Optimization of Sapphire Growth Process using Numerical Simulation

M. Szanto and, I. Gilad

Department of Mechanical Engineering, Ben-Gurion University of the Negev, Beer-Sheva, Israel

ROTEM industries Ltd. P.O.Box 9045, 84190, Beer-Sheva, Israel

Sapphire single crystal boules and near-net-shape domes are being grown at the crystal growth division of ROTEM industries *via* the Gradient Solidification Method (GSM). The GSM method is based on controlled melting of the content (raw material + seed) of a carefully designed molybdenum crucible, followed by the controlled cooling of the furnace, to facilitate unidirectional solidification and to ensure the growth of a defect-free single crystal. The temperature profile of the furnace during both melting and crystallization must therefore be carefully designed and controlled since it is a key factor in the success of the growth of high quality single crystals. This task was addressed using combined computational and experimental research efforts.

The numerical investigation of the heat transport, was performed by a commercial CFD code, FLUENT®. The numerical model is designed to solve a complete transient temperature field in the growing crystal, integrated with the whole furnace. The model incorporates conduction with radiation in an absorbing media by the District Ordinate (DO) approximation. Radiative heat transport, a highly nonlinear phenomenon, is particularly important during the growth of high-melting-point semitransparent crystals such as sapphire. The thermal conductivity of the graphite felt, used as an insulator material, depends both on the temperature and its degree of compression. Because of the extreme temperatures involved and the deformation at the assembly, the manufacturer's data has to be re-evaluated. There is also an uncertainty in the thermal properties of the different materials involved. To account for these uncertainties, the thermo-physical properties at elevated temperatures were adjusted to match the computed temperatures with the experimental data at the points of measurements.

The solution predicts the shape of the continuously changing solidification contour. An inappropriate shape is a major cause leading to defects in the crystals. The main contribution of the numerical analysis is in the optimization of the design of the furnace structure, in order to achieve proper growing conditions. Good correlation was found between the numerically predicted temperature gradients, and the phenomena observed in the grown crystals.