Fraunhofer
IISB

Fraunhofer Institute for Integrated Systems and Device Technology IISB

Annual Report 2022

Annual Report 2022

Achievements and Results

Online Version

The online version of the annual report can be found at:
iisb.fraunhofer.de/annual_reports

Prof. Jörg Schulze, director of Fraunhofer IISB

»As one of Europe's leading research institutions for power electronics based on wide-bandgap semiconductors, we ensure sustainable mobility and energy supply.

Editorial

Not untouched by the current challenges in the world, Fraunhofer IISB is also evolving continuously to even better meet our customers' and partners' needs.

So, after my first year as director of the institute, I am all the more pleased to report that Fraunhofer IISB is once again developing successfully in the right direction.

With scientific expertise, a focus on the demands of our customers and a broad cooperation network, we achieve trend-setting solutions to the benefit of society and our environment. This covers all aspects of our well-established value chain from materials to devices and packaging to energy conversion and storage systems. In addition, we support companies in technology transfer and the development of new product ideas with targeted initiatives such as joint labs or the «Leistungszentrum Elektroniksysteme«, thereby securing employment and technology sovereignty.

Efficient electronics and system technology offer great potential for energy savings and climate protection. As one of Europe's leading research institutions for wide-bandgap semiconductor-based power electronics, we ensure sustainable and economical mobility and energy supply.

At the IISB, we take great advantage of the fact that we also fully cover the underlying semiconductor technology. Starting from our silicon carbide technology and transfer platform, we are continuously opening up new applications such as quantum technologies as well as further ultrawide-bandgap semiconductor systems like aluminum nitride.

Alongside research, we also attach great importance to the education of qualified professionals. With our µe-bauhaus erlangen-nürnberg, we are currently establishing a new concept that focuses on the education of students and apprentices together in our cleanroom lab. Our close ties to four associated chairs at three universities are also essential in this regard.

I would like to thank our partners in industry and all our funding authorities at Bavarian, federal, and European level. And above all, I would like to express my deep gratitude to all my colleagues in the team at the institute for their successful work and outstanding commitment.

Now I cordially invite you to let yourself be inspired by the highlights of our work in 2022 on the following pages.

Sincerely yours,

Prof. Jörg Schulze
(Erlangen, January 2023)

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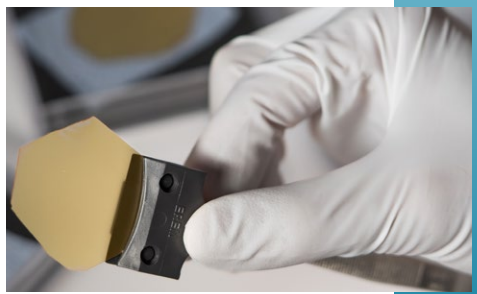

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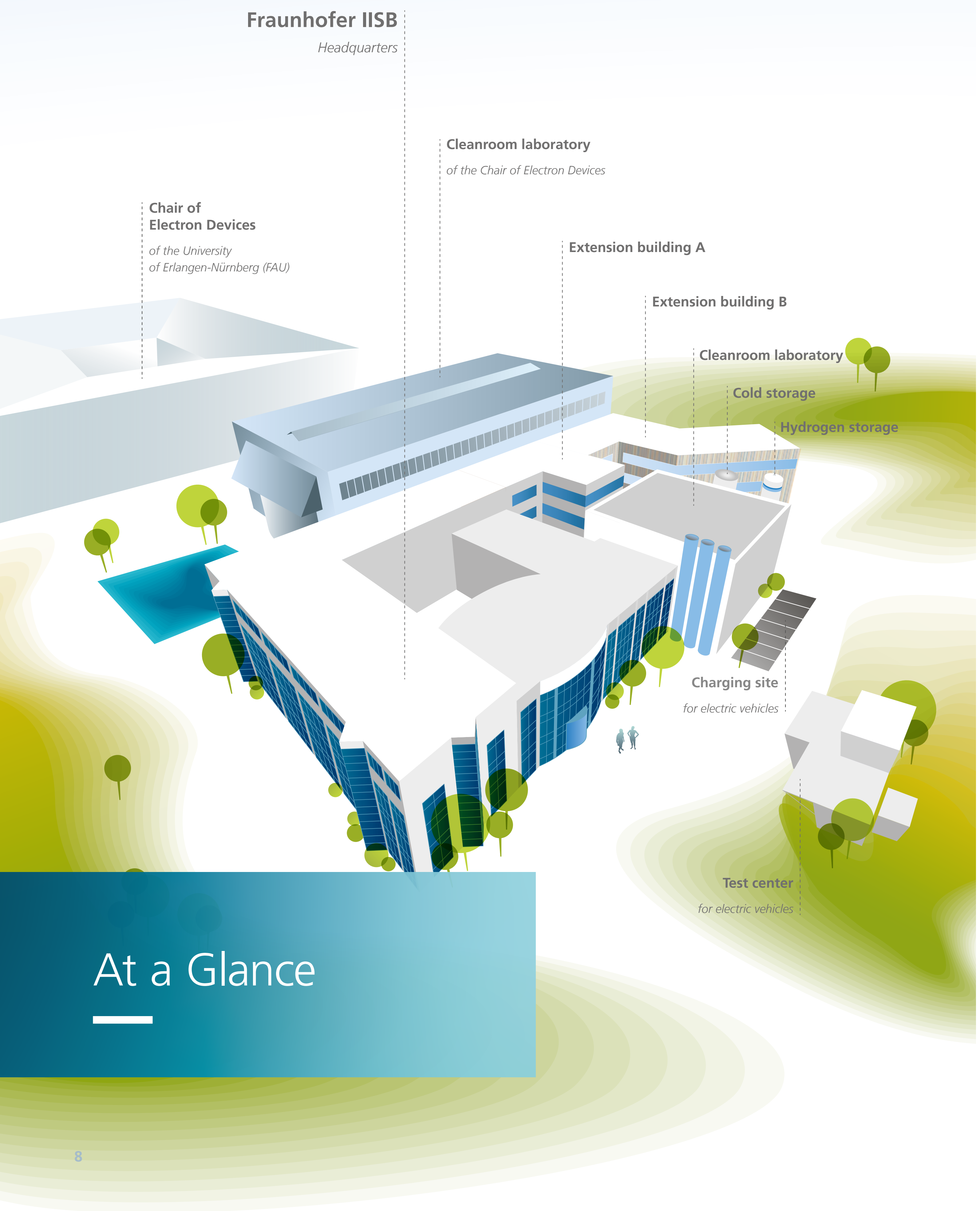
Fraunhofer IISB © Anja Grabinger / Fraunhofer IISB



At a Glance

Profile

Intelligent Power Electronic Systems and Technologies - following this motto, the Fraunhofer Institute for Integrated Systems and Device Technology IISB, founded in 1985, conducts applied research and development for the direct benefit of industry and society. With scientific expertise and comprehensive systems know-how, the IISB supports customers and partners worldwide in transferring current research results into competitive products, for example for electric vehicles, aviation, production, and energy supply.

The institute consolidates its activities in the two major business areas of Power Electronic Systems and Semiconductors. In doing so, it comprehensively covers the entire value chain from basic materials to semiconductor device, process, and module technologies to complete electronics and energy systems. As a unique European competence center for the semiconductor material silicon carbide (SiC), the IISB is a pioneer in the development of highly efficient power electronics even for the most extreme requirements. With its solutions, the IISB repeatedly sets benchmarks in energy efficiency and performance. By integrating intelligent data-based functionalities, new use cases are continuously emerging.

The IISB employs about 300 people. Its headquarters are in Erlangen, with another branch at the Fraunhofer Technology Center High Performance Materials (THM) in Freiberg. The institute cooperates closely with the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) and is a founding member of the Energie Campus Nürnberg (EnCN) as well as the Leistungszentrum Elektroniksysteme (LZE). In joint projects and associations, Fraunhofer IISB cooperates with numerous national and international partners.

