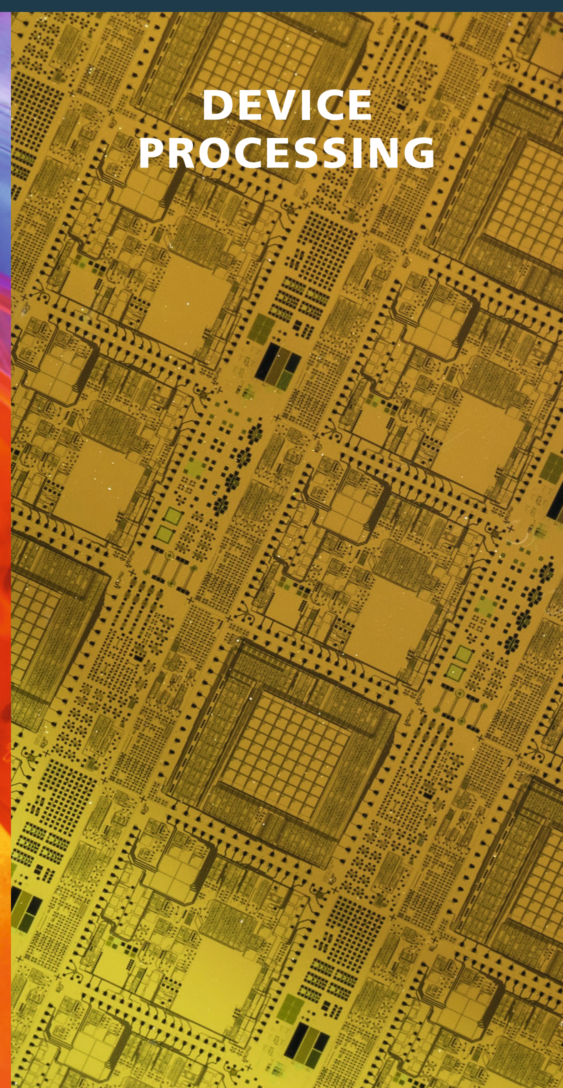
Fraunhofer IISB

FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

SEMICONDUCTOR MATERIAL DEVELOPMENT



Power Electronics | Communication Electronics | Sensors & Detectors | Quantum Technologies

MISSION, STRATEGY & COMPETENCES

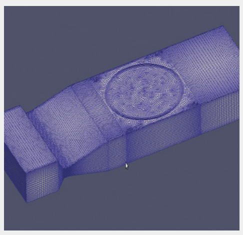
STRATEGY

Correlation of material properties
with production conditions and with performance and reliability of devices

Process Parameters

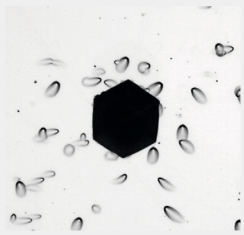
Mass fluxes, heater power

Growth Conditions



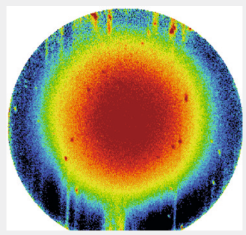
Temperature, flow, species

Defect Formation



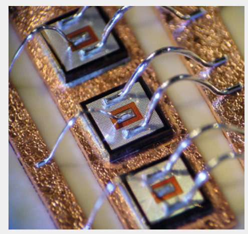
Desired or not desired

Material Properties



e.g. Carrier life time

Device Properties



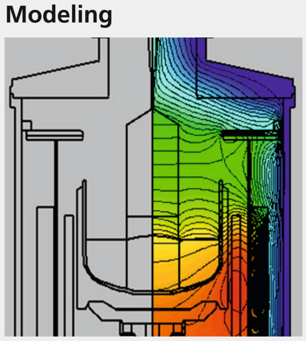
e.g. Reliability

APPROACH

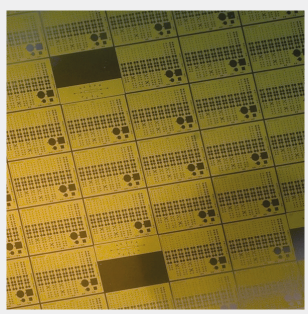
Experiments in combination with modeling, characterization and device processing

Experiments

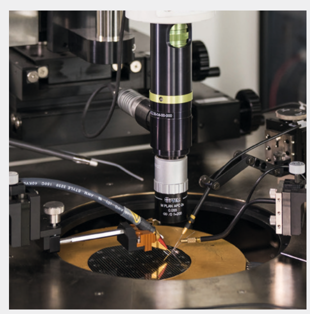
Modeling



Devices



Characterization



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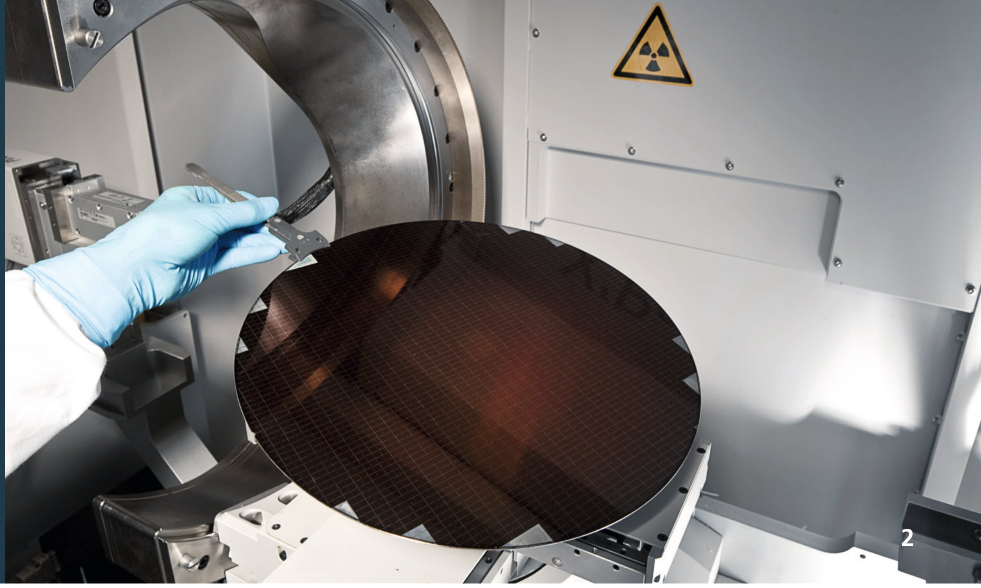

MISSION

We support material, device and equipment manufacturers and their suppliers by delivering scientific-technological solutions in the field of production and characterization of crystals, epitaxial layers, and devices. We support our customers to improve the material quality and to reduce the production cost. We identify defects harmful for device performance and reliability and look for solutions to avoid them. We develop technologies for new materials and we tailor the material properties for new applications. Our focus is on semiconductors for power electronics, communication electronics, sensors & detectors, and quantum technologies.

STRATEGY

Our strategy is the optimization of the manufacturing processes through a combination of thorough experimental process analysis, tailored characterization techniques, and numerical modeling. For that purpose, we have a well-suited infrastructure at hand, which consists of R&D type furnaces and epitaxial reactors, state of the art metrology tools for the investigation of the physical, chemical, electrical, and structural material properties as well as powerful simulation programs well suited for heat and mass transport calculations. Prototype devices can be processed in house in our qualified 150 mm SiC line (0.8 µm) or in our flexible R&D line.

COMPETENCES

We have profound experience in the areas of semiconductor crystal growth, epitaxy, and device processing including characterization and modeling. In the past we have significantly contributed to the development of the VGF technique for the industrial production of a variety of crystal materials as well as to the epitaxial growth of high quality SiC layers. Several national and international research awards underline the achievements of the Materials Department over the last years for its outstanding scientific-technological results as well as for its excellent contributions to the education of students and engineers.

1 *Strategy and Approach of the Materials Department © J. Friedrich / Fraunhofer IISB*

2 *X-ray analysis of a partially processed, 300 mm Si wafer © K. Fuchs / Fraunhofer IISB*

JOINT LABS


AIXTRON
Our technology. Your future
Fraunhofer
IISB
Forschungsfabrik
Mikroelektronik
1


Rigaku
XRTmicron
Fraunhofer
IISB
2

BENEFIT

Joint Labs offer industry the opportunity to collaborate with Fraunhofer IISB in form of a cross-organizational development team, which works together on the industry's key topics. This promotes a deeper understanding of the technology, which in turn facilitates technology transfer and accelerates integration into the product. To enable the team to work together successfully, premises are provided for the interdisciplinary team and the correspondingly necessary technical infrastructure, in which the team members can work together on the problems and develop new technologies and products. The Joint Labs can also function as a demo and application center for newly developed tools and equipment.

EXAMPLES

Based on the worldwide recognized expertise of the IISB in SiC epitaxy technology and characterization, the **SiC Epitaxy Demolab** will jointly enable the optimization of epitaxial production processes for 150 and 200 mm SiC wafers using Aixtron´s state-of-the-art G5WW production tools. The goal of the collaboration is the demonstration of efficient and economic high-volume manufacturing processes addressing the SiC material requirements of SiC power devices.
Rigaku Corporation and Fraunhofer IISB have built the **Center of Expertise for X-ray Topography** in Erlangen to support the semiconductor industry worldwide in improving and better understanding their wafer quality and yield by employing the Rigaku XRTmicron advanced X-ray topography tools. One aim is to develop industrial applicable measurement routines and defect counting algorithms which can be used in production and for R&D purposes.
The **Joint GaN HVPE Lab** together with Freiberger Compound Materials enables an efficient technology development by combining the know-how for HVPE processes and production equipment with material defect and characterization knowledge to fulfil the needs on material quality of future GaN markets.

