Contributions to the development of crystal growth technologies

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1. Shaped crystal Growth

Adapting the crystal shape as close as possible to the finite device form already during growth saves a lot of time and costs. This was demonstrated by i) layers with ordered eutectic periodic laminar structure pressed from a melt droplet between former plates, ii) casting of high-resistivity CdTe sheets in a slit of non-wetting mold, iii) growth of in situ core doped Cr,Nd : $LiNbO_3$ laser rods by double die EFG, and iv) facet-controlled Czochralski growth of Si crystals with rectangular cross section obtained by a travelling magnetic field.

2. Correlation between melt structure and quality of II-VI and IV-VI crystals

As it was revealed there exists a dependence of melt undercooling from overheating and a tendency of self-orientation in CdTe, ZnSe and PbTe crystals caused by residual melt clustering due to the high share of ionicity in the bond energy. Today, it is an accepted must of (Cd,Zn)Te crystal production to overheat the melt before the crystallization is started to improve the crystal quality. To protect a seed during melt overheating at Bridgman/VGF growth a modified furnace rotatable around the transversal axis was tested successfully.

3. In situ stoichiometry control to reduce intrinsic point defects and inclusions

Considering the shape of the compound existence region in the T-x diagram and deviation of the congruent melting point from stoichiometry CdTe and GaAs crystals with near stoichiometric composition and, thus, lowest intrinsic point defect concentration and minimized second-phase particles have been grown by horizontal and vertical Bridgman methods with Cd extra source and B_2O_3-free vapor pressure controlled Czochralski (VCz) technique in As atmosphere, respectively. Similar results were obtained by Czochralski growth of $PbMoO_4$ crystals with MoO_3 vapor source within the growth vessel.

4. Study of dislocation cell patterning and their prevention

The formation of dislocation cells takes place immediately behind the crystallization front in nearly all as-grown cooling crystals caused by the acting thermo-mechanical stress. Essential conditions are the dislocation climb by high-diffusivity of native point defects combined with dynamic polygonization and dissipative structuring due to irreversible thermodynamic situation. Cell structures impair the quality of devices due to the charge inhomogeneities. It was demonstrated that in near-stoichiometric GaAs crystals the cell structuring is prevented by minimization of native point content and, therefore, reduced dislocation climb. The same result was reached when VGF CdTe crystals were composition-hardened by selenium. Generally, undercritical thermal stress proves to be the main counteraction.

5. Melt growth under travelling magnetic field generated in a heater-magnet module

In industrial Czochralski crystal pullers, VGF facilities and mc-Si ingot crystallizers the CRYSTMAG® concept was installed to generate travelling magnetic fields (TMF) within the heater coils around the crucible. Careful numeric simulations helped to optimize the convection mode in the melt and to reduce the concavity of the growing interface by combining high- and low-frequency magnetic forces. TMF-VGF Ge and GaAs crystals with improved radial homogeneity and without striations have been grown. 640 kg mc-Si ingots for photovoltaics, grown in a self designed VGF equipment with heater-magnet, showed no second-phase inclusions, homogeneous IR transmission, reduced dislocation density and overall high carrier lifetimes. Both, equipment and method were transferred to industry.