History

The Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen is an established center of applied R&D for intelligent electronic systems, power electronics, semiconductor technology, and materials development in the Nuremberg metropolitan region, Germany, and Europe. It was founded in 1985 as the Electron Devices department AIS-B of the Fraunhofer Working Group for Integrated Circuits. In 1993, it became a Fraunhofer institute (IIS-B), but was still formally linked to its affiliate institute IIS-A, today's Fraunhofer Institute for Integrated Circuits IIS. In 2003, IIS and IISB became completely independent from each other as two individual Fraunhofer institutes. From 1985 until 2008, Prof. Heiner Ryssel was the head of the IISB. From 2008 to 2018, Prof. Lothar Frey was director, followed by Prof. Martin März until September 2021. Since then, the institute is led by Prof. Jörg Schulze. From the beginning, the IISB has been closely cooperating with the University of Erlangen-Nürnberg (FAU). In 2015, the IISB together with the IIS and the FAU Erlangen-Nürnberg founded the »Leistungszentrum Elektroniksysteme« (LZE).

Advisory Board

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Voith Group, CTO

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Saxon State Ministry for Science, Culture and Tourism, Head of Unit «Bund-Länder Research Institutions«

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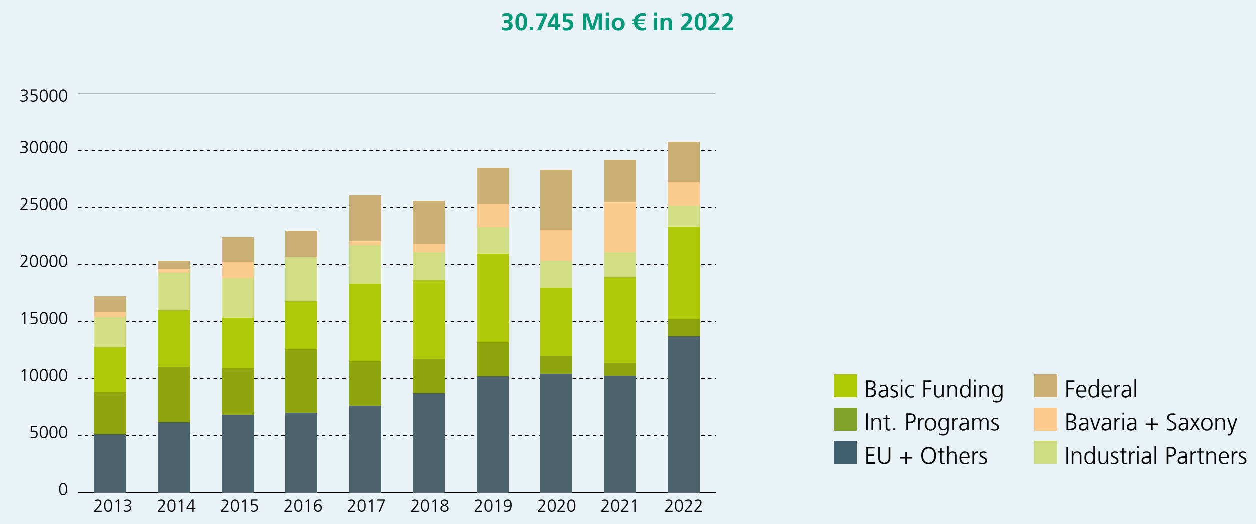
Infineon Technologies, Division President Industrial Power Control

Dr. Stefan Wimbauer
Bavarian Ministry of Economic Affairs, Regional Development and Energy, Head of Unit «Applied Research, Cluster Pollicy«

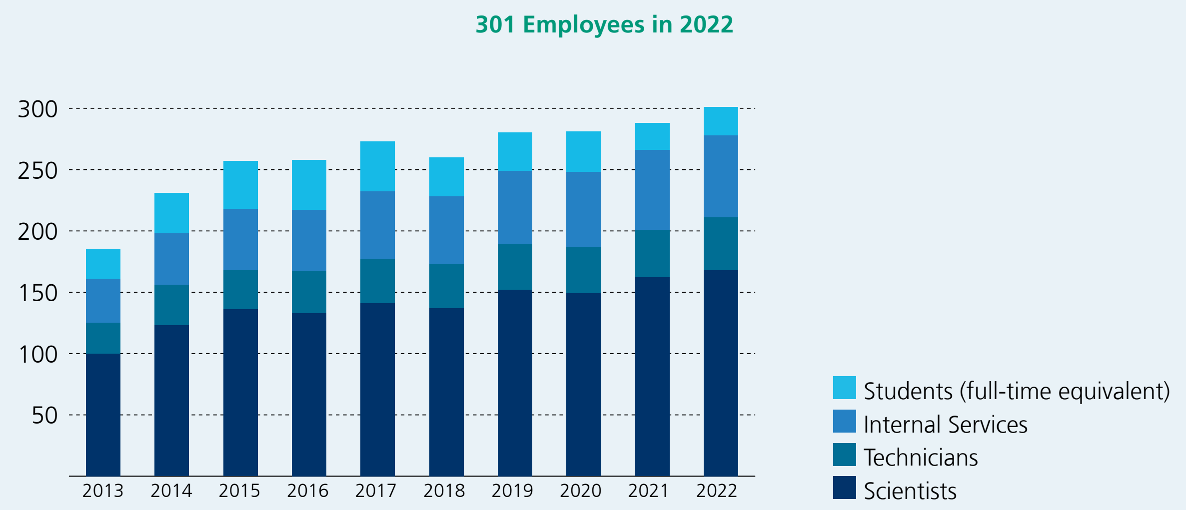
The IISB advisory board has a significant impact on the institute's strategic orientation.

It has members from science, industry and politics who advise the IISB directorate on strategic and structural development questions.

Operating Budget



Staff Development



Fraunhofer IISB: One Institute, many oppurtunities © Elisabeth Iglhaut I Fraunhofer IISB

Organizational Chart 2022

Institute Director
J. Schulze

Technology Center High Performance Materials
J. Heitmann

Division Semiconductor Technology
J. Schulze

Division Power Electronic Systems
M. März

Materials
J. Friedrich

Advance Development
temp. J. Schulze, J. Friedrich

Front End
S. Oertel

Hybrid Integration
A. Schletz

Modeling and Artificial Intelligence
J. Lorenz

Vehicle Electronics
B. Eckardt

Intelligent Energy Systems
V. Lorentz

Administration
H. Hermes

IT
G. Ardelean

Infrastructure
N. Kandziora

Pi Fab
J.Schulze

Strategic Marketing
S. Flack

In order to advance the development of the novel cell chemistry of the Al-ion battery (AIB) for later applications, the battery materials group at THM is working on the manufacturing technology for application-relevant cell concepts in addition to the elucidation of basic mechanisms in the AIB. For the graphite cathode, the current collector is coated with a water-based slurry. After drying, the graphite layer is compacted using a calander (photo) in order to ensure good contact between the graphite particles and thus achieve a high cell performance. The electrode sheet is cut to the required size of the cathode in the cell.
© Kurt Fuchs / Fraunhofer IISB

Division
Fraunhofer Technology Center High Performance Materials THM

»High-performance materials such as new semiconductor and energy materials are fundamental to solve the major challenges of our time: the transformation of our energy system towards sustainability, intelligent mobility and digitalization. Our main interest is a profound understanding of the material properties in order to develop new processes and integration schemes for the need of battery and semiconductor technology.«

Prof. Johannes Heitmann, Head of Technology Center High Performance Materials THM © TU Bergakademie Freiberg

At the IISB's branch office in Freiberg, Saxony, we investigate new, high-performance materials and the associated efficient manufacturing processes together with our partners, the Fraunhofer Institute for Ceramic Technologies and Systems IKTS and the Institute of Applied Physics (IAP) of the TU Bergakademie Freiberg.

By this manner, we developed novel Li-free Al-ion batteries, which are based on cost-effective electrode materials and non-flammable electrolytes, achieving high charging currents and high cycle stability. Researching a totally new battery approach allows us to address a recycling friendly design and to establish a model system for the realization of a circular economy already in an early stage of technology development. In the field of semiconductor materials and devices, one major point of our work is to evaluate the role of defects for the reliability and functionality of upcoming power electronic or quantum devices based on ultrawide-bandgap materials. The development of processes and materials and their integration into prototypes and test vehicles are among the most important tools we use here. We are developing in-operando characterization techniques using spectroscopy and X-ray metrology for the characterization of our devices in working conditions or for the identification and recognition in sorting and recycling processes.

The Fraunhofer THM is a research partner for industry within the framework of industrial contracts and publicly funded projects in the production, application, and recycling of semiconductor and energy materials.