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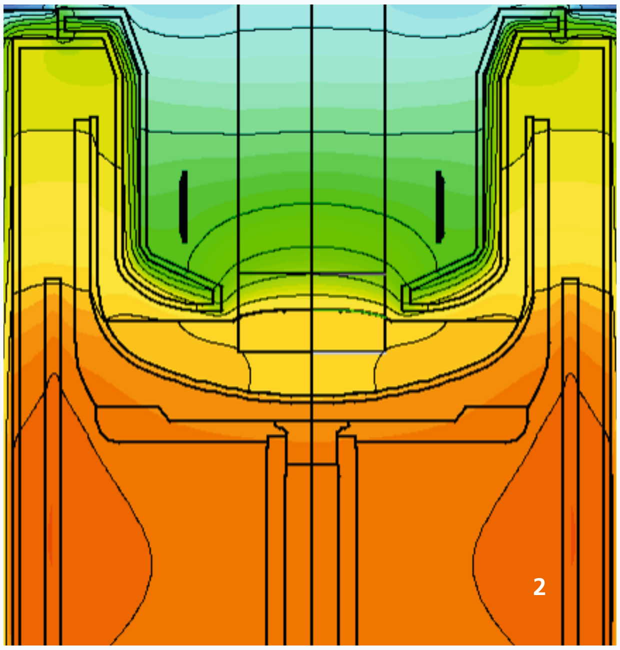
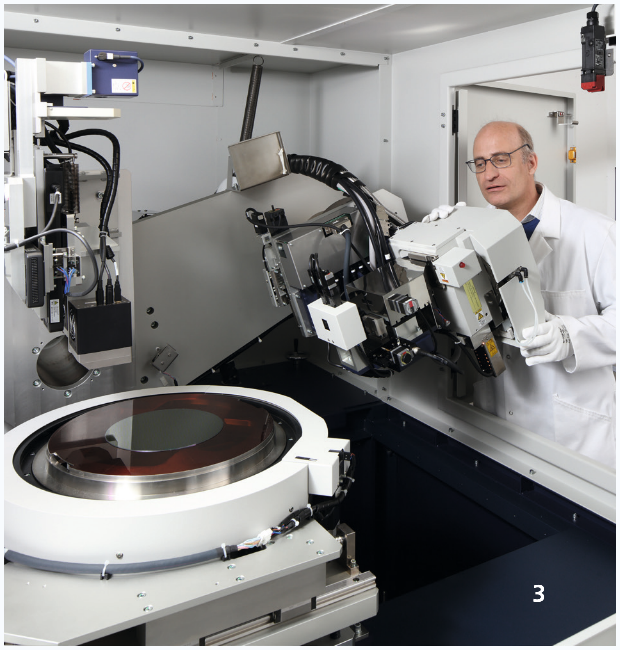
1 *Insight in the SiC Epitaxy Demolab jointly operated with Aixtron SE © K. Fuchs / Fraunhofer IISB*

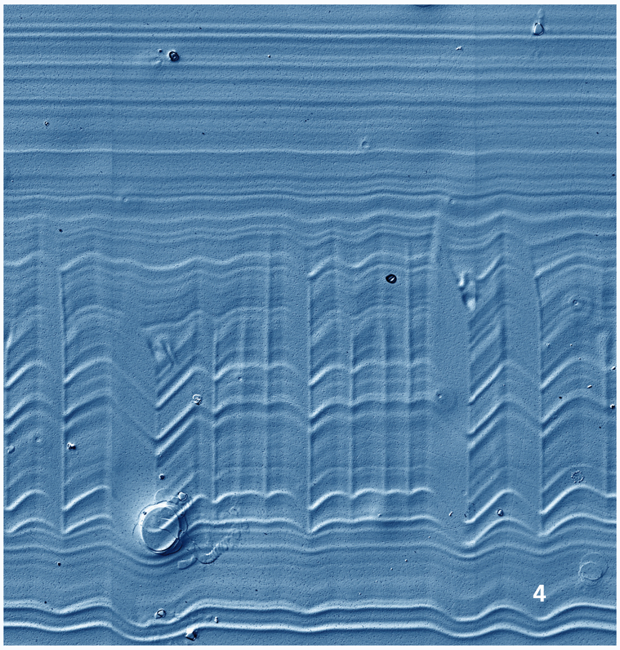
2 *Inauguration of the Center of Expertise for X-ray topography together with Rigaku Corporation © K. Fuchs / Fraunhofer IISB*

3 *Team of the Joint GaN HVPE Lab together with Freiberger Compound Materials © K. Fuchs / Fraunhofer IISB*

SILICON







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RESEARCH TOPICS

We perform specific research on the growth of silicon crystals by the Czochralski technique with respect to higher yield and improved material quality. For example we push the pull speed to its limit by optimization of the hot zone using numerical modeling or we unlock the secrets of the growth ridge in order to detect defect formation during crystal pulling. In the field of directional solidification emphasis is put on technology development and characterization of the Si ingots to be used for example as sputter targets or as mechanical components in the semiconductor industry.

SERVICES

- Specific crystal growth experiments in special R&D furnaces in house and at partners' sites
- Investigation of melt – crucible interaction phenomena for Cz and DS configurations
- Spray coating of crucibles, or furnace parts based on Si_3N_4, SiO_2, SiC and TaC suspensions
- Characterization:
  - shape of the solid-liquid interface by LPS
  - microstructural analysis of defect selectively etched samples
  - imaging of structural defects by X-ray topography
  - analysis of growth ridge geometry
  - determination of O, C, N by FTIR
  - minority carrier life time mappings (µPCD, MDP)
  - DLTS
- Simulation of heat and mass transport for Cz, FZ and DS including magnetic fields

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1 *Specific crystal growth experiments © Th. Richter / Fraunhofer IISB*

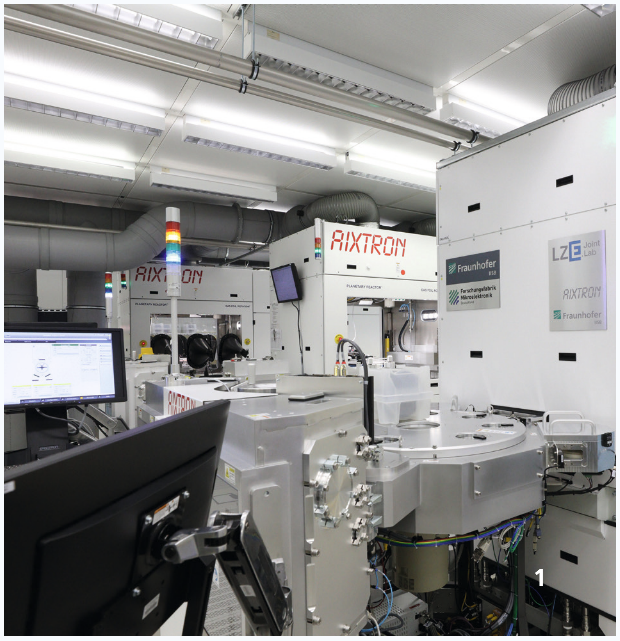
2 *Numerically calculated temperature field in Cz hot zone with active crystal cooler © T. Jung / Fraunhofer IISB*

3 *Full wafer mapping of defects by XRT © K. Fuchs / Fraunhofer IISB*

4 *Analysis of growth instabilities in heavily doped Si © L. Stockmeier / Fraunhofer IISB*

5 *300 mm Si Cz crystal © K. Fuchs / Fraunhofer IISB*

SILICON CARBIDE



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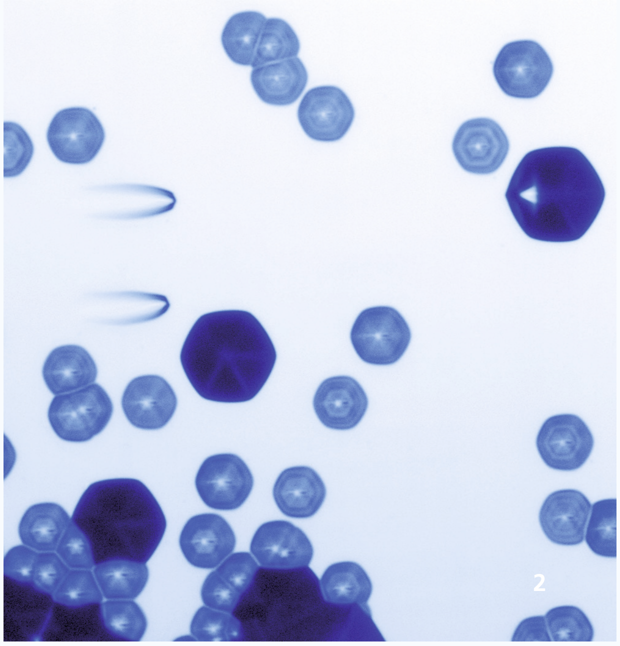
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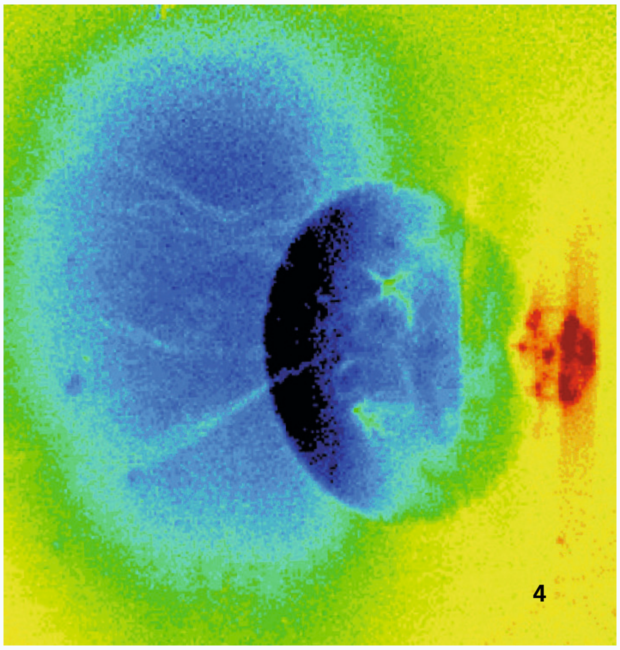
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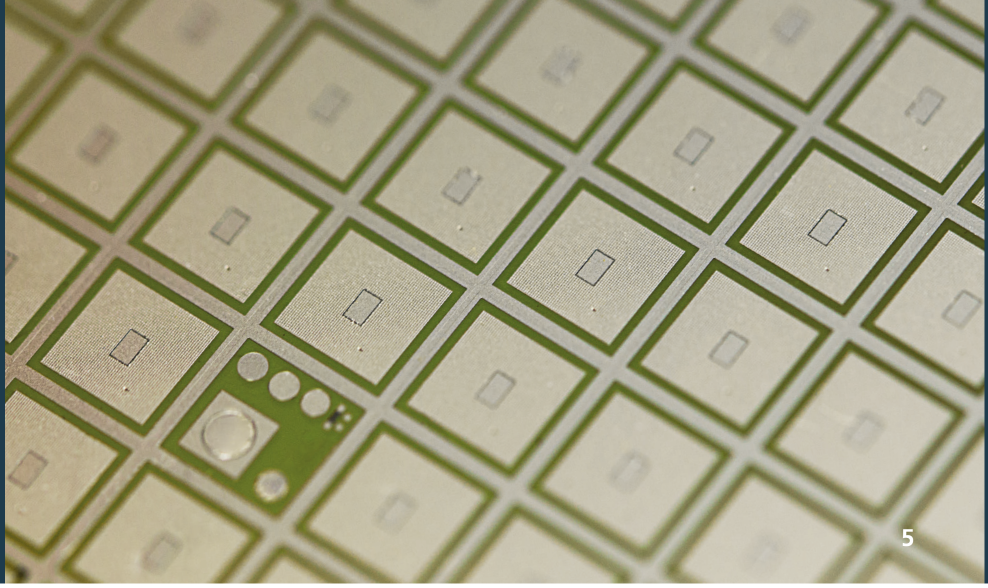

RESEARCH TOPICS

We develop the 150 mm SiC epitaxy process with emphasis on improved material quality, thick epilayers, p-doping, and minority carrier lifetime. In the frame of our 200 mm SiC demo lab we pioneer the epitaxy and the implant annealing on 200 mm SiC substrates. State of the art metrology tools such as UV-PL or XRT together with the possibility to process complete devices in our qualified 150 mm SiC line allows us to correlate the properties of the epilayer and the substrate with electrical device parameters. Based on the findings solutions are demonstrated how to overcome harmful defects.

