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CRYSTALS AND CRYSTALLINE FUNCTIONAL LAYERS

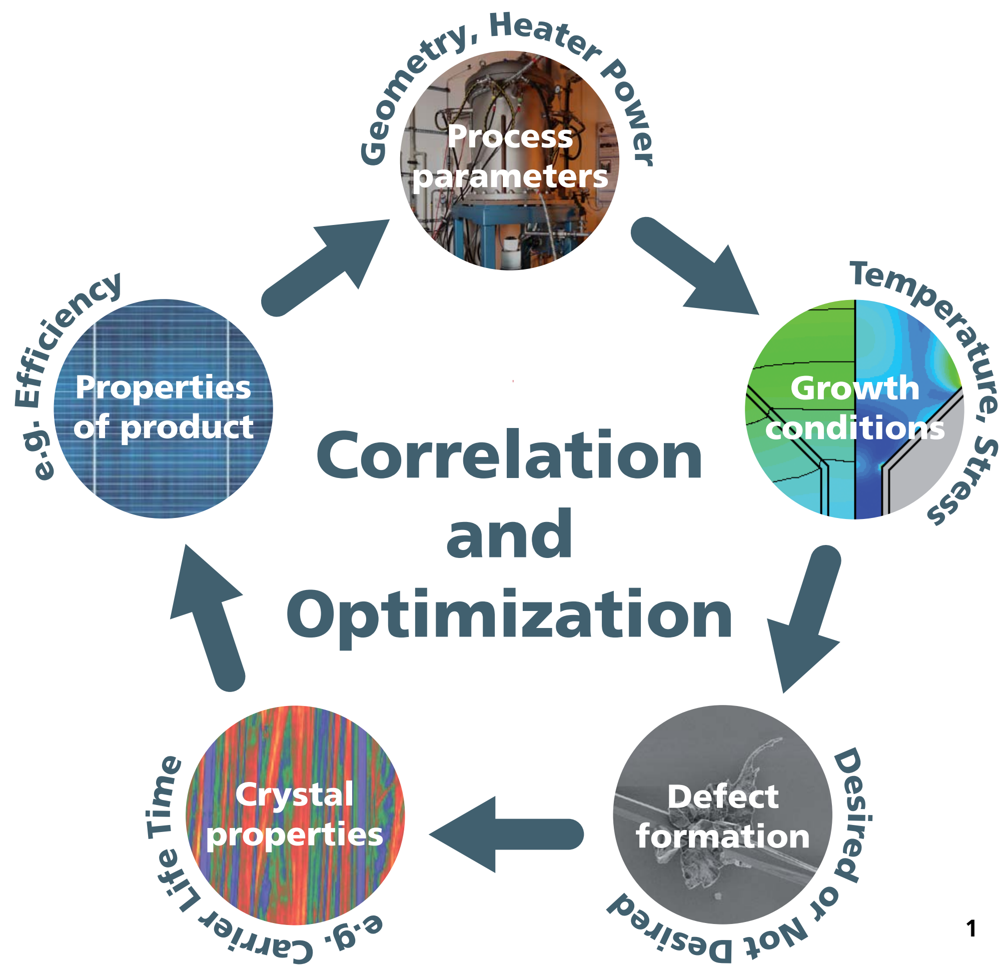
MISSION AND STRATEGY

Mission

Our research focus is to clarify – in close collaboration with our industrial partners – how the material properties of bulk crystals as well as those of thin epitaxial or other functional layers correlate with their respective manufacturing conditions. This basic understanding between material quality and growth conditions is of utmost importance for an improvement of bulk crystal growth and layer deposition techniques used in industry with respect to larger crystal dimensions, less harmful crystal defects, more uniform electrical and structural properties, and new materials.

Strategy

Our strategy is the optimization of crystal growth and epitaxial processes through a combination of thorough experimental process analysis, tailored characterization techniques, and numerical modeling. For that purpose, we are provided with a well-suited infrastructure consisting of R&D-type furnaces and epitaxial reactors, state-of-the-art metrology tools as well as powerful and user-friendly simulation programs. These programs are especially suitable for heat and mass transport calculations in high-temperature equipment with complex geometry.