Line for backend-of-line processing for silicon carbide (SiC) © Kurt Fuchs / Fraunhofer IISB

Division Semiconductor Technology

»Wide-bandgap semiconductors already are a powerful basis for energy-efficient and highly performant power electronics, advanced sensor technologies, and novel photonics. As the number one technology and transfer platform for silicon carbide (SiC) devices in Europe, Fraunhofer IISB goes one step further. Originating from our huge experience in materials development, we are consequently heading towards solid-state quantum electronics based on silicon carbide. By combining quantum properties and electronic devices, isotopically pure SiC offers an enormous value creation potential and could enable a broad breakthrough of quantum technology in industry and SMEs.«

Prof. Jörg Schulze, Director of Fraunhofer IISB, Head of Semiconductor Technology Division and Chair of Electron Devices © Kurt Fuchs / Fraunhofer IISB

The division Semiconductor Technology of Fraunhofer IISB represents the comprehensive first half of our end-to-end value chain from materials to systems, with focus on wide-bandgap semiconductors and a deep understanding of the respective application areas. Our R&D portfolio covers the development of crystalline and other functional materials, device and processing technologies on silicon and silicon carbide, as well as heterogeneous integration, packaging, and innovative power modules. This is supported by modeling and artificial intelligence. Our unique SiC prototyping fab ensures high flexibility with regard to our customers' needs. Furthermore, we are constantly enhancing our activities on ultrawide-bandgap semiconductors like, e.g., aluminum nitride. In addition to research, we increasingly pursue our new education concept, the µe-bauhaus erlangen-nürnberg, for the combination of academic and technical education in order to train highly qualified professionals for industry. In this context, the IISB is the competence center and contact point for power semiconductors, especially for silicon carbide, within the Fraunhofer-Gesellschaft and the Research Fab Microelectronics Germany (FMD).

Materials

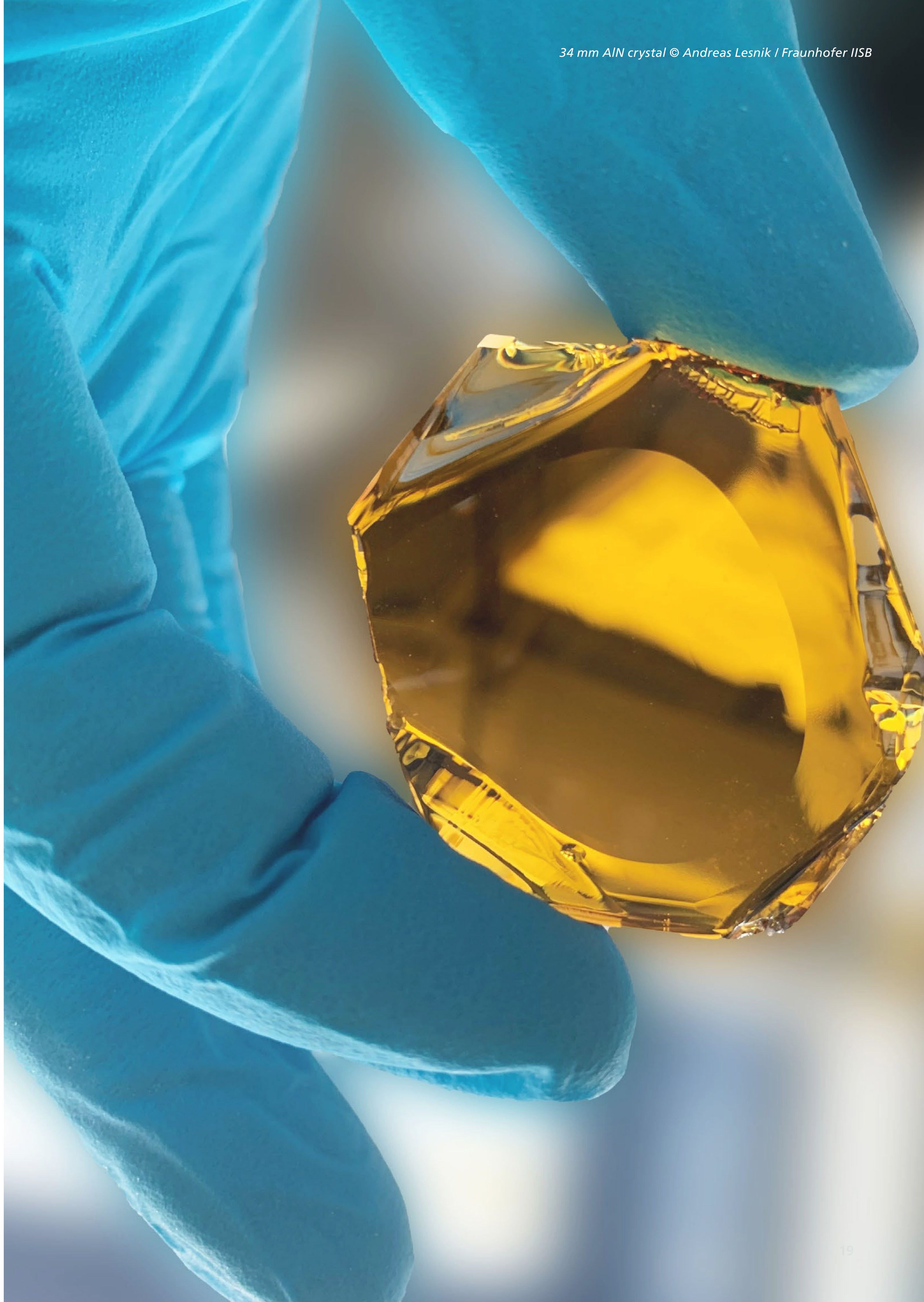
We identify defects harmful for device performance and reliability and find solutions to avoid them.

Dr. Jochen Friedrich,
Head of Materials Department
© Amelie Schardt / Fraunhofer IISB

»The R&D activities of the IISB cover the complete value chain for complex and intelligent electronic systems, from basic materials to devices and modules all the way to complete systems for application in mobility and energy technologies, with power electronics being a consistent backbone of the institute.«

We support material, device, and equipment manufacturers as well as their suppliers with scientific-technological solutions in the field of production and characterization of crystals, epitaxial layers, and devices. We improve the material quality and reduce the production cost. We identify defects harmful for device performance and reliability and find solutions to avoid them. We develop technologies for new materials, and tailor the material properties for new applications.

Our focus is on semiconductors for power electronics, communication electronics, sensors & detectors, and quantum technologies. Our strategy is to optimize manufacturing processes through a combination of experimental process analysis, tailored characterization techniques and numerical modeling. For that purpose, we have a well-suited infrastructure consisting of R&D furnaces and epitaxial reactors, state-of-the-art metrology tools for investigating the physical, chemical, electrical, and structural material properties, and powerful simulation programs for heat and mass transport calculations.



34 mm AlN crystal © Andreas Lesnik / Fraunhofer IISB

Advance Development

We pay special attention to the development of SiC based high-temperature electronics and sensors.

Prof. Jörg Schulze,
prov. Head of Advance Development Department
© Kurt Fuchs / Fraunhofer IISB

»The IISB is your partner for the design, realization and characterization of single process steps and devices up to prototypes manufactured on our continuous silicon CMOS and silicon carbide process line in an industry-compatible and ISO 9001 certified environment. Examples for our current activities are sensor devices, advanced integrated power devices on SiC, or high-temperature electronics.«

We develop innovative device solutions with a strong focus on power electronics. This includes novel device concepts on silicon carbide and related materials as well as on silicon providing a »technology-push« towards new and more powerful applications. Furthermore, we pay special attention to research and development on silicon carbide based high temperature electronics and sensors suitable for particularly demanding environments. We cover activities ranging from monolithic integration of electron devices, through development and integration of passives, including new dielectric materials and especially capacitors, to novel device concepts.

We offer custom-tailored process solutions in order to realize innovative, power- and cost-efficient devices based on silicon carbide. With our know-how and technology, we focus on proof-of-concept prototyping and proof of manufacturability for advanced fabrication processes. Having proven processes in combination with an accordingly aligned and already proven process flow reduces the entry barrier for introducing such a prototype into volume fabrication. In this case, the IISB also offers a small volume fabrication to close the gap between prototype development and high-volume fabrication.

Division Semiconductor Technology

Front End

As our partners, especially small and medium-sized companies gain access to semiconductor technology.