SERVICES

- n- and p-type service epitaxy on 4H-SiC wafers (150 mm, 200 mm)
- Processing of SiC prototype devices (e.g. JBS, VDMOS, diodes, CMOS)
- Correlation of material defects with device performance and reliability along the whole device processing chain
- Characterization
  - imaging of structural defects by x-ray topography on full wafer scale
  - imaging of structural defects by combined optical surface and photoluminescence mappings on full wafer scale
  - defect selective etching
  - carrier lifetime measurements
  - deep level transient spectroscopy (DLTS)
  - mCV and FTIR measurements
- Simulation of heat and mass transport for SiC epitaxy, and other high temperature SiC specific processes

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1 *Epitaxy on SiC substrates (150 mm, 200 mm) © K. Fuchs / Fraunhofer IISB*

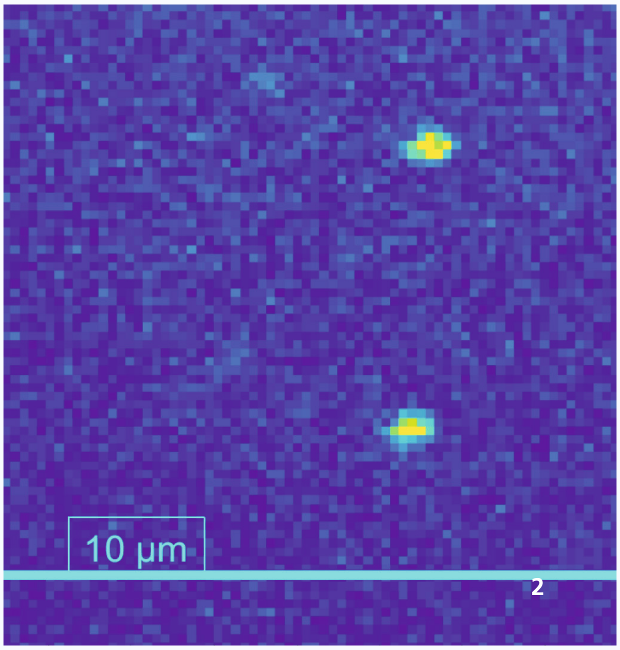
2 *Various dislocations in SiC visualized by DSE © B. Kallinger / Fraunhofer IISB*

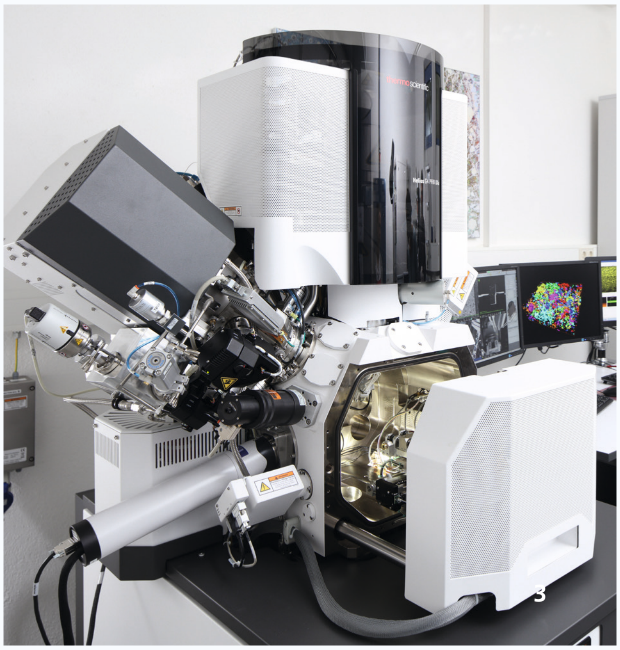
3 *UV-PL defect scanner for characterization of SiC © K. Fuchs / Fraunhofer IISB*

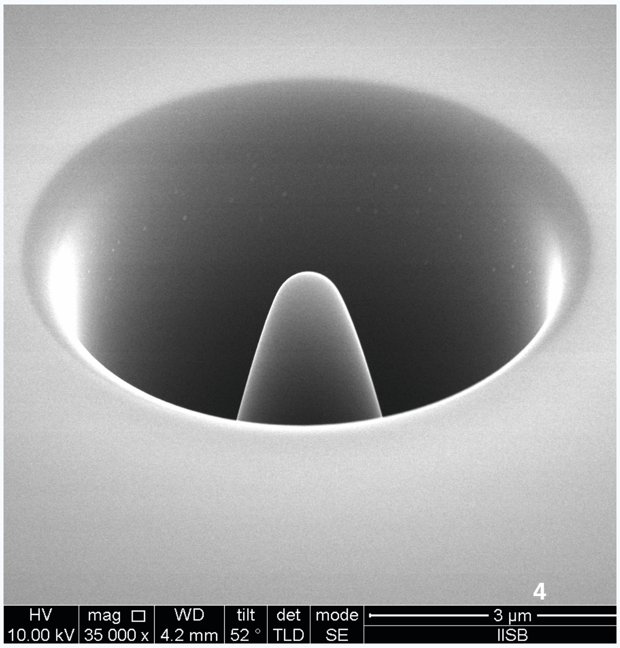
4 *Lifetime map of SiC epilayer © J. Erlekampf / Fraunhofer IISB*

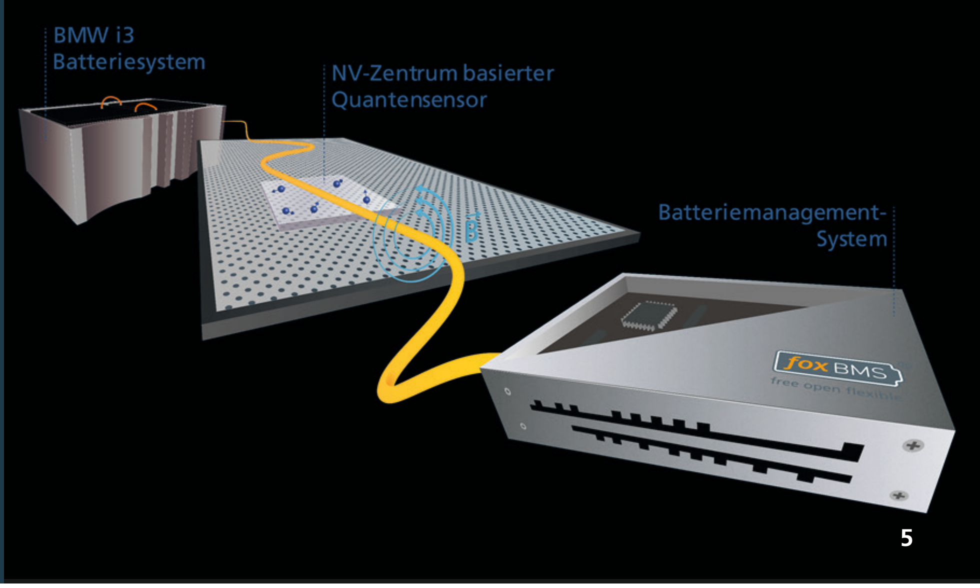
5 *In house processed SiC power devices © A. Grabinger / Fraunhofer IISB*

QUANTUM MATERIALS (SiC, Diamond)









RESEARCH TOPICS

We pioneer the development of SiC and diamond for quantum applications. Our research covers the entire value chain, from material development, the creation of color centers, design and processing of quantum devices, and their integration into system demonstrators. One focus is on the deterministic generation of high quality color centers with long spin coherence on a nanometer scale. Special characterization set-ups are available to characterize the quantum systems. Furthermore, we use tailored simulation tools to support the material and technology development.

SERVICES

- Epitaxy of isotopically pure SiC for quantum application
- Generation of color centers in SiC and diamond by ion implantation, E-beam, He-FIB
- Stabilization of color centers by surface conditioning of SiC and diamond
- Characterization of color centers by optical DLTS, cryogenic photoluminescence, ODMR
- Nanostructuring of SiC and diamond by E-beam, He-FIB
- Design of novel device concepts for quantum applications
- First principle quantum simulations of influence of material properties on spin coherence time in SiC and diamond
- Development and test of system demonstrators, e.g.
    - highly precision diamond based magnetic field sensors
    - SiC based quantum repeater
    - SiC based memory-assisted quantum network
    - diamond based quantum computers

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1 *Epitaxy of isotopically pure SiC © K. Fuchs / Fraunhofer IISB*

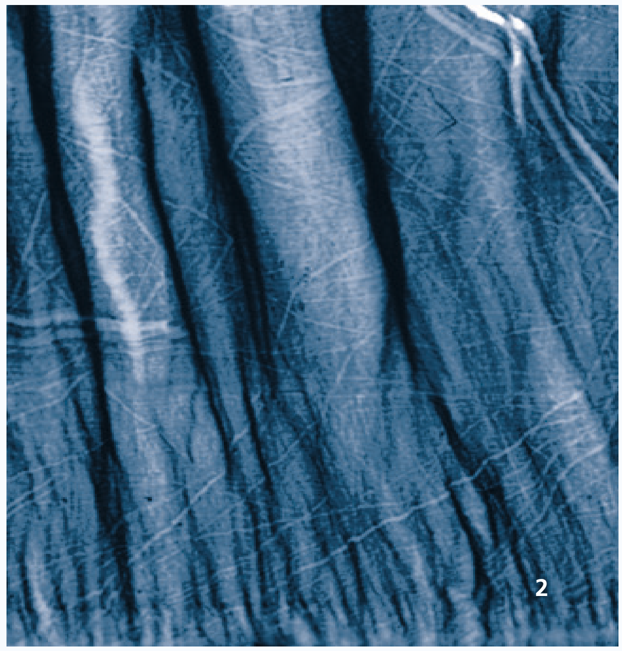
2 *Two color centers generated by ion implantation in SiC epilayer grown @ IISB © Ch. Gobert / Fraunhofer IISB*

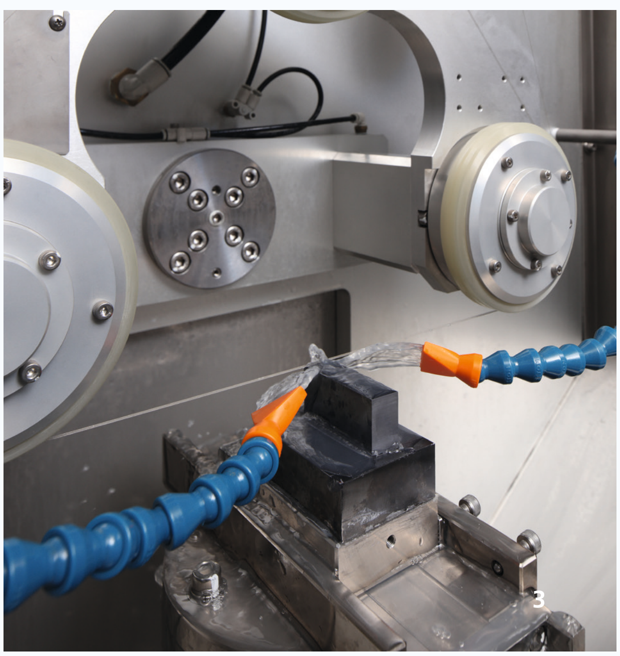
3 *Nanostructuring of SiC & Diamond by FIB © K. Fuchs / Fraunhofer IISB*

