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# A fundamental limitation on growth rates in the traveling heater method

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**Abstract**

A comprehensive mathematical model of the traveling heater method is applied to understand interactions of flow, segregation, and stability for the crystal growth by the traveling heater method. We demonstrate that the formation of a secondary, counter-rotating vortex near the growth interface limits the transport of segregated solvent, leading to large concentration gradients and supercooling of the liquid near the interface. The secondary vortex arises from the same mechanism responsible for the formation of lee waves in atmospheric flows, and its spatial form scales with the Brunt–Väisälä frequency. Significantly, this supercooled layer of liquid arises from the lateral transport of solute, which is predominantly affected by the secondary flow vortex, rather than the axial diffusion of solute, as assumed in the classical derivation of constitutional supercooling by Mullins and Sekerka. Thus, supercooling in a model cadmium zinc telluride system occurs at growth rates of order 1 mm/day, nearly an order of magnitude smaller than expected from classical arguments. Paradoxically, the traditional strategy to alleviate constitutional supercooling during crystal growth, namely increasing the temperature gradient at the interface, is expected to strengthen the lee-wave vortex and accentuate the onset of instability. Other approaches will be needed to overcome growth limits in the traveling heater method.

*Keywords:* A1. Computer simulation, A1. Convection, A1. Mass transfer, Heat transfer, A2. Traveling heater method growth, A2. Traveling solvent zone growth, B2. Semiconducting II-VI materials



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