Dr. Susanne Oertel, Head of Front End Department
© Elisabeth Iglhaut / Fraunhofer IISB

»The Front End Department is your partner for the implementation and characterization of sophisticated process steps and reliable electron devices and prototypes. As part of the π-Fab, we run a continuous silicon CMOS and silicon carbide process line in an industry-compatible and ISO 9001 certified environment.«

Six technology areas make up the Front End Department: Wet etching, lithography, dry etching, metallization, ion implantation, and hot processing. The newly created process development group takes care of further enhancements of proven process steps as well as customer-specific changes of process steps. The team consists of technical and scientific experts with longtime expertise in processing and manufacturing, working in clean room facilities, as well as on the education and training of microtechnologists. Together with the Department Advanced Development, we aim to support our customers in realizing new processing concepts. Resulting devices allow for the evaluation of the concepts, e.g., in regard to robustness or reliability. Ideally, these activities lead to a customer or market accepted small series that can be routinely commissioned. As our partners, especially small and medium-sized companies (SEM) gain access to semiconductor technology.

Our 150 mm SiC and Si process line has reached a high level of technological readiness, which will be increased in the future. We handle silicon wafers with diameters of 150 mm and 200 mm by default as well as further diameters on request. The process line is based on a 0.8 µm SiCMOS technology. We offer our CMOS technology on the Europractice platform, starting with an early access prototype.

The IISB closes the gap between single sample manufacturing and high-volume fabrication of industrially operated foundries. Our department addresses versatile markets, such as custom-tailored devices, power devices, sensors, and CMOS devices. With regard to semiconductor materials, we have taken a big step toward silicon carbide (SiC) in terms of wafer starts. Silicon (Si) is the second semiconductor that plays a major role at the IISB. In order to expand our 200 mm capabilities, a furnace for 200 mm SiC wafers and temperatures of up to 2000 °C has been installed in 2022. Our newly established manufacturing execution system enables cooperating within the Research Fab Microelectronics Germany (FMD) community.

Hybrid Integration

Our powerful packaging lab offers prototyping at high technology readiness levels up to small volume manufacturing for system demonstrators.

Andreas Schletz, Head of Hybrid Integration Department
© Amelie Schardt / Fraunhofer IISB

»In 2022, the restructuring of our department, which we undertook in 2021, has settled well. There is a huge number of very interesting research and development projects that are mainly driven by industry partners.«

The working group »Innovative Power Modules«, headed by Dr. Hubert Rauh, works on packaging concepts. That covers power modules with high switching performance as well as high current capability, enabled by enhanced electrical, thermal and thermo-mechanical design. Our powerful packaging lab offers prototyping at high technology readiness levels up to small volume manufacturing for system demonstrators. The excellent link to the in-house power electronic system departments keeps research on the right track towards application. On the other hand, the in-house customer has good access to customized solutions.

The new working group »Functional Material Systems«, headed by Dr. Michael Jank, has integrated perfectly with our activities. The research topics »smart sensors«, »thin-film technologies« and »packaging technologies« got new momentum by addressing power electronics. This includes all activities on corrosion and coating topics.

The »Test and Reliability« working group, headed by Dr. Jürgen Leib, improved the power electronic testing using the new research test method of dynamic gate stress for silicon carbide. The thermo-mechanic lifetime simulation has made great progress regarding physics of failure lifetime prediction. A generic model for silicon carbide was developed. The working group highlights our vertical integration of research within the institute by a specific project. A special silicon carbide substrate material was investigated by power cycling tests. Therefore we manufactured, packaged and tested a new device concept. The results will be presented on PCIM 2023 exhibition.

Modeling & Artificial Intelligence

The combination of physics-based simulation with techniques from the area of artificial intelligence enables breakthrough developments.

Dr. Jürgen Lorenz,
Head of Modeling & Artificial Intelligence Department
© Amelie Schardt / Fraunhofer IISB

»Nowadays, simulation is indispensable for the development of microelectronics, nanoelectronics, and power electronics. The work of our department is based on physical understanding and on the application of artificial intelligence, and ranges from equipment and processes to devices, circuits and electronic systems.«

The department continues to combine the development of simulation capabilities with their application to technological challenges at the institute or with external partners: Application knowledge is essential to guide tool development in terms of priorities and relevant effects. Our expertise in the capabilities and limitations of the physical models and algorithms used is fundamental to the efficient and reliable application of simulation.

Our work benefits from decades of experience in Technology Computer-Aided Design (TCAD) and a broad cooperation with highly qualified partners all over Europe, among others in European projects coordinated by us. Various results from our cooperative projects are widely used in industry and research within standard TCAD tools. This solid foundation has also allowed us to embark on new simulation approaches such as physics-informed artificial intelligence or new promising application areas such as supporting the development of quantum computing or its use for optimization tasks. Among others, the department supports the development of silicon carbide devices at the IISB including the broad access to this technology via Europractice, the development and application of quantum computing in the Munich Quantum Valley initiative, and the industrial development of EUV lithography at the European level.

Furthermore, its optics simulation competence is also applied and extended into the area of photonics, currently for spin-based quantum bits and for industrial direct laser writing for nanostructure materials. The department has demonstrated that the combination of physics-based simulation with techniques from the area of artificial intelligence enables breakthrough developments in various application areas, e.g. masks for EUV lithography or circuits, systems for power electronics and extraction of optimization strategies based on experiments and physical simulation.

ZEPOWEL © Thomas Richter / Fraunhofer IISB

Division Power Electronic Systems

»Sustainability in energy supply and mobility is a key in meeting the imminent environmental and economic challenges our society is facing. Innovative solutions require fresh thinking, leaving beaten tracks, and a comprehensive view of the overall system. This is exactly the mission and motivation behind the research work at Fraunhofer IISB on intelligent power electronics and energy systems.«

Prof. Martin März, Head of Power Electronic Systems Division and Chair of Power Electronics LEE © Amelie Schardt / Fraunhofer IISB

One focus of our research work is on sustainable mobility systems whether in the automotive sector, commercial vehicles, ships, or aircrafts. Electric flying in particular poses enormous challenges for power electronics, especially with regard to safety, robustness, availability, power density, and weight. In addition, there are demanding technical boundary conditions such as cryogenic cooling media, the use of superconductors or cosmic radiation. We are also constantly expanding our research activities in the area of local DC networks, particularly with regard to new protection components and converter concepts for applications up to the medium-voltage and megawatt power range. Another important field of research is cognitive power electronics, i.e., power electronics that is able to generate maximum information about its environment – whether it is monitoring the stability of grids or the condition of customer systems and machines.

Intelligent Energy Systems

We integrate innovative data analytics technologies into our solutions, enabling smart diagnostics and monitoring.

Prof. Vincent Lorentz,
Head of Intelligent Energy Systems Department
© Anja Grabinger / Fraunhofer IISB

»Our department develops and integrates innovative hardware and software solutions for the digitalization of electrical energy storage and conversion systems. We address mobile applications like automotive, airborne and waterborne as well as stationary applications for industry and renewables.«

The Intelligent Energy Systems Department at Fraunhofer IISB develops advanced technologies and electronic solutions for the digitalization of energy storage and power conversion systems for mobile and stationary applications, thus building our Cognitive Power Electronics (CPE) ecosystem that covers the entire power range from a few milliwatts up to several multiple gigawatts.

We integrate innovative data analytic technologies into our solutions, enabling smart diagnostics and monitoring self-healing functions. These technologies are implemented and demonstrated in our cutting-edge electronic power converters, in our high-performance battery system designs as well as hydrogen systems, including our disruptive unique open-source battery and fuel-cell management system foxBMS®, developed in cooperation with the University of Bayreuth and its Bavarian Center for Battery Technology (BayBatt).

Our research and development efforts focus on power and control electronic hardware and software algorithms as well as data processing technologies – using the latest developments in artificial intelligence – to detect anomalies in energy conversion systems and management systems targeting the transportation and energy domains.

Vehicle Electronics

We can already demonstrate power electronic solutions today that will be in production in 2030.

Dr. Bernd Eckardt,
Head of Vehicle Electronics Department
© Anja Grabinger / Fraunhofer IISB

»Mobility goes electric, powered by ultra efficient and light-weight electric power trains. The change is becoming more and more visible by the number of electrified vehicles on the road. But also in the fields of small and large trucks, ships, and aircrafts, the transformation has already started.«

The focus of the vehicle electronics department is on designing the next generation of power electronics and on bringing wide- and ultrawide-bandgap semiconductors, advanced power electronic concepts and control strategies into applications. Together with our partners from industry and research, we can already demonstrate power electronic solutions today that will be in production in 2030. Therefore, the latest power semiconductors from silicon carbide (SiC) and gallium nitride (GaN) devices are taken into account and new power modules with low parasitic impedance and optimized thermal conductivity are developed. These modules are integrated into advanced mechatronic solutions for small size, low weight, and high mechanical robustness to provide the most advanced technology for the bench or test vehicle integration.