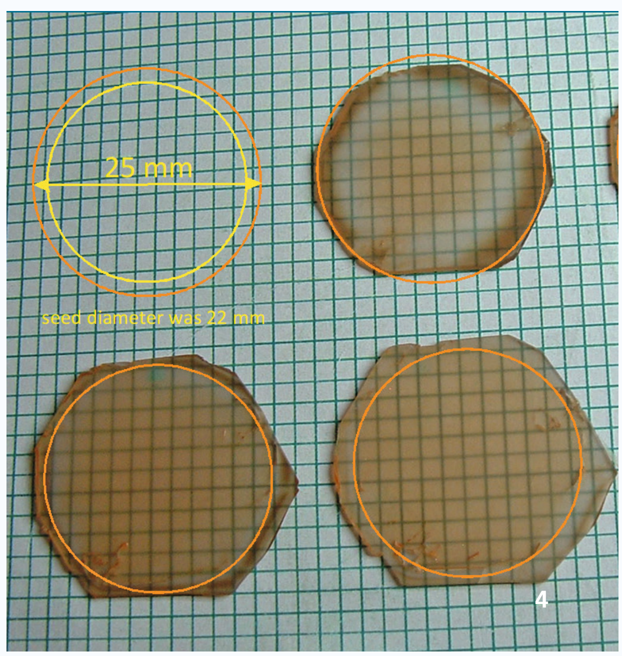
4 *Lense Structures in SiC & Diamond by FIB © M. Rommel / Fraunhofer IISB*

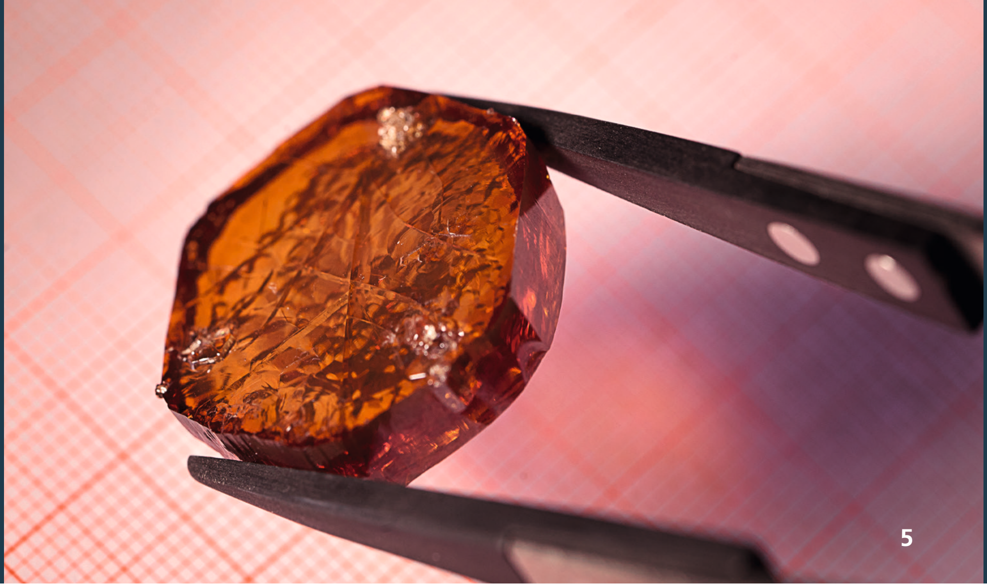
5 *Artwork of a diamond quantum sensor to monitor the battery status of a e-vehicle © A. Grabinger / Fraunhofer IISB*

GaN & AlN









RESEARCH TOPICS

We develop the HVPE growth of GaN crystals. The process is optimized towards a high uniform V/III ratio along the growing interface by comparing in-situ process data, ex-situ determined properties of the crystal with results from numerical modeling of the growth process. We pioneer the PVT growth of AlN crystals with focus on deeper understanding of growth mechanisms and upscaling towards larger crystal diameters. In our wafering line we explore advanced GaN and AlN crystal preparation and characterization technologies for epi-ready wafers.

SERVICES

- Growth of GaN and AlN crystals
- Epitaxy of AlGaN on GaN, AlN and sapphire substrates up to 4" diameter
- Simulation of heat and mass transport of the HVPE and PVT process
- Identification of device critical defects in nitrides
- Characterization of crystals and epitaxial structures:
  - imaging of extended defects by x-ray topography
  - defect selective etching
  - Cathodoluminescence
  - Photoluminescence
  - Raman- and FTIR spectroscopy
- Investigation of electrical properties of extended defects by conductive atomic force microscopy and electron beam induced current measurements and imaging techniques

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1 *Crystal growth of AlN by the PVT technique © A. Grabinger / Fraunhofer IISB*

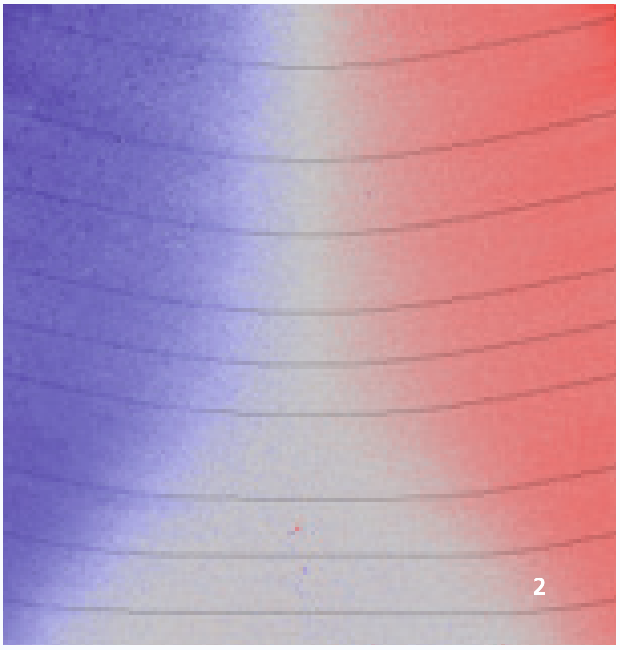
2 *XRT image of HVPE GaN sample © M. Knetzger / Fraunhofer IISB*

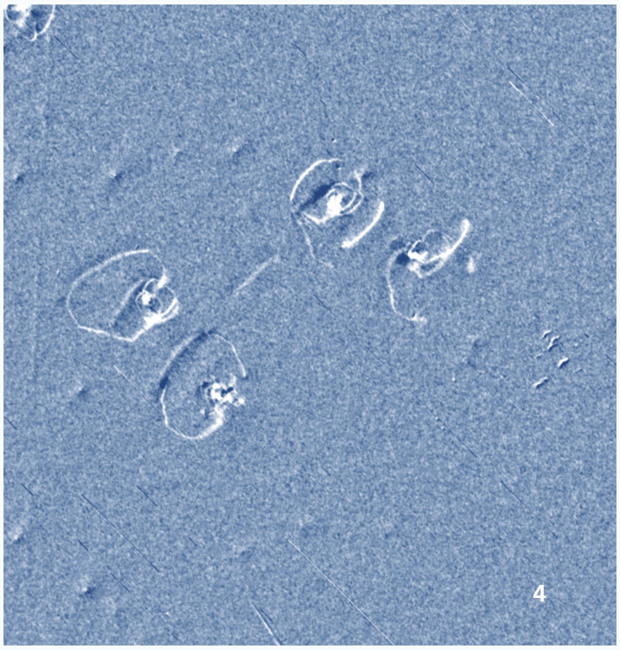
3 *Wafering line for nitride materials © K. Fuchs / Fraunhofer IISB*

4 *Multiple AlN wafer with 1 inch diameter © B. Epelbaum / Fraunhofer IISB*

5 *Aluminium Nitride crystal © A. Grabinger / Fraunhofer IISB*

OTHER CRYSTAL MATERIALS





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RESEARCH TOPICS

We are well experienced in the growth and characterization of a variety of other semiconductor materials (Ge, GaAs, InP, CdTe) as well as of optical, laser and scintillator crystals (sapphire, oxides (LSO, YVO_4, Y_2O_3) or halides (CaF_2, $CeBr_3$)) by different melt and solution growth techniques. We support our customers in the development of new crystal growth and epitaxy equipment and processes based on our broad material expertise and by using numerical simulation. Furthermore, we offer specific characterization services of crystal and wafer material.

SERVICES

- Support of the development of crystal growth and epitaxy equipment by using thermal modeling and our expertise in the engineering of in-situ measuring techniques
- Specific crystal growth experiments in special R&D furnaces in house and at partners' sites
- Sample preparation for the analysis of the properties of the materials
- Characterization of structural, optical, physical, chemical, and electrical properties
- Simulation of heat and mass transport phenomena including the effects of magnetic fields

1 *VGF crystal growth furnace © K. Fuchs / Fraunhofer IISB*

2 *Solid-liquid interface shape in 6" Cz Ge crystal visualized after DSE and automated image processing © Ch. Kranert / Fraunhofer IISB*

3 *Polishing and defect selective etching © K. Fuchs / Fraunhofer IISB*

4 *Frank Read type dislocation loops in VGF GaAs visualized by XRT © Ch. Kranert / Fraunhofer IISB*

5 *GaAs crystals, grown by the VGF process © B. Birkmann / Fraunhofer IISB*

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FUNCTIONAL COATINGS (SiO_2, Si_3N_4, SiC, TaC)

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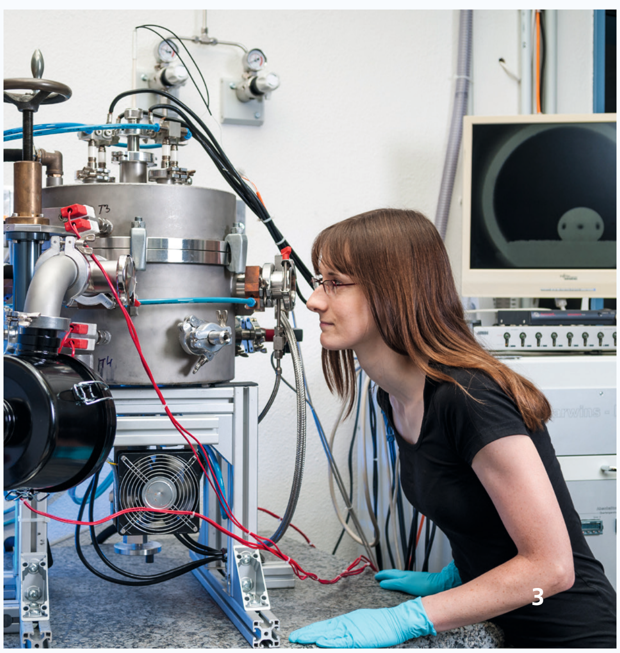

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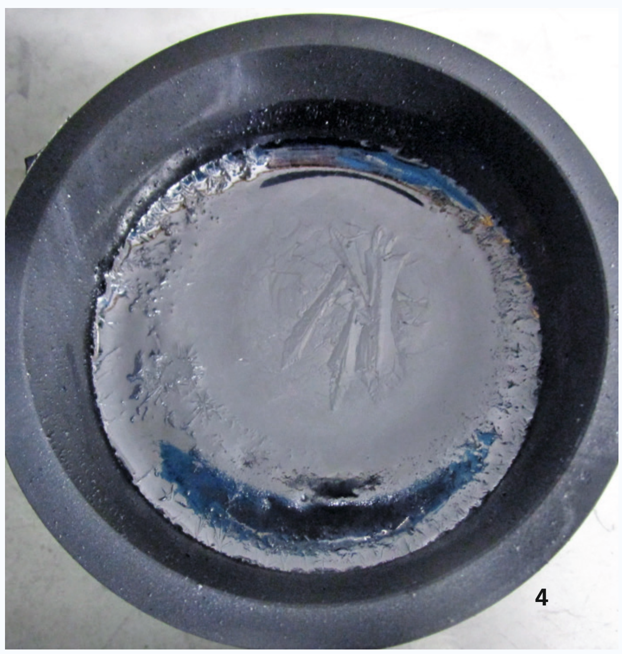

