Test of Dendrite Growth Theory and Nucleation of Polytetrahedral Phases in from the Melt

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In this talk, we will present two recent examples of our work on the fundamentals of solidification:

(i) a parameter-free test of dendrite growth theory by a combination of levitation and pulsed-laser melting techniques;[1] and,

(ii) an analysis of the nucleation of polytetrahedral crystals (Laves phase) from the melt during solidification in a gas-filled drop tube.[2]

In rapid alloy solidification, the dendrite growth velocity depends very sensitively on the deviations from local interfacial equilibrium manifested by kinetic effects such as solute trapping. In a collaboration with Dieter Herlach's group at the DLR in Köln, Germany, the dendrite velocity-undercooling function of the dendrite tip was measured in dilute Ni(Zr) alloys over the range 1-25 m/s and 50-225 °K using electromagnetic levitation techniques, and compared to theoretical predictions of the model of Trivedi and co-workers with deviations from local equilibrium. For the first time, the input parameters to which the model predictions are most sensitive, the diffusive speed v_D, characterizing solute trapping and the liquid diffusivity D_L, were not used as free parameters, but were measured independently by pulsed laser melting techniques: v_D=26 m/s and D_L=2.7x10^{-9} m^2/s. We find excellent agreement between theory and experiment.

$Zn_{40}Mg_{36}Ga_{24}$ is an alloy that forms many polytetrahedral phases: the Laves phase, $MgZn_2$, a stable quasiperiodic phase with icosahedral symmetry, and a large number of icosahedral approximants. Drops of this alloy were solidified in a gas atmosphere in a short drop tube. Dendrites of the Laves phase are found homogeneously throughout each droplet. The number density of dendrites was measured as a function of droplet size. To analyze the data, first a new analysis was made of heat and fluid flow in the drop tube experiment. The evolution of the temperature in the drop, as well as the fluid flow induced by the shear at the surface, were calculated. Nuclei were introduced by Poisson statistics, based on steady-stated classical nucleation theory. Populations containing more than 100 nuclei per droplet have been created. The dependence of the number of nuclei on the droplet size is similar in the model and the experiments. The corresponding interfacial tension is an order of magnitude lower than that in a simple metal, such as Hg, as expected from the structural similarity between the polytetrahedral Laves phase and its melt.

References

1. C.B. Arnold, M.J. Aziz, M. Schwarz, and D. M. Herlach, *Physical Review B* (1998 - submitted).
2. J. Fransaer, A.V. Wagner, and F. Spaepen (1998 - in preparation).