An upcoming topic besides SiC traction drive inverters is the development of SiC and multi-level GaN inverters for high-speed drives. These are needed for electric air compressors in fuel cell systems that spin up to 160.000 RPM. The inverters must operate at switching frequencies in the range of 100 kHz to keep the magnetic losses in the motor as low as possible. The low switching losses of wide bandgap semiconductors are a major advantage for improving the efficiency.

Another important component for fuel cell applications are DC/DC converters, adapting the output voltage of the cell to the DC link voltage of the vehicle. For such applications, Fraunhofer IISB has more than 20 years of experience in realizing customized designs of converters for all kinds of requirements. There are several converter prototypes running in test vehicles and trucks on the road to demonstrate the benefits of this new technology.

To cover the complete powertrain, the vehicle electronics department is expanding its know-how to electric motor drives, magnetic and mechanic design, testing and co-simulation of electric motors, and power electronic drive inverters. This improves the performance of the drive systems and provides reliable data for performance and efficiency.

For reliable solutions, we operate an electromagnetic compatibility (EMC) test lab and are working on new solutions for active and passive EMC filters. This will further reduce the size and weight of next generation power converters.

During the last 20 years, we saw the demand for power significantly growing – from a tenth of a kW up to several mW. To tackle this challenge, we have established our medium-voltage and high-power lab, where we can test voltages up to 30 kV, electrical power up to 10 MW, and electric motors up to 1 MW.

This makes Fraunhofer IISB an excellent partner for the development of power electric solutions.

THM Freiberg © Kurt Fuchs / Fraunhofer IISB

Locations and Network

Headquarters of Fraunhofer IISB

Schottkystraße 10, 91058 Erlangen

The headquarters of Fraunhofer IISB in Erlangen are located close to the University of Erlangen-Nürnberg. About 10,000 m^2 of laboratories and office area allow research and development on a broad range of power electronics, semiconductor technology, and materials development. The available infrastructure includes among others: a test center for electric cars, a medium-voltage test bench, an application center for DC grid technology, and an extensive cleanroom area for semiconductor technology on silicon and silicon carbide, which is partly operated together with the Chair of Electron Devices of the University.

Technology Center High Performance Materials THM

Am St.-Niclas-Schacht 13, 09599 Freiberg

High-performance materials such as semiconductors and energy materials are fundamental to solving the major challenges of the future: Intelligent mobility, Industry 4.0, the energy transition, or the Internet of Things. Supported by the Free State of Saxony, Fraunhofer THM is a research and transfer platform of the Fraunhofer Institute for Integrated Systems and Device Technology IISB and the Fraunhofer Institute for Ceramic Technologies and Systems IKTS. Together, semiconductor and energy materials are transferred into new applications and at the same time, future material recycling is considered and developed. Both the development of new, high-performance materials and the associated efficient manufacturing processes play a major role here, as well as a sustainable recycling economy that enables the economic recovery of valuable materials. One major point is the role of defects for the reliability and functionality of upcoming devices and the integration of processes and materials into prototypes and test vehicles. Fraunhofer THM is a research partner for industry within the framework of industrial contracts and publicly funded projects in the production, application, and recycling of semiconductor and energy materials.

thm.fraunhofer.de

TU Bergakademie Freiberg

For more than 15 years, the THM in Freiberg has been conducting joint research with the TU Bergakademie Freiberg and for 7 years with the Institute of Applied Physics (IAP), complementing each other's competencies and sharing resources in the field of electronic device fabrication, characterization, and material processing. Main activities of the IAP are the development and evaluation of new materials and processes, like thin film dielectrics and contact material formation for nitride semiconductor and photovoltaic devices, synthesis and characterization of semiconductor nanostructures, and the defect characterization of semiconductor materials and its impact on and the reliability of microelectronic and photovoltaic devices.

tu-freiberg.de

Employees of the IISB in front of the cleanroom building © Elisabeth Iglhaut I Fraunhofer IISB

Cooperation

Within its research activities, Fraunhofer IISB pursues cooperations with numerous national and international partners in joint projects and associations:

- Since its foundation, the IISB has been closely cooperating with the University of Erlangen-Nürnberg (FAU), especially the Chairs of Electron Devices and Power Electronics. The joint operation of infrastructure as well as the exchange in education and training create extensive synergies.
- The IISB is in close cooperation with the Technical University TU Bergakademie Freiberg in the area of semiconductor materials.
- The IISB is a core member of the »Leistungszentrum Elektroniksysteme LZE«, www.lze.bayern.
- The IISB is a member of the »Energie Campus Nürnberg« EnCN, www.encn.de.
- The IISB closely cooperates with industry and research associations, such as the European Center for Power Electronics, the Bavarian Clusters for Power Electronics and Mechatronics & Automation, or the German Crystal Growth Association DGKK e.V.
- The IISB is a close partner of the »Förderkreis für die Mikroelektronik e.V.«
- The IISB is a member of several associations regarding hydrogen research (h2b, hy+, cluster mobility and logistics, Fraunhofer Netzwerk Wasserstoff).

Consortial Projects

- The IISB is partner of the excellence projects at the University of Erlangen-Nürnberg www.eam.uni-erlangen.de, www.aot.uni-erlangen.de/saot/.
- The IISB is the coordinator and partner of numerous European research projects, such as MUNDFAB, a Horizon 2020 project www.mundfab.eu.

Fraunhofer Groups and Alliances

- Fraunhofer Group for Microelectronics www.mikroelektronik.fraunhofer.de
- Fraunhofer Energy Alliance www.energie.fraunhofer.de
- Fraunhofer Battery Alliance www.batterien.fraunhofer.de
- Fraunhofer Research Fab Microelectronics Germany FMD www.forschungsfabrik-mikroelektronik.de
- Fraunhofer Nanotechnology Alliance www.nano.fraunhofer.de

»Red Place« at the Faculty of Engineering of the FAU © Erich Malter

University of Erlangen-Nürnberg FAU

LEB building and cleanroom labratory © Thomas Richter I Fraunhofer IISB

Chair of Electron Devices (LEB)

The Fraunhofer IISB and the Chair of Electron Devices (German abbreviation: LEB) of the University of Erlangen-Nürnberg are both headed by Prof. Jörg Schulze. Within the framework of a cooperation agreement, the two institutions not only jointly operate the University's cleanroom facility and other laboratories, but also work closely together with regard to teaching and research.

The cooperation of the Chair of Electron Devices and the Fraunhofer IISB makes it possible to cover the entire chain of topics from basic research to the transfer to industry. For many years now, the vocational training as a microtechnologist has been offered jointly by the IISB and the Chair of Electron Devices. Employees of the IISB assist in courses and internships at the university.

leb.tf.fau.de

Chair of Power Electronics (LEE)

The Chair of Power Electronics (German abbreviation: LEE) is headed by Prof. Martin März. It conducts research on current topics in the field of power electronics for electric power supply. Besides stationary decentralized electrical power systems, the addressed application fields also include the power grids in vehicles, ships, railways, and airplanes. The LEE is part of the Energie Campus Nürnberg (EnCN) in the Fürther Straße in Nuremberg, and the first chair grown out of the EnCN.

lee.tf.fau.de

Academic Teaching

Lecturer	Lecture
Dr. Bernd Eckardt	Electrical Energy Storage Systems
Dr. Andreas Erdmann	Optical Lithography
Dr. Tobias Erlbacher	Power Semiconductor Devices
Prof. Dr. Marc Hainke	Medical Product Development
	Medical Technology Materials
	Materials Engineering
	Engineering Mechanics I
	Engineering Mechanics II
	Basics of Construction
	Construction & Development
	Construction & CAD
	Fluid Mechanics & Thermodynamics
Prof. Dr. Johannes	Physics for Scientists III
Heitmann	Semiconductor Chemistry
	Fundamental Physics for Engineering
	Physics for Engineers
	Materials Analysis
	Nanoelectronic Devices II
	Functional Nanomaterials
	Semiconductor Chemistry
Dr. Michael Jank	Flexible Electronics
	Nanoelectronics
Dr. Jürgen Lorenz	Process and Device Simulation

Lecturer	Lecture
Prof. Dr. Vincent	Digital Circuit Technology
Lorentz	Analog Circuit Technology
	Electrotechnical Fundamentals of
	Electrochemical Energy Storage Systems
	Battery System Technology II
Prof. Dr. Martin März	Power Electronics (Basics)
	Power Electronics
	in the Vehicle and Powertrain
	Power Electronics for Decentral Energy
	Systems
	Thermal Management in Power Electronics
Prof. Dr. Schulze	Bipolar Technology
	Semiconductor Devices
	Quantum Electronics
	Technology of Integrated Circuits

IISB's scientific staff supervises a multitude of final theses.