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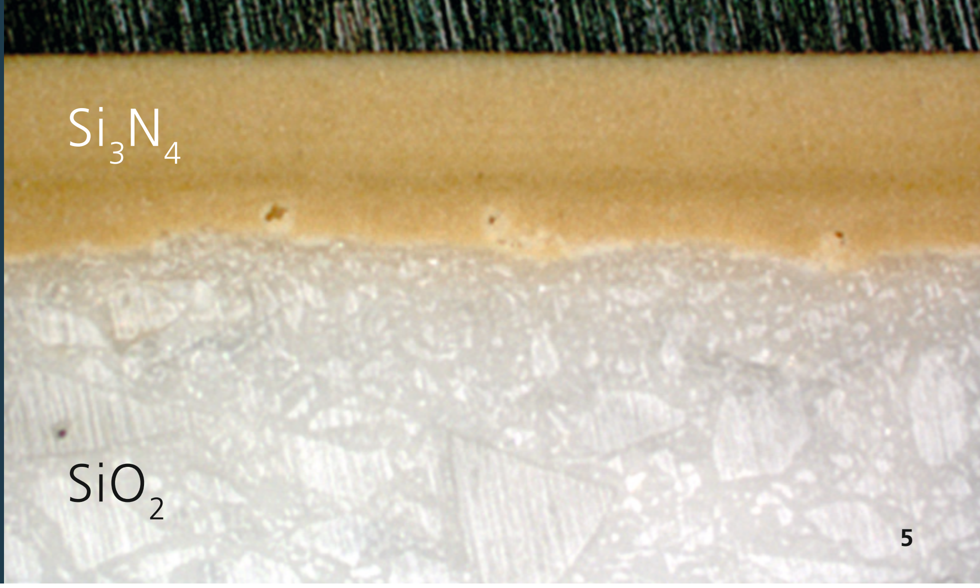

RESEARCH TOPICS

We use spray coating of e.g. SiO_2, Si_3N_4 and SiC to functionalize crucibles and other furnace parts in order to reduce harmful defects and impurities and to increase the lifetime of the furnace parts. For Cz silica crucibles we have a qualified vacuum bake out test procedure in order to investigate bubble behavior and cristobalite formation. Another focus is on ultra-high-temperature and chemical resistant protective TaC coatings on graphite and other materials. We develop this novel patented technology for applications in semiconductor industry, especially for SiC PVT crystal growth and epitaxy, but we address also space and aviation applications.

SERVICES

- Spray coating of SiO_2, Si_3N_4, SiC, and TaC on graphite, silica, ceramics, refractory metals
- Analysis of wetting behavior of silicon and other melts according to the sessile drop method
- Vacuum bake out test and analysis of Cz crucibles
- Microstructural characterization of coatings and crucibles
- Test of coatings under application conditions

1 *Spray coating of crucibles and furnace parts with SiO_2, Si_3N_4, SiC and TaC © K. Fuchs / Fraunhofer IISB*

2 *TaC coated graphite parts © M. Lang / Fraunhofer IISB*

3 *Sessile drop facility to measure the wetting behavior of coatings with melts © Th. Richter / Fraunhofer IISB*

4 *Graphite crucible coated with Si_3N_4 after directional solidification of a Si ingot © F. Sturm / Fraunhofer IISB*

5 *Shard of a fused silica crucible with a 270 µm thick Si_3N_4 coating © S. Schwanke / Fraunhofer IISB*

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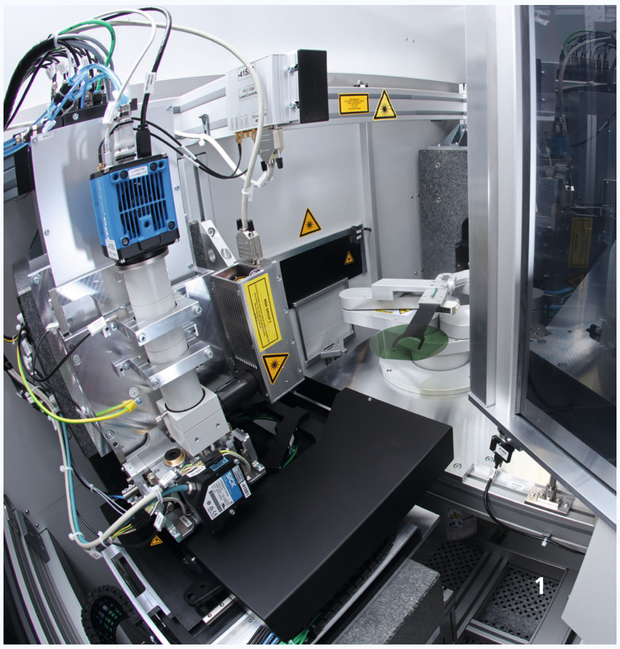
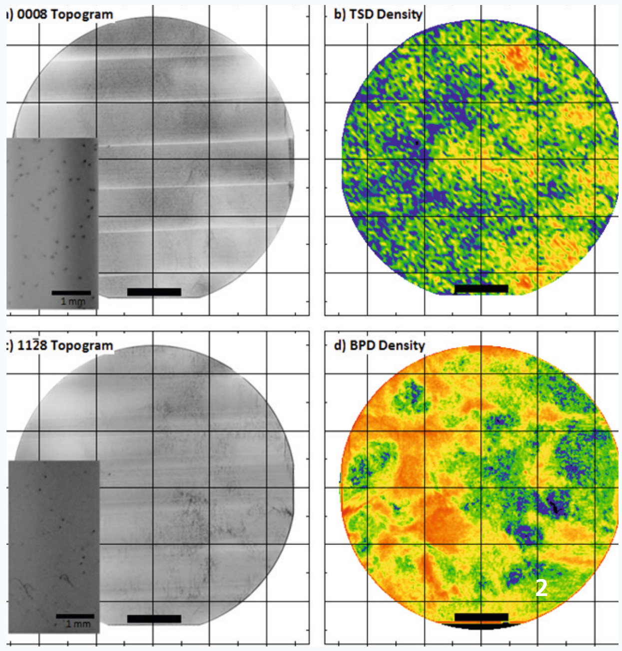
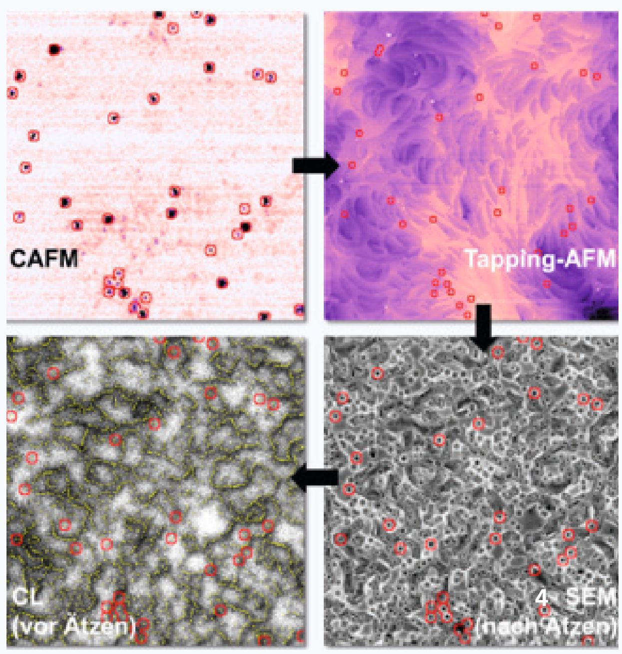
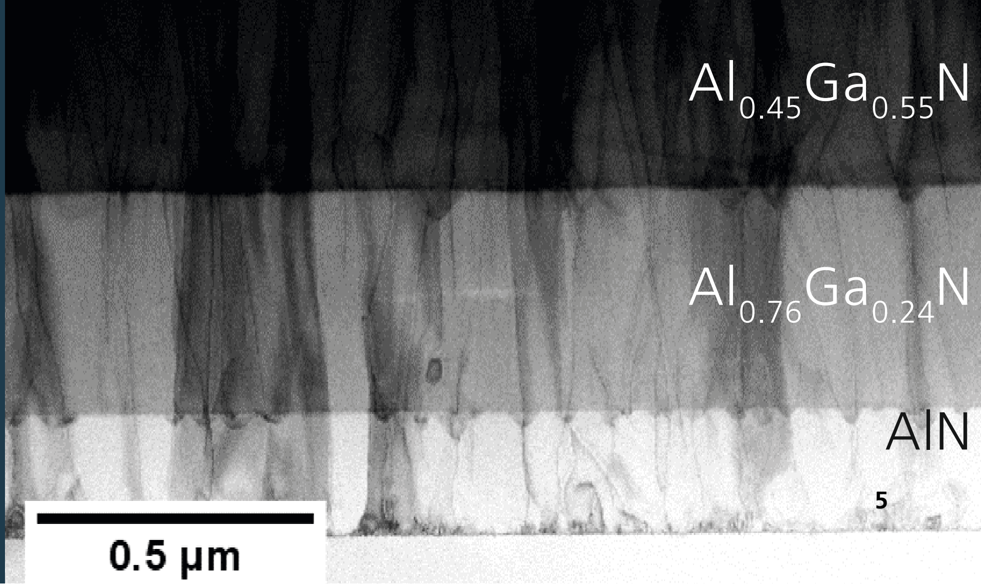
MATERIALS ANALYSIS









RESEARCH TOPICS

We are experienced with the characterization of the optical, electrical, structural, physical, and chemical properties of different crystal, wafer and epi materials as well as of partially and fully processed devices. This allows us on the one hand to perform service measurements within a fast return time for our customers. On the other hand we use this toolbox, especially our in-house epi reactors in combination with the possibility to process test devices, to identify defects critical for device performance and reliability, to understand their origin and to find solutions together with our customers how to overcome the critical defects.

