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PLANAR TO CELLULAR TRANSITION DURING DIRECTIONAL SOLIDIFICATION OF Al-0.5 wt. %Cu

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Introduction

Directional solidification is one of the most widely used methods for production of high quality components, as it permits a precise control of the resultant microstructure. The formation of cellular or dendritic interfaces is influenced by microsegregation and thermal profiles ahead of the interface (1). These structures influence the mechanical properties of the final product. Hence, the instabilities of a planar interface and its development into a periodic array of cells or dendrites have received particular attention from the metallurgist (2–5).

Directional solidification is a non-local, time dependent problem, in which the thermal and microsegregation fields depend on the non-linear form of the interface shape. The first analysis of this problem is the commonly known Constitutional Supercooling Criterion (6), which ignores the stabilizing effects of the interfacial energy and, therefore, is valid only at very low velocities (7). Mullins and Sekerka developed a more detailed model for the planar interface instability, under the hypothesis of an infinitesimally small amplitude of interface deformation. With this analysis it is possible to examine the linear stability with respect to a perturbation of a given wavelength λ. In the low velocity regime, Mullins and Sekerka's result can be expressed as a modified Constitutional Supercooling Criterion, due to the consideration of interfacial energy, latent heat and conductivities of the solid and liquid (8). For this analysis, the critical wavelength of the first neutrally stable mode encountered when the control parameter changed is given by (7):

$$\lambda_C = 2\pi\left(\frac{2\Gamma k D_L^2}{m(k-1)}\right)^{1/3} \frac{1}{C_0^{1/3}} \frac{1}{V_C^{2/3}} \tag{1}$$

where k is the partition coefficient of the binary alloy, D_L is the diffusion coefficient of the solute in the liquid, m is the liquidus slope in the equilibrium diagram, C_0 is the nominal concentration of solute and $\Gamma \equiv \gamma T_M / L$ is a capillary coefficient with γ the interfacial energy, T_M the melting temperature of pure material and L the latent heat. In equation *(1)*, V_C is given by