µe-bauhaus erlangen-nürnberg

The µe-bauhaus erlangen-nürnberg transfers the teaching concept of the famous Bauhaus Weimar-Dessau-Berlin to the idea of a «Bauhaus of Microelectronics« within the Chair of Electron Devices (LEB) and Fraunhofer IISB. This includes the self-understanding that «teachers« and «learners« work together and jointly plan and realize extensive ideas and designs. The indispensable basis of this creative work is the thorough technical training of students in laboratories and at trial and work stations, which enables them to learn and work independently in teams in a creative manner. What makes the modern, progressive engineering training at µe-bauhaus erlangen-nürnberg different from other courses of study or training centers? Here, the theoretical study of natural sciences and electrical engineering and information technology runs parallel to practical training along the process chain, starting with the design of devices, their development and production up to their validation, trial and testing.

iisb.fraunhofer.de/bauhaus

University of Bayreuth © Prof. Jan Philipp Schmidt

University of Bayreuth

Bavarian Center for Battery Technology (BayBatt)

The entire energy storage value chain

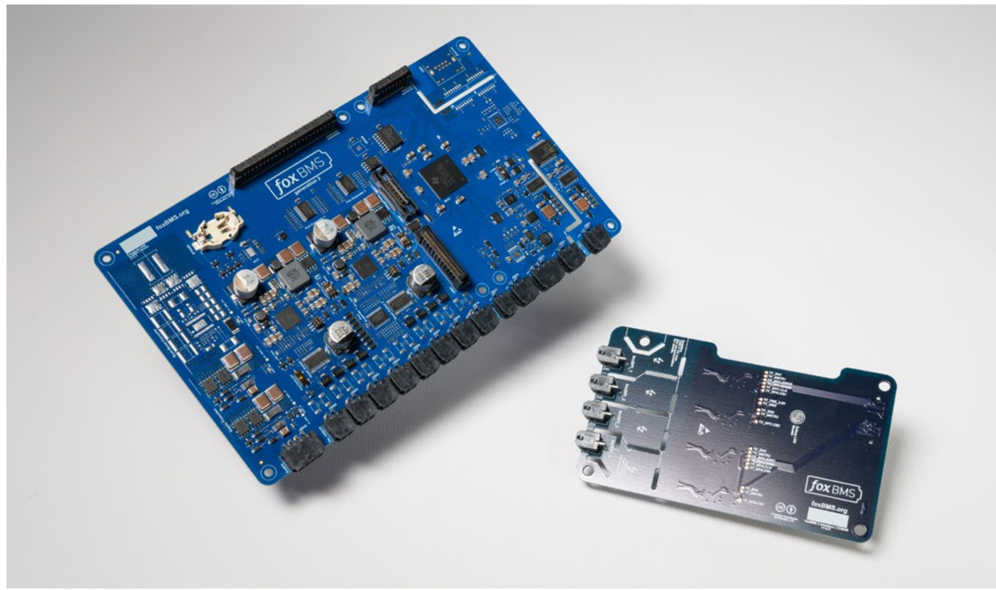
The Bavarian Center for Battery Technology (BayBatt) at the University of Bayreuth is a research center that bundles interdisciplinary fundamental research, the development of innovative battery technologies, and technology transfer to the industry.

The energy transition in Germany is increasing the demand for storage technologies, e.g., to ensure grid stability as the share of renewable energies grows. With the BayBatt, an expertise center is being established that will provide the necessary know-how and research to meet these challenges. Here, electrochemical, materials science, and engineering experts will focus on the entire value chain of electrochemical energy storage systems.

The core topics of the BayBatt are the safety and sustainability of batteries and their components, the intelligent use of the storage medium, and economic efficiency. The entire spectrum of battery technology is considered, from the molecular basis to the structuring of electrodes and cell development. Specific focus is on the battery cells and systems, and the use of batteries in connected energy storage systems. These battery storage systems are being researched, e.g., for mobile and stationary applications in electromobility, power tools, buildings, and grids.

Within BayBatt, Fraunhofer IISB cooperates closely with the Chair of Electronics for Electrical Energy Storage, led by Prof. Vincent Lorentz, at the University of Bayreuth. Prof. Lorentz is also head of the Intelligent Energy Systems Department at Fraunhofer IISB.

The main focus of the chair's research is on solutions for the electronic monitoring and control of electrical energy storage systems such as batteries, supercaps, and fuel cells, which are used in mobile and stationary applications. For example, the foxBMS® battery management system platform emerged from an initiative of Fraunhofer IISB in 2015. It is being further developed in BayBatt and enables research and validation of safer, more robust and reliable system architectures.



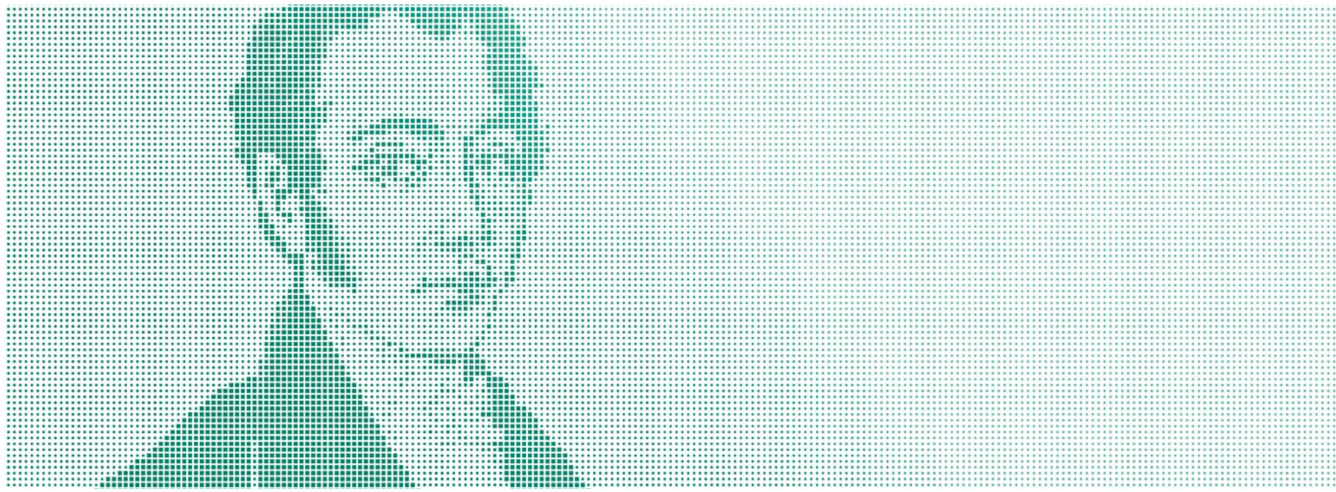
foxBMS® is IISB's free, open and flexible R&D environment for battery management systems. © Thomas Richter / Fraunhofer IISB

baybatt.uni-bayreuth.de

electronics.uni-bayreuth.de

Locations of the Fraunhofer-Gesellschaft © Fraunhofer

The Fraunhofer-Gesellschaft



Joseph von Fraunhofer © Fraunhofer IISB

Fraunhofer – The World’s Leading Applied Research Organization

The Fraunhofer-Gesellschaft, based in Germany, is the world’s leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, the Fraunhofer-Gesellschaft supports science and industry with inspiring ideas and sustainable scientific and technological solutions and is helping shape our society and our future.

At the Fraunhofer-Gesellschaft, interdisciplinary research teams work with partners from industry and government to turn pioneering ideas into innovative technologies, coordinate and implement system-relevant research projects and strengthen the German and European economies with a commitment to value creation that is based on ethical values. International collaboration with outstanding research partners and companies from around the world brings the Fraunhofer-Gesellschaft into direct contact with the most prominent scientific communities and most influential economic regions.

