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Numerical Study of Heat Transfer during Sapphire Crystal Growth by Heat Exchanger Method

LiLi Zhao, Wencheng Ma, Guoqiang Ding, Yang Yang, Tiezheng Lv, Lijun Liu

Department of Applied Chemistry, Harbin Institute of Technology, 92 Xidazhi Street, 150001, Harbin, China

ABSTRACT: We developed a transient global model to study the heat transfer in sapphire crystal growth by heat exchanger method (HEM). Internal radiation in the semi-transparent sapphire was modeled with a rigorous discrete ordinate model and phase change was calculated based on a fixed-grid method in our simulations. The evolutions of thermal field, melt flow and melt-crystal (m-c) interface shape were predicted during the whole crystal growth process. Simulation results show that a U-shape distribution of axial temperature gradient appears along the centerline of the sapphire crystal and melt, respectively, due to the effect of internal radiation. The m-c interface is severely curved near the crucible wall and relatively flat at the central region with an increasing convexity when crystal grows. The sapphire melt flow is in a laminar state dominated by the thermal buoyancy force. The high growth rate at the final stage of the solidification process resulted in bubbles at the top layer of the grown crystal. The formation mechanism of the grain boundaries at the crystal periphery was discussed. The numerical simulation results show a good agreement with the experiment data. The developed global model herein provides important information to improve the growth process of sapphire crystal by the HEM technique.

Keywords: Transient global model, Computer simulation, Heater transfer, Internal radiation, Sapphire crystal