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NUMERICAL STUDY OF THERMAL AND SOLUTAL MARANGONI CONVECTION IN A 3-DIMENSIONAL FLOATING FULL-ZONE LIQUID BRIDGE

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ABSTRACT

Since there is no possibility of contamination from the crucible to the grown crystals, the Floating-zone (FZ) technique has the potential of growing bulk single crystals with desired quality required by the electronic and information device industry. During FZ growth, the surface tension gradient due to temperature and concentration variations along the free surface gives rise to Marangoni convection in the liquid zone, often leading to unstable fluid flow and temperature distributions. Such unstable and time-depending structures induce undesirable growth striations into the grown crystal even under the microgravity environment. In order to understand the role of Marangoni convection, several researchers have studied the FZ growth process both numerically and experimentally. However, almost of these studies have focused on the Half-zone (HZ) configuration.

In order to have better predictions for the actual FZ growth process, a numerical simulation of the Marangoni convection in a three-dimensional Full-zone configuration was performed in the present study. Continuity, momentum, energy and diffusion equations, and associated boundary conditions were discretized by the finite difference method, and analyzed by the HSMAC (Highly Simplified Marker And Cell) method. The crystal growth of Si/Ge under microgravity field was simulated.

The computational simulation study led to the following results:

1. In early stages of the simulation, the flow and temperature fields were still 2-dimensional, and 2 vortexes with the same size existed in the melt.
2. However, the concentration field exhibited a three-dimensional behaviour even the flow and temperature fields were still axisymmetric.
3. As time proceeds, the flow, temperature and concentration fields become three-dimensional.
4. In the case of small Marangoni number, 3-dimensional flow, temperature and concentration fields were steady and independent of time.
5. In the case of large Marangoni number, size of the vortexes periodically changed in spite of assumed axisymmetric thermal boundary conditions.
6. Rotation of the crystal and feed was beneficial in growing axisymetrically uniform crystals.