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Melt Flow Control in the Czochralski Single Crystal Growth Process

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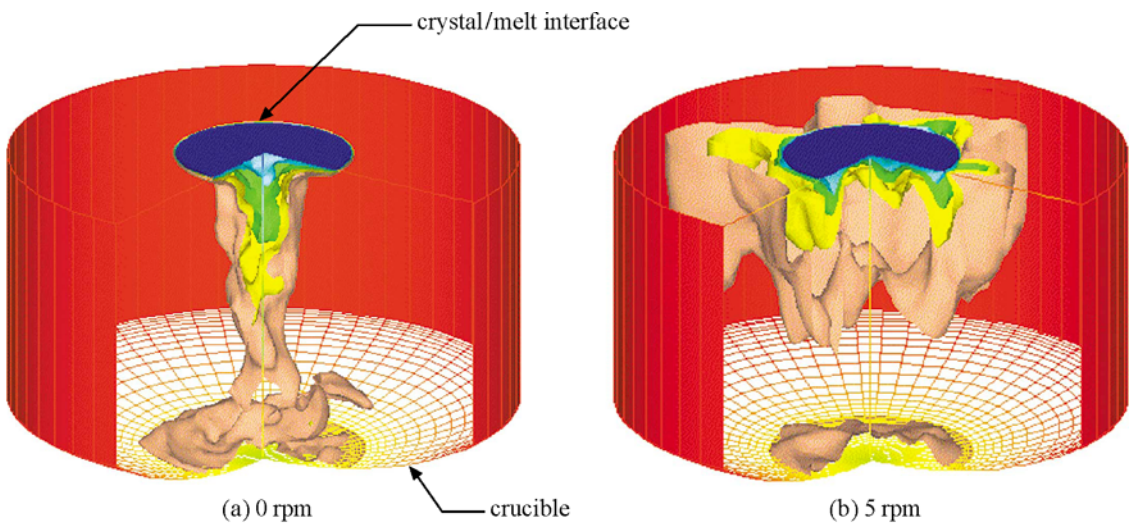
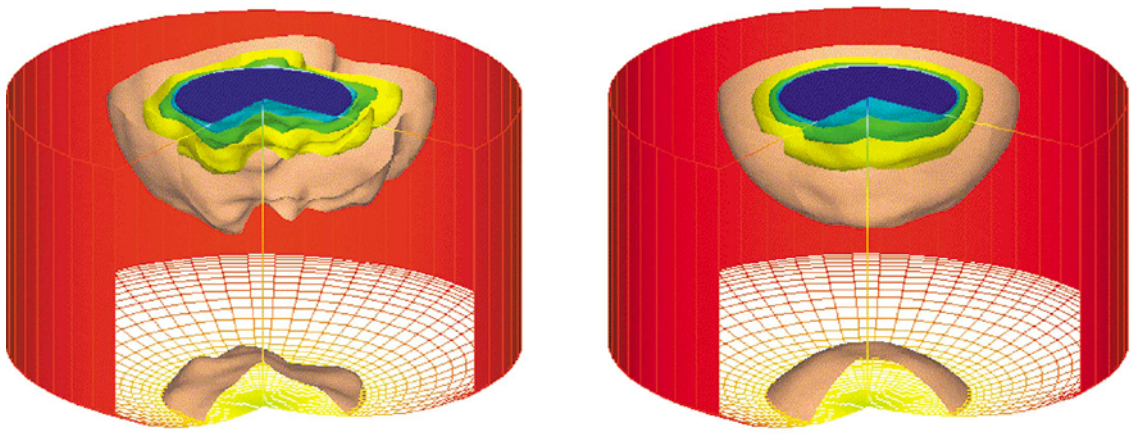


(a) 0 rpm (b) 5 rpm



(c) 10 rpm (d) 20 rpm

Isothermal surfaces

In the Czochralski crystal growth process, it is important to control silicon melt flows to produce a single crystal with high quality. As a diameter of the product becomes large, the melt flow structure gets easily turbulent because of the increase of Reynolds and Rayleigh numbers. However, the Coriolis' force generated by the crucible rotation also works strongly in the melt. Thus, to investigate the melt condition, three-dimensional numerical simulations are carried out with various rotation rates using GSMAC-FEM. Figs. (a)-(d) show the isothermal surfaces (ΔT = 3K) with different rotation rates obtained by assuming the adiabatic condition on the free surface. In Fig. (a), the melt temperature steeply varies under the crystal/melt interface according to the direction of the natural convection. When the rotation rate is set small, the flow structure gets complicated as shown in Fig. (b) because of the competition between the natural convection and the Coriolis' force. With the increase of the rotation rate, the effect of the Coriolis' force becomes dominant and the flow structure turns into a two-dimensional axisymmetrical flow as shown in Figs. (c) and (d).