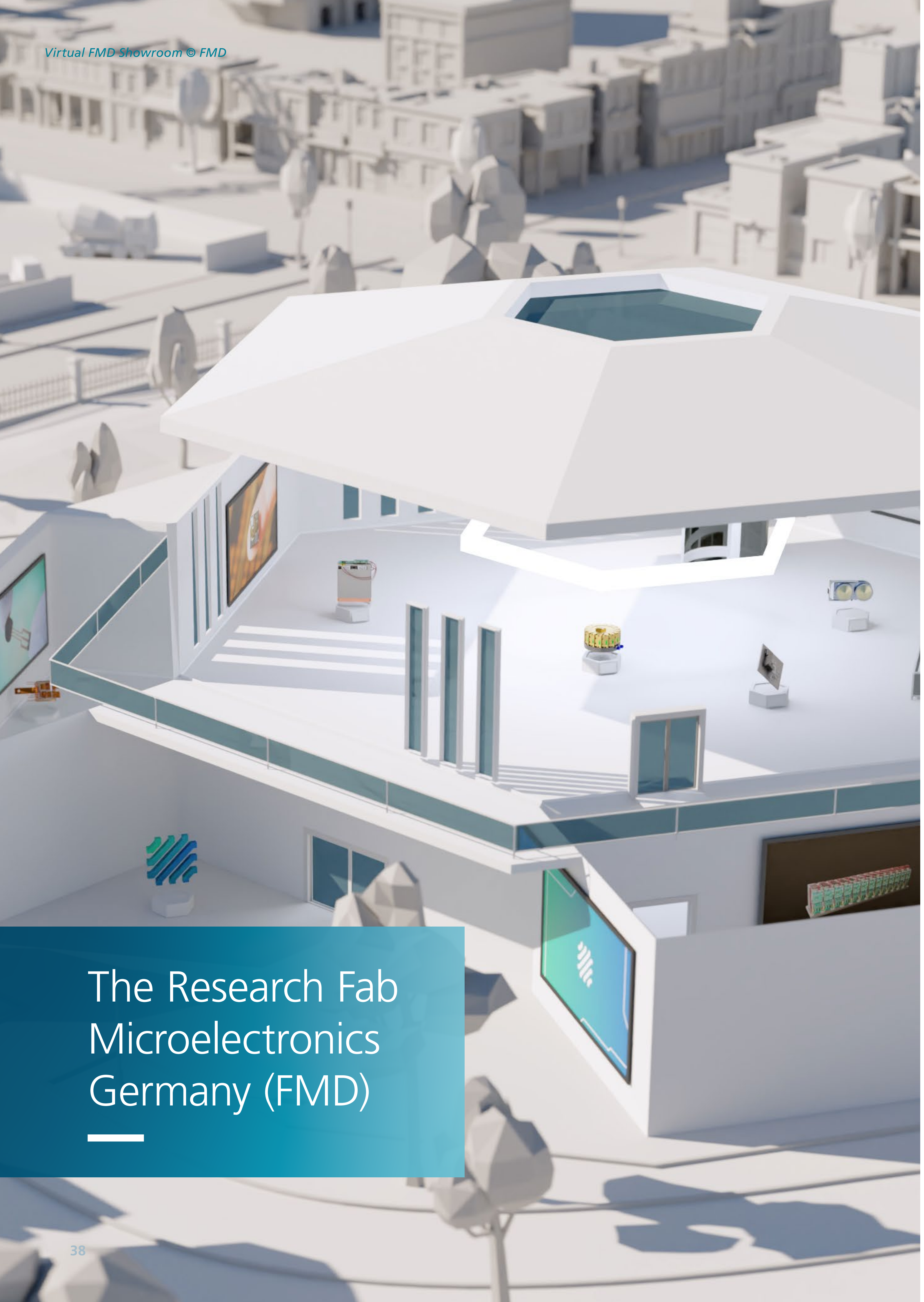
Founded in 1949, the Fraunhofer-Gesellschaft now operates 76 institutes and research units throughout Germany. Currently around 30,800 employees, predominantly scientists and engineers, work with an annual research budget of about 3.0 billion euros, 2.6 billion euros of which is designated as contract research. Around two thirds of Fraunhofer contract research revenue is generated from industry contracts and publicly funded research projects. The German federal and state governments contribute around another third as base funding, enabling the Fraunhofer institutes to develop solutions now to problems that will drastically impact industry and society in the near future.

The impact of applied research goes far beyond the direct benefits to the client. Fraunhofer institutes strengthen companies’ performance and efficiency and promote the acceptance of new technologies within society while also training the future generation of scientists and engineers that the economy so urgently requires.

As a scientific organization, the key to our success is highly motivated employees engaged in cutting-edge research. Fraunhofer therefore offers its researchers the opportunity to undertake independent, creative and, at the same time, targeted work. We help our employees develop professional and personal skills that will enable them to take up positions of responsibility within Fraunhofer itself or at universities, within industry and in society at large. Students involved in projects at Fraunhofer institutes have excellent career prospects on account of the practical vocational training they enjoy and the opportunity to interact with contract partners at an early stage in their career.

The Fraunhofer-Gesellschaft is a recognized non-profit organization named after Joseph von Fraunhofer (1787–1826), an illustrious researcher, inventor, and entrepreneur hailing from Munich.

fraunhofer.de



Virtual FMD Showroom © FMD

The Research Fab Microelectronics Germany (FMD)

The Central Partner for Business and Science, Politics and Society

Fraunhofer IISB has been part of the Research Fab Microelectronics Germany (FMD) since 2017. As a cooperation of the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP, the FMD is the central contact for all questions concerning micro- and nanoelectronics in Germany and Europe. As a pioneer for cross-location and cross-technology cooperation, the FMD is actively addressing the current and future challenges of electronics research, providing key impulses for the development of elementary innovations for the world of tomorrow.

In 2022, the FMD has further grown. Currently, more than 4,500 employees contribute their expertise to the research and development of micro- and nanosystems. The FMD is thus one of the largest R&D associations of its kind in the world.

Major projects launched for sustainable electronics and new computing technologies

Building on the competences, structures, and services created within the framework of the FMD, two new major projects – the «Green ICT @ FMD« and the «FMD-QNC« – were launched in 2022.

As part of the Green ICT @ FMD project, the Fraunhofer and Leibniz Institutes cooperating in the Research Fab Microelectronics Germany, together with the Fraunhofer ISI, are setting up a cross-location competence center for resource-conscious information and communication technology (ICT). Within this framework, Green ICT-specific issues can be addressed in a bundled manner, and cross-technology ICT solutions up to a high level of technical maturity can be provided to partners in industry and research – all from a single source. This project, launched in August 2022, is funded by the German Federal Ministry of Education and Research (BMBF) under the Green ICT Initiative, which in turn is part of the Federal Government's Climate Action Program 2030.