SERVICES

- Identification of device critical materials defects and correlation with device performance
- Epitaxy (SiC, AlGaN) and device processing
- Characterization of crystals, epitaxial structures and devices:
  - x-ray topography, x-ray diffraction
  - optical microscopy, scanning and transmission electron microscopy
  - various atomic force microscopy methods
  - LPS to determine interface shapes
  - electrical and optical defect spectroscopy like
    - DLTS, optical DLTS
    - cathodoluminescence, photoluminescence
    - PL scanner for full wafer imapging
    - EBIC, Raman- and FTIR spectroscopy
  - minority lifetime measurements (µPCD, MDP)
  - IV & CV measurements, and much more
- Development of tailored metrology techniques together with metrology manufacturer

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1 *Photoluminescence imaging of wide band gap materials © K. Fuchs / Fraunhofer IISB*

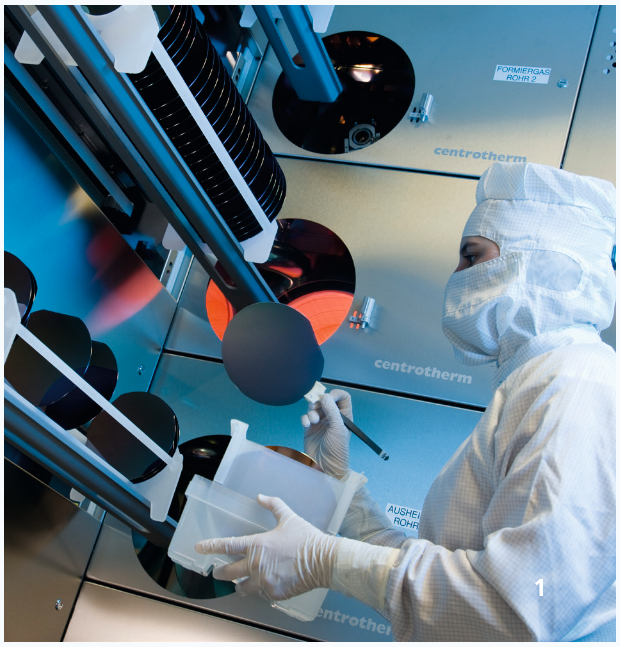
2 *TSD and BPD mappings of SiC wafers by x-ray topography © Ch. Kranert / Fraunhofer IISB*

3 *Optical and electron microscopy © K. Fuchs / Fraunhofer IISB*

4 *Visulalization of leakage current pathways and their correlation to certain dislocation types by different techniques © S. Besendörfer / Fraunhofer IISB*

5 *TEM micrograph of a AlGaN heterostructure with V-pits at the interfaces of the AlN, AlGaN layers © S. Besendörfer / Fraunhofer IISB*

TEST DEVICES



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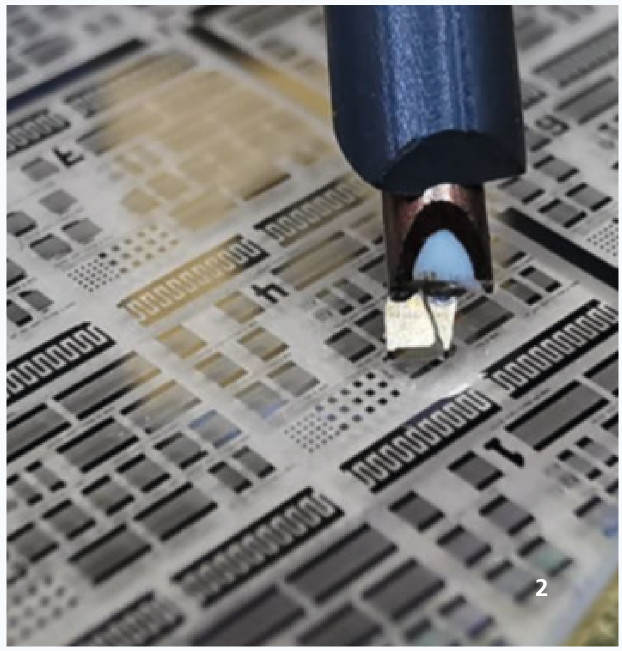
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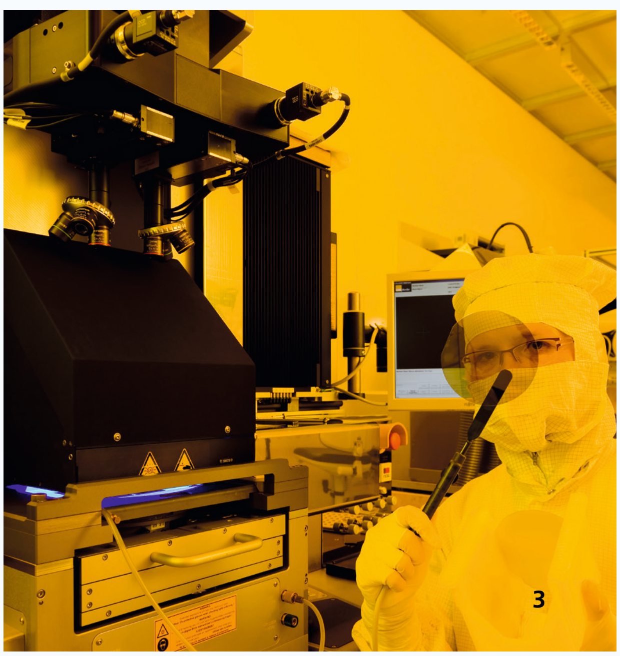
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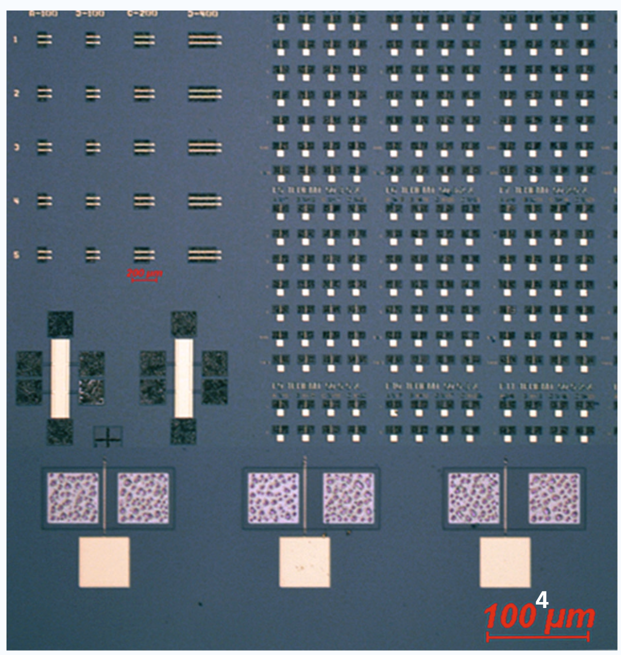

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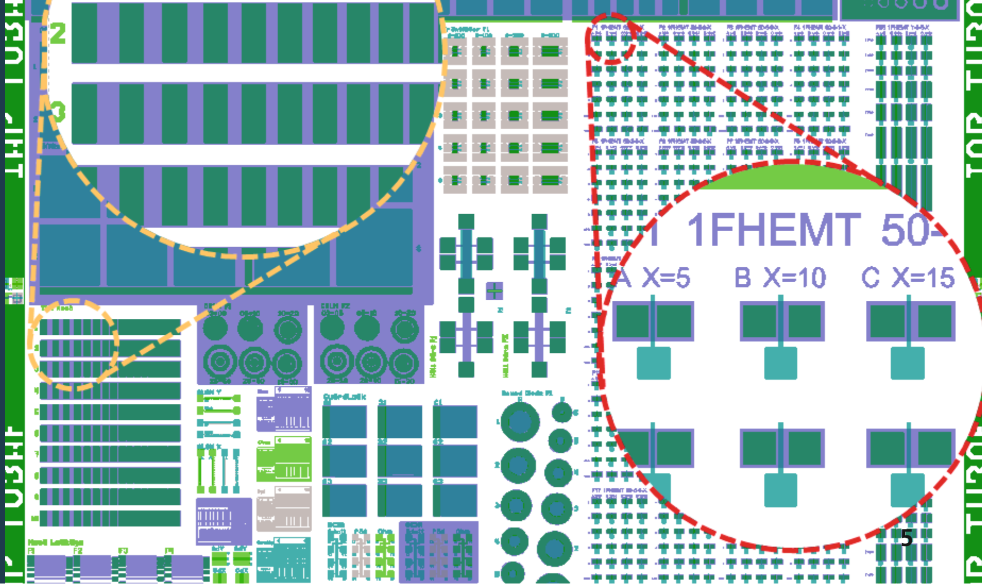

RESEARCH TOPICS

As part of the Research Fab Microelectronic Germany (FMD) we operate a continuous 150 mm silicon carbide process line in an industry-compatible environment at our headquarter in Erlangen. With three decades of experience in microelectronics research and development we extended our activities to industry-oriented low-volume prototype fabrication of custom-tailored SiC devices, with a focus on power devices, CMOS devices, passives, sensors. Furthermore, we utilize a customized design of test devices, which are processed in our flexible fully CMOS equipped clean room facility in our subsidiary in Freiberg, in order to correlate the material properties to device performance and to identify device critical defects.

SERVICES

- Low-volume prototype fabrication of SiC devices (e.g. JBS, VDMOS, diodes, CMOS)
- Customized design of test devices
- Processing of test devices (e.g. GaAs, InP, GaN, AlN, AlScN, Diamond) in a flexible R&D line
- Development of device process steps (ALD, ALE, passivation, etching, metallization)
- Epitaxy (SiC, AlGaN)
- Identification of device critical materials
- Electrical characterization of devices on wafer level by IV, CV measurements

1 *Oxidation furnace © K. Fuchs / Fraunhofer IISB*

2 *AlN SAW structures on sapphire © Ch. Miersch / Fraunhofer IISB*

3 *Optical inspection of a SiC wafer © K. Fuchs / Fraunhofer IISB*

4 *Microscopy image of GaN high-electron-mobility Transistors (HEMT) with varying gate length and other device test structures. © F. Weichelt / Fraunhofer IISB*

5 *Mask design of device test structures, especially HEMTs and linear transfer line structures for contact resistance measurements. © Ch. Miersch / Fraunhofer IISB*

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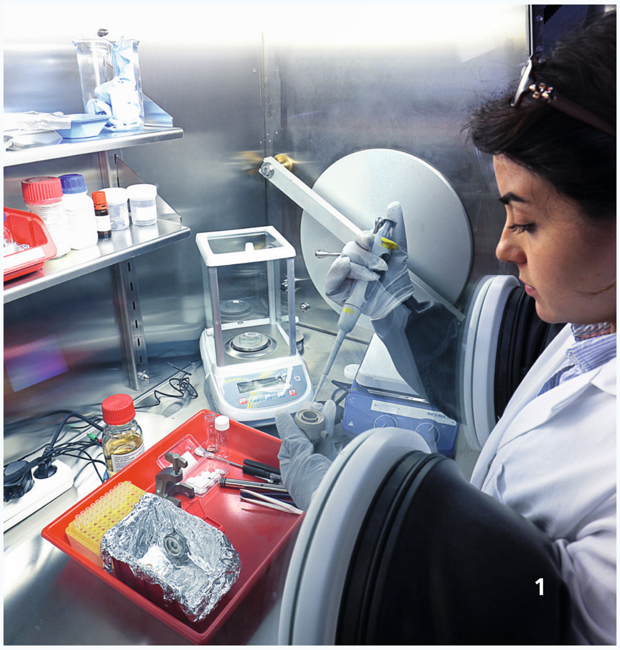
franziska.beyer@iisb.fraunhofer.de
www.**iisb**.fraunhofer.de/**beyer**

