.82 \pm 0.05 \) independent on the modulation amplitude \( A \) and frequency \( \omega \), and a phase-shift \( \phi(t) \) increasingly lag behind \( T_B \) as a function of time. We discuss a mushy-layer growth model based on the Neumann solution of the Stefan problem with periodical boundary conditions, and show that the numerical results are in agreement with the experimental observations.

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