Dendritic Crystallization: Re-evaluating fundamentals

ABSTRACT

Dendrites form archetypal solidification microstructures comprised of complex patterns. Dendritic crystals are of technological importance from the perspective of process modeling to improve the perfection of near net–shape castings, raise the throughput of continuous castings, and avoid defects in ingots of non-ferrous alloys, welds, etc. Since the early 1980s it has been clearly recognized that thermal and solutal convection almost always accompany the terrestrial solidification of metals and alloys. Melt convection modifies transport processes—diffusion and heat flow—that are responsible for crystallization. Low–earth orbit, first made accessible on a reasonably predictable schedule via the Space Shuttle, provided the long-duration microgravity environment required to suppress convection, thus allowing solidification under pure diffusion control. Three successfully executed flights of the Isothermal Dendritic Growth Experiment (IDGE) will be described briefly: the first, launched in 1994 on the United States Microgravity Payload mission (USMP-2); the second, launched in March, 1996; and the most recent launched in November, 1997, aboard USMP-4. Each of these in-space experiments yielded hundreds of solidification cycles that provide a rich archive of images from which growth speeds and morphological details are available to test transport and interfacial theories of dendritic growth. Such theories form the basis of contemporary solidification scaling laws for process engineers, and the data provide accurate benchmarks for assessing computer simulations, including phase-field as well as sharp interface methods. Finally, recent findings from the IDGE will be described that contribute fresh insight into the fundamental cause of dendritic patterns.