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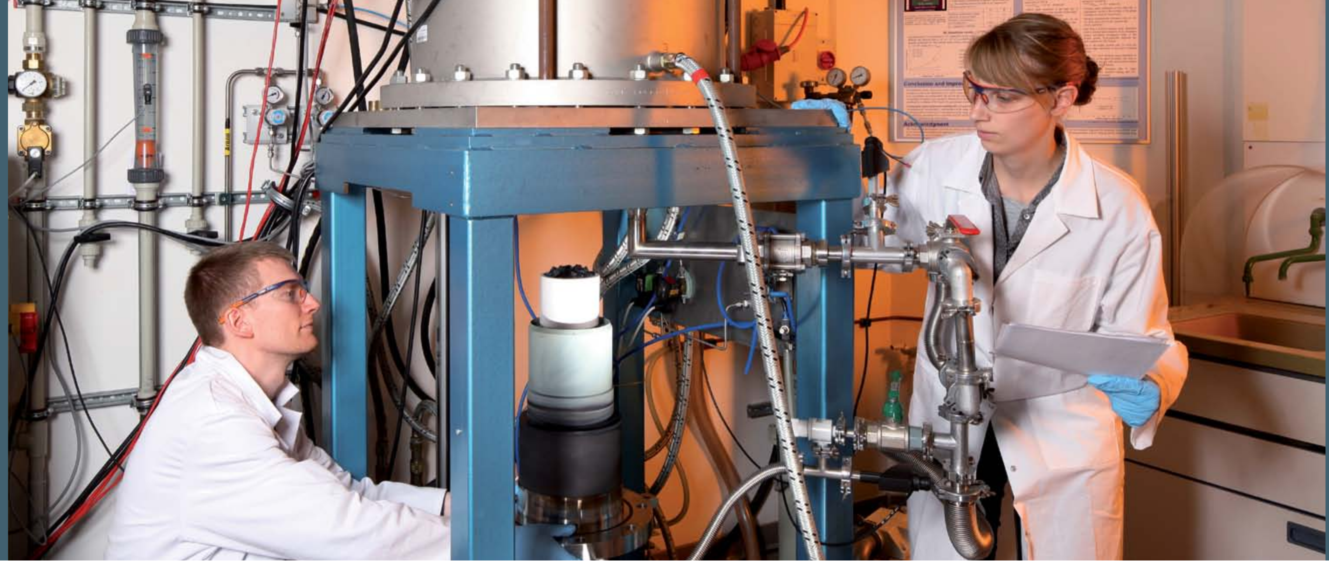
1 *A combination of experimental analysis and computer simulation is used to identify the correlation between crystal properties and growth conditions.*
This is the starting point for an optimization of the crystal growth processes.

COMPETENCIES AND REFERENCES



Competencies

We have profound experience in a variety of crystal growth techniques and materials to be used in microelectronics, power electronics, communication technology, photovoltaics, and optical technologies. We have significantly contributed to the development of the Vertical Gradient Freeze technique for the industrial production of GaAs, InP, CdZnTe, and CaF_2, to the optimization of the crystallization of multicrystalline silicon, as well as to the upscaling of the silicon Czochralski process from 200 mm to 300 mm. Fundamental results have been achieved on the dislocation dynamics during epitaxial growth of GaN and SiC layers as well as on the avoidance of polycrystalline growth during pulling of sapphire ribbons.

Structure

The Department of Crystal Growth of Fraunhofer IISB currently consists of in total 45 crystal growth experts organized in five topical teams focusing on bulk crystal growth techniques, epitaxial processes, related equipment and process technologies, defect engineering, and modeling. Since 2005, the department has extended its activities from Erlangen to Freiberg / Saxony, where it is engaged in the Fraunhofer Technology Center for Semiconductor Materials THM.

References

Several scientific awards for the Department of Crystal Growth serve as signs for its world-wide leading position in the field of crystal growth. These awards were granted for outstanding scientific achievements as well as for excellent contributions to the education of students and engineers. The members of the department are engaged on a national and international level in several associations and conferences in order to promote crystal growth and epitaxy.

