New developments of KRIST*MAG*® technology for improved semiconductor crystal growth

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The growing demand for semiconductor devices is associated with continuously increasing requirements on substrate materials with regard to their size and to the homogeneity of their material properties. Hence, the ongoing development of industrial semiconductor crystal growth is driven by wafer yield and crystal quality, as well as production costs. They can be reduced by various measures, such as reduced energy consumption, decreased process time through higher crystal growth rates, increased feed weights, extension of crucible lifetime and much more.

Most important factors for improved crystal quality are impurity control of the feedstock, crucible as well as hot-zone, and the crystal growth process itself. A crucial growth parameter is an exact and continuous control of the melt flow during the entire process. In order to allow crystal growth from larger melt volumes, for example, the melt convection can be effectively controlled by applying contactless external forces, in particular magnetic fields.

The idea of using the heater itself in a modified configuration to generate suitable travelling magnetic fields (TMF) in the melt was put into practice at the Leibniz Institute for Crystal Growth (IKZ). This technology was developed in close cooperation with industrial and academic partners, within a framework of several related projects. The resulting heater magnet modules (HMM), also known as KRIST*MAG*® heaters, simultaneously combine direct current (DC) and alternating current (AC) operation, which enables decoupled generation of heat and TMF. The generated Lorentz forces ensure the control of melt flow. The direction and magnitude of the TMF can be adjusted by the variation of AC/DC ratio, frequency, and phase shift between the heater coils. The suitable parameter field is estimated with the help of numeric simulations and according to the desired growth conditions.

KRIST*MAG*® technology is applicable to a wide range of processes in the areas of crystal growth and epitaxy. Successful crystallization experiments of bulk semiconductors, especially Si, Ge and GaAs, were carried out by Vertical Gradient Freeze (VGF) techniques and by Czochralski (Cz) method. Starting from an overview about previously designed HMM´s for these growth techniques [1] the results of recent developments at IKZ will be presented. The equipment has been upscaled for larger crystal diameters, such as for Cz silicon up to 150 mm. The control of melt motion in the Si melt should reduce erosion of the fused silica crucible, thereby decreasing the incorporation of oxygen into the crystals and simultaneously extending the crucible life time. Furthermore, latest developments in VGF growth are presented including applications of HMM, and perspectives for a broader range of materials are shared.

For industrial applications of the HMM, the power generation hardware was completely redesigned and further developed.

Reference
[1] Christiane Frank-Rotsch, Natasha Dropka, Frank-Michael Kießling, Peter Rudolph. Semiconductor Crystal Growth under the Influence of Magnetic Fields. Crystal Research and Technology. 2020; 55:1900115.