ENERGY MATERIALS



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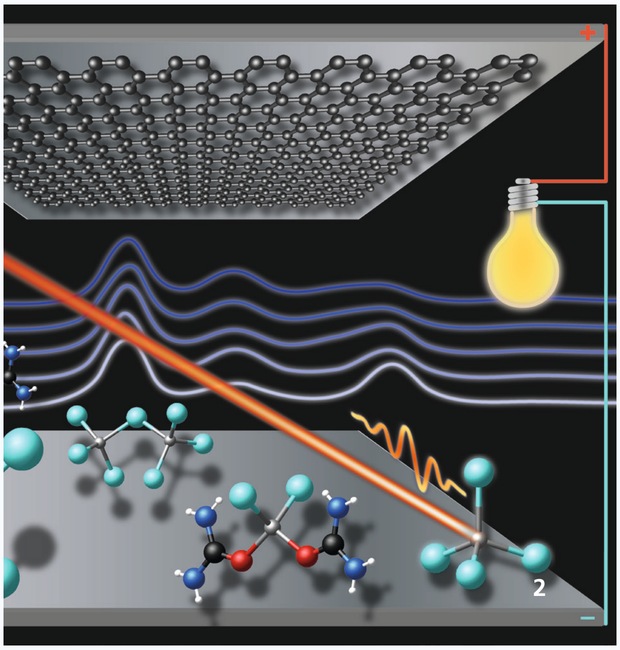

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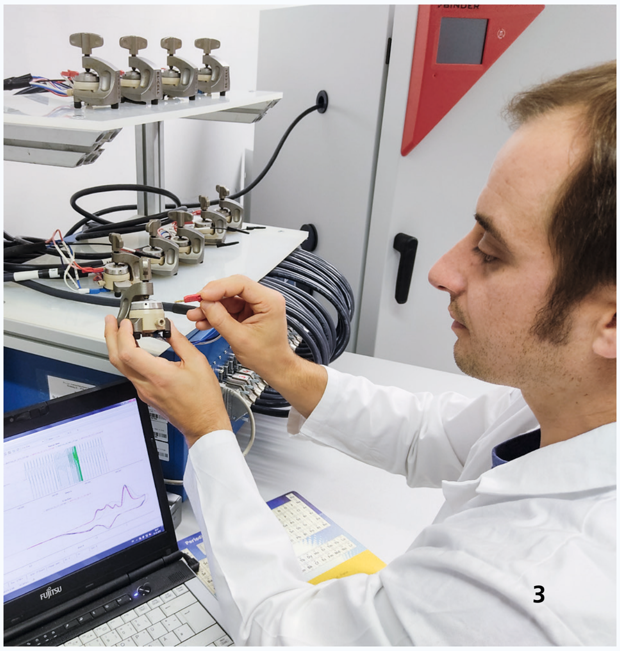

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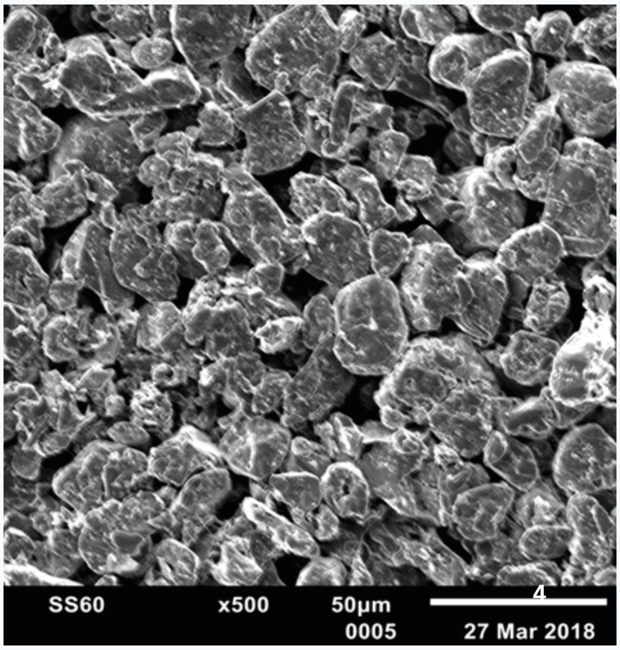

4

RESEARCH TOPICS

We develop and analyze sustainable battery systems in particular rechargeable aluminum ion battery system (AIB) as a low cost and non-flammable storage system. We have demonstrated energy densities of 135 Wh/kg regarding the active mass by using graphite as cathode material. Our AIB can be charged and discharged in less than 20 seconds. The process is reversible and we have shown more than 10.000 cycles with a charging efficiency of over 90% in lab and coin cells. We test application-relevant cell designs such as pouch cells. The currently achieved performance of the AIB is already comparable to NiMH batteries. Thus, AIB have a great potential for stationary and mobile applications.

SERVICES

- Synthesis and functionalization of powders for use as electrode materials and other functional applications
- Preparation of slurries and manufacturing of electrodes with different coating processes
- Morphological and structural characterization of particles and layers using
  - SEM
  - Raman with in situ option
  - XRD with in situ option (in preparation)
  - FTIR, ATR-IR
  - BET
  - Laser diffraction
- Characterization of electrolytes
  - Conductivity
- Electrochemical characterization by CV and EIS using lab cells (EL-CELL®) and coin cells

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1 *Assembly of battery cells © K. Fuchs / Fraunhofer IISB*

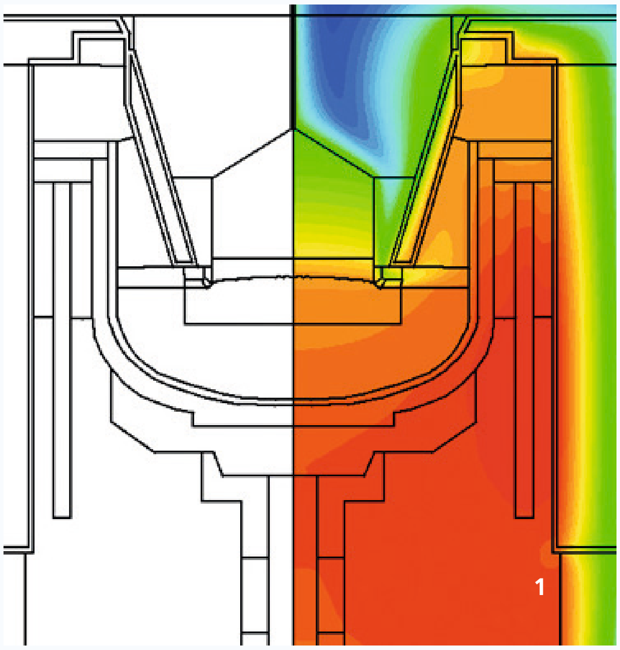
2 *Artwork of a low-cost Al-graphite battery with Urea and Acetamide-based electrolytes © Th. Richter, F. Jach / Fraunhofer IISB*

3 *Electrochemical characterization of laboratory cells (EL-CELL®) © U. Wunderwald / Fraunhofer IISB*

4 *SEM image of natural graphite flakes used as cathode material in the AIB @ F. Jach / Fraunhofer THM*

5 *The most important components of AIB: Al foil, graphite powder, and a special electrolyte @ M. Wassner / Fraunhofer THM*

SIMULATION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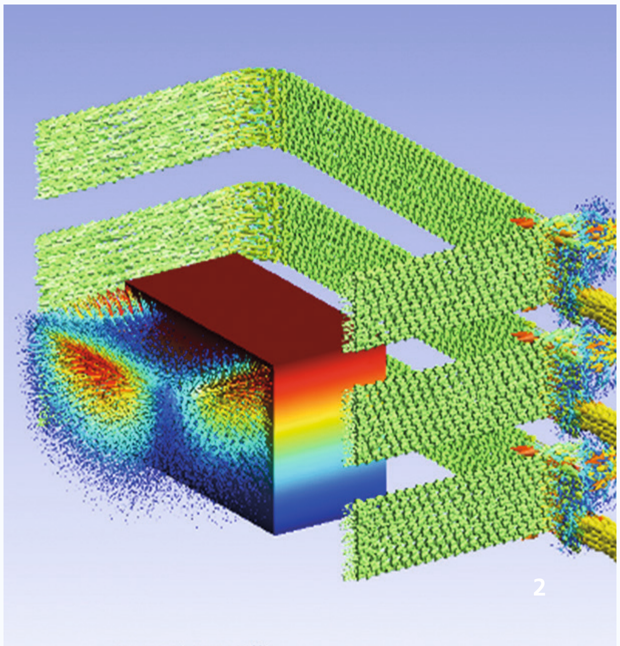
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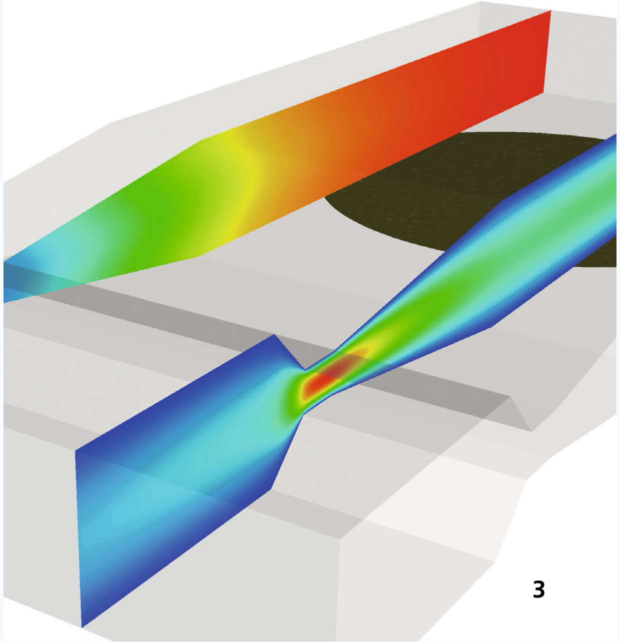
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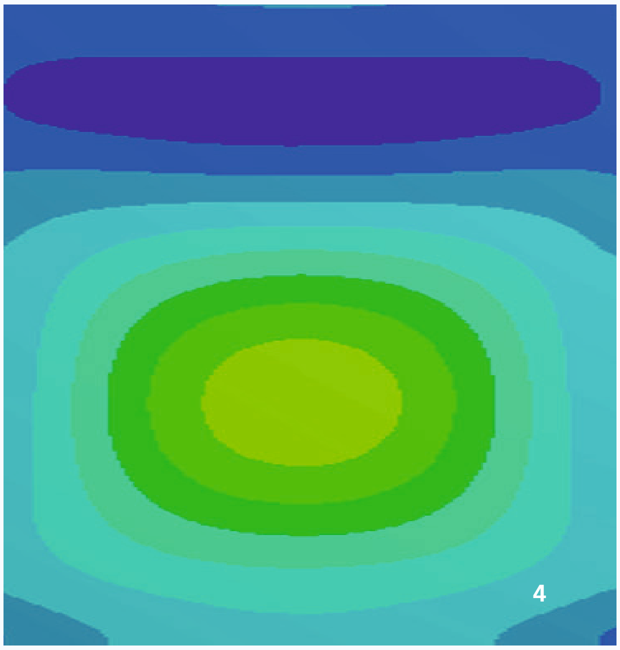
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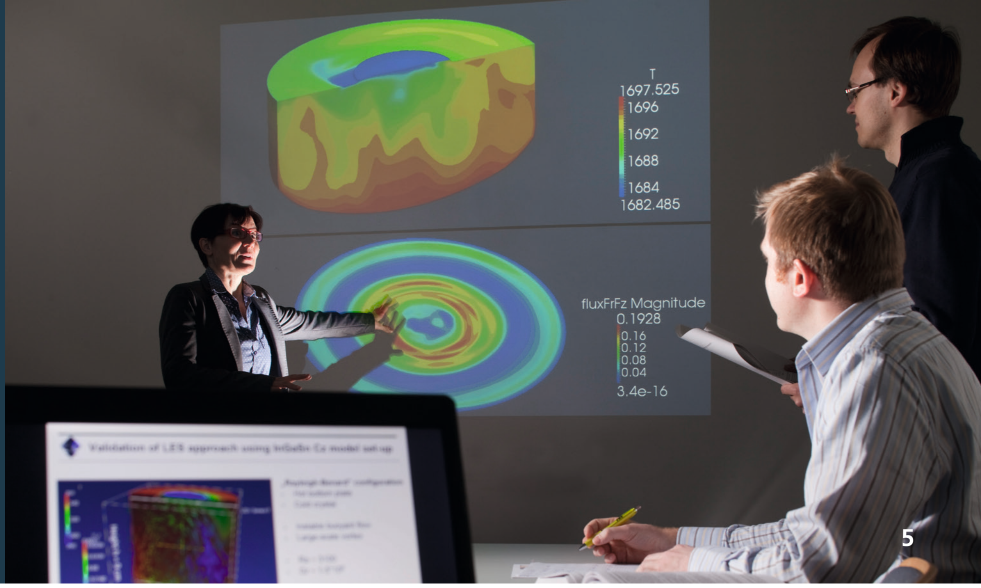