Education

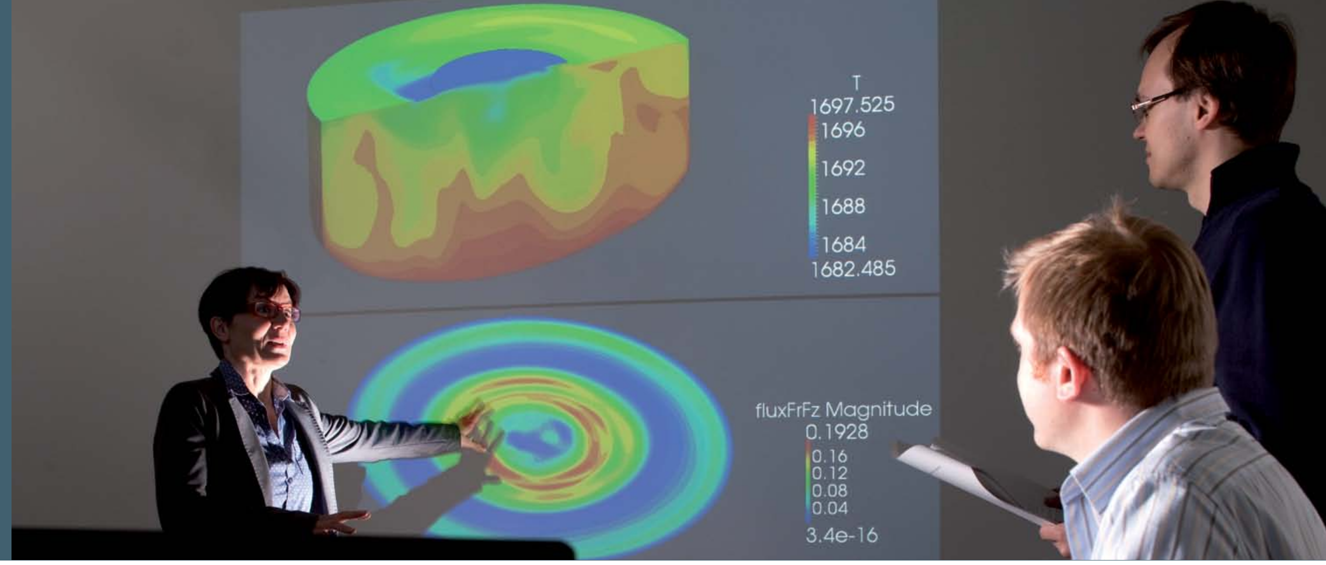
In Erlangen, we have a close collaboration with the Department of Materials Science of the University of Erlangen-Nuremberg as well as with different chairs of the Georg-Simon-Ohm University of Applied Sciences in Nuremberg. In Freiberg, we are closely cooperating with the Technical University of Freiberg. In agreement with these universities, students can carry out their project, bachelor or master thesis in our department.

Table

Overview of our experience in methods and materials.

Process	Material
Czochralski Technique and its Variants	Si, Ge, III-V, Oxides, Fluorides
Bridgman and Gradient Freeze Techniques	Silicon, III-V, II-VI, Fluorides, Oxides, Metallic Alloys
Growth of Shaped Crystals (EFG, String Ribbon)	Silicon, Oxides
Bulk Growth from Solution and Vapor Phase	SiC, GaN, AlN
Epitaxial Processing	SiC, Nitrides

MATERIALS AND METHODS



Mono and Multicrystalline Silicon

We examine how crystal growth processes for producing mono- and multicrystalline silicon with various dopants can be improved to avoid forming defects, which limit carrier lifetime and thereby also the efficiency of solar cells. Experiments are carried out in lab scale furnaces and in special R&D pilot plant scale furnaces with the goal to reduce for example detrimental dislocation clusters and harmful grain boundaries. Other topics under research are the interaction of crucible and crucible coating with silicon as well as the interaction between particles in the melt and the moving solid-liquid interface. Furthermore, the application of magnetic fields as well as the recycling of silicon are under investigation.

Wide-Band-Gap Semiconductors

Compared to conventional silicon-based devices, power electronic devices made of silicon carbide (SiC) and gallium nitride (GaN) possess a high potential to increase energy efficiency. However, the production of these materials is currently difficult and results in many crystal defects, which may have a negative effect on performance and reliability of devices. We undertake deep analyses to determine how such crystal defects influence electrical performance and how to prevent the formation of the most harmful of these during bulk and epitaxial growth of these materials.

Detector and Laser Crystals

In the area of detectors and optical materials for high energy physics, earth exploration, safety, and medical technology, there is a high demand for new materials for the generation and detection of high-energy radiation. Based on our experience in the growth of optical crystals, we have started to develop the technological basis for the production of special detector and laser materials, with which we will rate the market potential of these new materials and manufacturing methods.

Functional Layers

We are contributing to the development of new materials which have a high application potential for future energy conversion and storage systems. Our know-how in material science is the basis to correlate the properties of such functional layers to the conditions of their synthesis using physical and chemical routes. The development of small application demonstrators out of these new materials in-house gives us an important feedback for optimizing the material properties.

Defect Engineering

We are using different methods to analyze the structural, electrical and optical properties of crystals and thin layers – beginning at the macroscopic scale down to the atomic level: from the examination of defect etched samples using optical microscopy, for life time, resistance and grain structure mappings of complete wafers, to special analytical methods such as elemental analysis using a special energy dispersive X-ray detector inside a scanning electron microscope or the examination of cathodoluminescence within a transmission electron microscope, to name a few examples.

Modeling

We are contributing to the development of next-generation high temperature equipment and processes for crystal growth, as well as for thermal treatment of semiconductor wafers by using our expertise in modeling heat and mass transport phenomena. Besides thermal simulations we have profound knowledge to optimize fluid flow problems. For that purpose we are equipped with tailored software tools such as CrysMAS, OpenFOAM, and Fluent, which run on our high-performance computing cluster, and which are continuously being improved.