

MELT FLOW CONTROL IN THE DIRECTIONAL SOLIDIFICATION OF BINARY ALLOYS

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Abstract

Our main project objectives are to develop computational techniques based on inverse problem theory that can be used to design directional solidification processes that lead to desired temperature gradient and growth velocity conditions at the freezing front at various levels of gravity. It is known that control of these conditions plays a significant role in the selection of the form and scale of the obtained solidification microstructures.

During the first half of this project, a number of melt flow control problems were addressed for directional solidification processes with a sharp freezing front. Various flow mechanisms were accounted in the design process including thermo-solutal, Marangoni and magneto-convection. The examined inverse/design problems were stated as optimization problems in functional spaces with over-specified conditions on the freezing front and incomplete boundary or other process conditions. In the present analysis, we considered as design variables the thermal boundary conditions (furnace design) as well as the magnitude and direction of an externally applied magnetic field. The developed techniques will be demonstrated here with an example of designing the boundary thermal fluxes for the directional growth of a germanium melt with dopant impurities in the presence of an externally applied magnetic field. The design is shown to achieve a stable interface growth at a prescribed desired growth rate. The method will also be demonstrated with the directional growth of a Sb-8.6% Ge melt in an open-boat configuration under the influence of an external horizontal magnetic field such that a stable vertical interface advances with a desired growth velocity.

We will also review current work in progress including extending the present computational melt flow design techniques to multi-phase volume-averaging based solidification models. In addition, we will highlight a computational design framework under development that will allow coupling across length scales with an explicit modeling and design of solidification microstructures using level set methods. Finally, the role that the design techniques being developed may play in the real time feedback control of solidification processes in the presence of uncertainty will be discussed.

Keywords: computational design, solidification control, inverse problems, fluid flow control