5

RESEARCH TOPICS

We support the development of high-temperature equipment and processes by our expertise in numerical modeling of heat and mass transport phenomena. Specific expertise is available for crystal growth and epitaxial processes. We are also experienced with other thermal processes like e.g. wafer annealing. We elaborate solutions for furnace modifications in order to optimize the systems for the respective application and we give new insights into the processes, especially for parameters that are hardly accessible via measuring techniques like species distributions or convection pattern.

SERVICES

- Thermal simulations (conduction, convection, radiation)
- Flow simulations (gas, melt, turbulence including magnetohydrodynamics)
- Stress simulations
- Electromagnetic field simulations
- Simulation of species transport including chemical reactions
- Software tools: CrysMAS, OpenFOAM, Ansys
- Processes: Cz, VGF, DS, FZ, EFG, LPE, THM, CVD, PVT, HVPE, Annealing
- Materials: Si, Ge, GaAs, InP, GaN, AlN, SiC, CdZnTe, Halides, Oxides

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1 *Global simulation of a Czochralski puller*
© T. Jung / Fraunhofer IISB

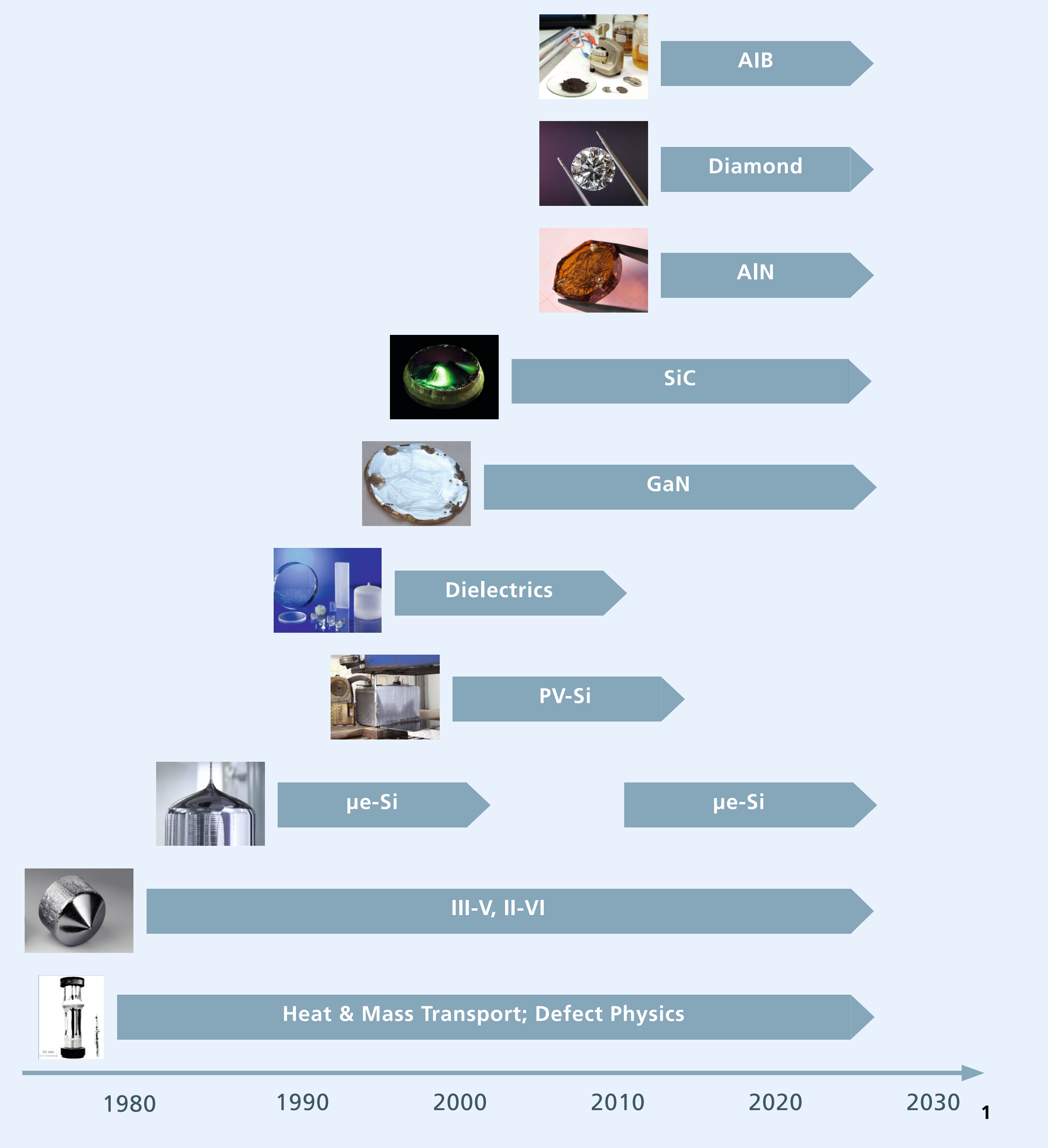
2 *3D electromagnetic simulation of Lorentz forces*
© T. Jung / Fraunhofer IISB

3 *3D CFD model of a CVD process*
© J. Seebeck / Fraunhofer IISB

4 *Stress distribution in a semiconductor crystal*
© S. Hürner / Fraunhofer IISB

5 *Support of customers by modeling*
© K. Fuchs / Fraunhofer IISB

HISTORY


AlB
Diamond
AlN
SiC
GaN
Dielectrics
PV-Si
µe-Si
µe-Si
III-V, II-VI
Heat & Mass Transport; Defect Physics
1980
1990
2000
2010
2020
2030

1

ERLANGEN

In the 1950s famous Siemens engineers pioneered the semiconductor technology in the Erlangen area. Innovations were made such as the Siemens and the Floating Zone process or the discovery of the compound semiconductors. This work promoted R&D at the University Erlangen-Nürnberg which resulted in the foundation of the Crystal Growth Laboratory (CGL) in the 1970s. In the 1990s CGL established a department at Fraunhofer IISB. In 2005 this department became also responsible for the Fraunhofer THM in Freiberg (Saxony).

FREIBERG

Freiberg was famous for its silver mining in the Middle Ages. In the 19th century Indium and Germanium were discovered at the Technical University Freiberg. In the German Democratic Republic it was the center for the production of semiconductor materials. This triggered R&D on semiconductors at the Technical University Freiberg. After the reunification the companies which emerged from the original "VEB Spurenmetalle" had close collaborations with the researchers from Erlangen, who founded the Fraunhofer THM, a subsidiary of Fraunhofer IISB, in 2005.

1 *Materials at CGL and IISB © J. Friedrich / Fraunhofer IISB*

2 *Silver found in Freiberg © TU Bergakademie Freiberg*

MILESTONES

2021 Semi standard on TSD determination of SiC by XRT in frame of Joint Lab with Rigaku

2020 V-Pits identified as root cause for leakage currents in GaN HEMT structures

2019 Generation of NV centers in diamond by ion implantation @ IISB

2018 Laser writing of color centers in SiC epilayers grown @ IISB

2017 Root causes for dislocation formation in heavily doped Cz Si found

2016 First AlN PVT crystal grown

2015 first 6" SiC epilayers grown in the frame of Joint Lab with Aixtron

2014 first 2" thick, crack free HVPE GaN crystals grown in the frame of Joint Lab with FCM

2013 Prediction of bipolar degradation of pin SiC diodes by using UV PL scanner

2012 Coupled 2D-3D Cz simulation software validated for 200 kg Si Cz process

2011 Twin formation during DS of quasi mono PV Si clarified

2010 BPD free SiC epitaxial layers on 3" substrates demonstrated

2009 Advantages of time-dependent magnetic fields in DS of PV Si demonstrated

2008 Doping effects on etch pit geometry of DSE SiC substrate and epilayers clarified

2007 Root cause for Si_3N_4 and SiC formation during DS mc Si understood

2006 First SiC epilayers grown on 2" SiC substrate in VP508

2005 Reduction of dislocation density in VB CZT crystals achieved by the help of numerical simulation

2004 20 µm thick 2" LPE GaN grown on sapphire with EPD ~ 107cm^{-2} demonstrated

2003 Advantages of time-dependent magnetic fields for VGF grown GaAs crystals demonstrated

2002 In-situ temperature and oxygen measurements during 300 mm Si Cz growth

2001 First 6" VGF CaF_2 crystal grown

2000 Need for 2D-3D modeling for CZ Si and MCZ Si realized

1999 Inverse modeling concept introduced into the field of crystal growth

1998 First 4” VGF GaAs single crystal with a weight of 10 kg grown

1997 3” VGF GaAs sinlge crystal with EPD=50 cm^{-2} (Si doped) demonstrated

1996 First software license granted

1995 Compensation mechanisms in s.i. InP clarified

1994 First 3” VGF GaAs single crystal grown

1993 FZ GaAs single crystal with 20 mm diameter grown during German Spacelab Mission D2

1992 First 2” VGF InP single crystal grown

1991 Comparison of different MHD models on the damping effects of static magnetic fields

1990 Determination of the critical Marangoni number for GaAs

1989 Worldwide first LEC InP single crystal with 3” diameter grown

1988 Novel model for description of the dislocation dynamics in semiconductor melt growth

1987 Root cause for non-uniformities in semiconductor melt growth clarified

1986 Proof of the theory of Jackson and Hunt by data from space experiments

1985 Directional solidification experiments with InSb-NiSb onboard German Spacelab Mission D1

1984 Tenfold growth rate for THM GaSb achieved by growth on a centrifuge

1982 Suppression of doping striation by forced convection demonstrated

1983 Directional solidification experiments with InSb-NiSb onboard 1. Spacelab Mission

1981 First use of a time-dependent magnetic field to enhance convection

1980 First GaSb and InSb crystal grown by THM

1974 Foundation of Crystal Growth Laboratory

CONTACT

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2 *Prof. Dr. Johannes Heitmann, site manager Fraunhofer THM*
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LEFT *Fraunhofer IISB headquarters in Erlangen*
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