On the control of crystal growth processes using magnetic fields and magnetic field gradients[1]

By

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Mathematical formulations along with various computational strategies for the optimal design of crystal growth processes are introduced. In particular, vertical and horizontal Bridgeman growth as well as the directional solidification of materials will be considered. The framework discussed here is used to optimize the growth of both conducting materials like metals and alloys, as well as non-conducting materials like macro-molecular organic materials and proteins. The control of non-conducting materials is achieved through the spatial variation of the applied magnetic field e.g. a specified magnetic field gradient.

Minimizing the convection in the melt towards achieving a diffusion dominated growth, maximizing growth rate, maintaining a planar interface are some of the objectives of the design framework to be addressed. The control parameters are the heat flux applied and the spatial-temporal variation of the applied magnetic field. Various process constraints are considered for example to account on the type or strength of magnetic fields that commercially available gradient coils can produce.

A number of parametric studies of the effects on growth of the various design parameters are discussed. An analytic design solution is presented obtained under specific conditions. Then, two broad possibilities of numerical gradient-based optimization approach to design are considered; an adjoint formulation in an infinite-dimensional function space and, a continuum sensitivity-based optimization procedure based on a finite-dimensional control space.

Finally, an extensive range of examples including natural convection, double-diffusive convection, and Marangoni convection dominated growth of both conducting and non-conducting materials are considered to illustrate the design framework. In conclusion, the possibility of real time feedback control of these continuum crystal growth systems is discussed.

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