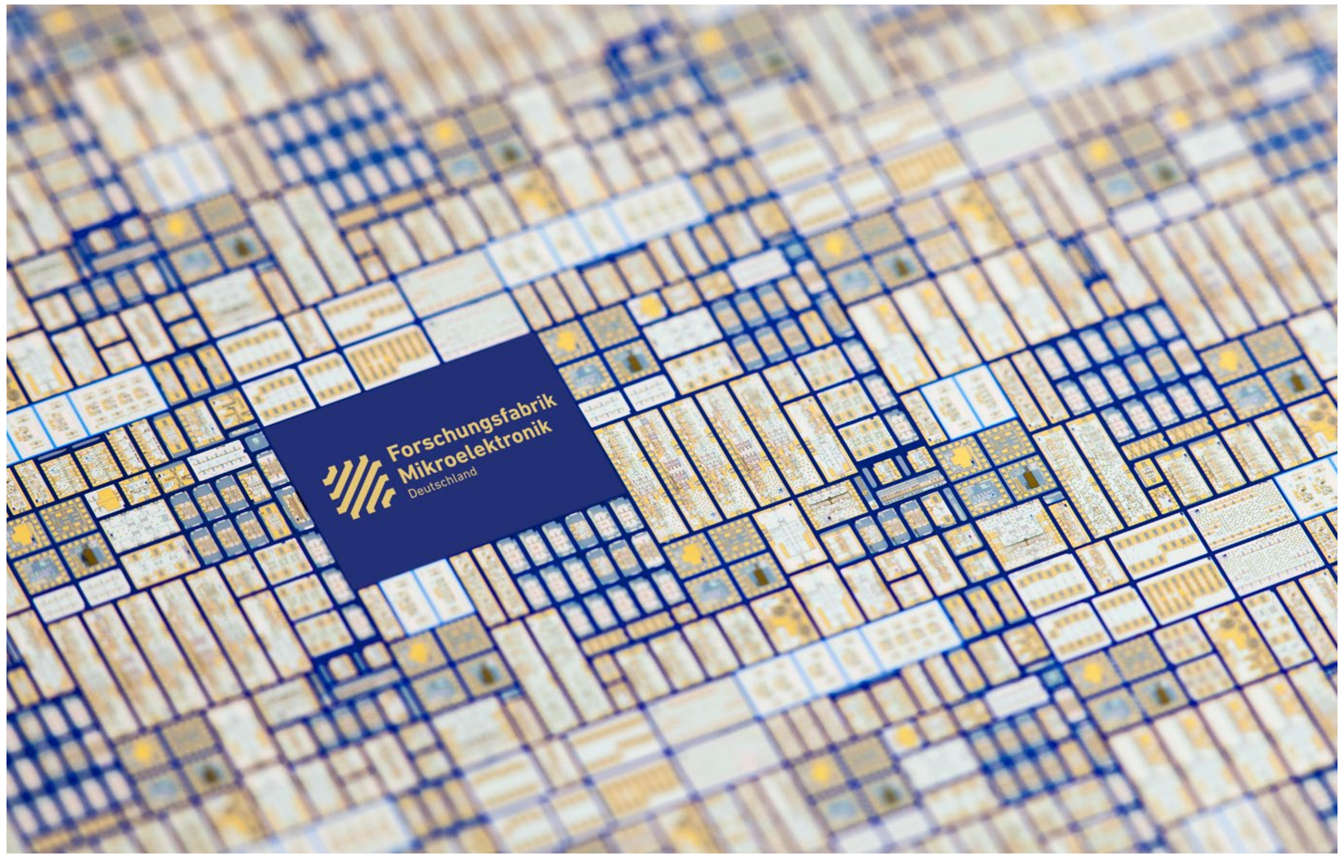
Furthermore, to bring together and expand the existing microelectronic research and the developments related to quantum and neuromorphic computing carried out in Germany, the FMD together with four further Fraunhofer institutes, the Research Center Jülich, and AMO GmbH launched a joint project in December 2022: The Research Fab Microelectronics Germany - Module Quantum and Neuromorphic Computing (FMD-QNC). FMD-QNC is a nationwide collaboration aimed at supporting researchers and companies in developing customized microelectronics and scalable manufacturing and integration processes for new computing technologies. The equipment and structural setup required for this is being funded by the BMBF.

Green ICT @ FMD: forschungsfabrik-mikroelektronik.de/press-GreenICT

Setting up a Microelectronics Academy

As part of the Green ICT @ FMD and the FMD-QNC projects, a Germany-wide micro-electronics academy will be established over the next three years. In December 2022, the kick-off of the conceptualization phase took place and with it, the establishing of the Academy and the enabling of modern training opportunities in the field of micro- and nano-electronics. Regarding its thematic foundation, the Academy is structured in three thematic pillars. The first two pillars, resource-conscious ICT and practice-oriented semiconductor engineering and technology (both derived from the Green ICT @ FMD and FMD-QNC projects), are further complemented by the third pillar focusing on design of microelectronic circuits and systems. In the process of setting up the Microelectronics Academy, the FMD is not only assuming the organizational management, but also taking responsibility for the three thematic pillars. The overarching

FMD-QNC: forschungsfabrik-mikroelektronik.de/press-QNC



The FMD is a cooperation of the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP © FMD

goal is to improve the quality of the training for skilled workers in the field of microelectronics as well as, in the long term, to actively impact and drive forward areas such as climate protection and sustainability, new computing technologies and trustworthiness in the semiconductor and chip sector.

Increasing the innovative strength of microelectronics in Europe

To ensure that Germany and Europe remain key players in the global value chain, the FMD undertook crucial preparatory work for the technological foundation of the «European Chips Act« in 2022. For instance, the FMD-QNC is being complemented at the European level by the PREVAIL project (Partnership for Realization and Validation of AI hardware Leadership). This project brings together four European research organizations, CEA-Leti, Fraunhofer, imec and VTT, to create a networked 300 mm technology platform for manufacturing chip prototypes used in advanced artificial intelligence and neuromorphic computing applications. The national part of PREVAIL constituted by four Fraunhofer institutes EMFT, IIS, IPMS and IZM, which as part of FMD are broadening their 300 mm fabrication, design and test facilities to complement the 300 mm technology of their European research partners.

Microelectronics Academy: forschungsfabrik-mikroelektronik.de/press-MEA

Information about the FMD: forschungsfabrik-mikroelektronik.de/en.html

Check out the 3D virtual showroom: fmd-insight.de/showroom

Fraunhofer IISB – The SiC Specialists within the FMD

Within the FMD, the IISB has a unique selling point with its integrated, certified production line for the processing of individual SiC-based prototype devices in an industry-compliant environment.

In the front-end area for wafer sizes of mainly 150 mm, all necessary process steps can be performed at Fraunhofer IISB, such as epitaxy, ICP dry etching, growth of silicon dioxide, aluminum implantation at elevated temperatures, activation anneal, and metallization. Usually, vertical devices are manufactured in SiC for power electronics. Therefore, the processing of the backside of the SiC wafers is of critical importance. The FMD investments enables the bonding and debonding of already finally processed wafers at the front side, the thin grinding of wafers at the backside, and the reduction of contact resistance at the backside by means of advanced metallization and laser silicidation.

New integration technologies and innovative assembly and system concepts for prototyping and the production of future power modules are available in the backend area. This makes it possible, for example, to realize particularly complex and compact structures, heavily stressed (special) applications with sometimes small quantities or durable high-temperature power electronic modules.

Extensive, complementary methods are available along the process chain for quality control. The most important of these are a fast, high-resolution X-ray topography system for the analysis of the structural properties of crystals, wafers, and partially processed wafers, and a combined surface inspection photoluminescence device for the analysis of the near-surface material properties of SiC along the process chain. The SiC metrology is supplemented by special measuring stations, which are adapted to the specific, sometimes extreme conditions of power electronics, such as an extra-high voltage measuring station as well as special lifetime and reliability test laboratories.

FMD: A pioneer for cross-location and cross-technology cooperation © FMD

For the research on new semiconductor materials with large band gaps, crystals of these materials are needed, which then have to be further processed into wafers in order to evaluate the potential in the FMD for power electronics or for other applications such as in quantum technology. Since the new crystal materials, such as GaN, AlN, Ga_2O_3 or diamond, are usually crystals with smaller diameters (50 mm or smaller), Fraunhofer IISB operates a special substrate and wafer laboratory to produce wafers from such crystals. The quality of the wafers used to manufacture the devices is tested using various analytical methods, including the determination of their epitaxial suitability and the production of special test structures.

forschungsfabrik-mikroelektronik.de

iisb.fraunhofer.de/SiC

SiC services from epitaxy to power electronic systems

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Dr. Elke Meißner, Head of the Nitride Materials Group
© Elisabeth Iglhaut / Fraunhofer IISB

Dr. Elke Meißner on Aluminum Nitride

Crystals have »always been fascinating« to Elke Meißner - not least because her father studied mining engineering and enjoyed collecting and examining minerals with his family. Initially, Elke wanted to become a goldsmith. Being part of the baby boomer generation, however, she did not get one of the few apprenticeships. So, she decided to study mineralogy with a focus on crystallography. Elke wrote her dissertation on the physical properties of crystals during her second parental leave. In 2001, she accepted an offer from Fraunhofer IISB to join the institute's Materials Department and conduct research on crystal growth of gallium nitride. Now, Elke has been successfully leading the Nitride Materials group at the IISB since 2007.

Abbreviations

AlN: Aluminum nitride
CPU: Central processing unit
GaN: Gallium nitride
SiC: Silicon carbide
Si: Silicon
UWBG: Ultrawide-bandgap
MOSFET: Metal-oxide semiconductor field-effect transistor
WBG: Wide-bandgap
2DEG: Two-dimensional electron gas

If we want to realize extreme applications in power electronics, we must first look at the material base. In 2022, all eyes were on aluminum nitride for being a promising ultrawide-bandgap semiconductor material. As an expert on nitrides at Fraunhofer IISB, Dr. Elke Meißner explains where this hype comes from, why aluminum nitride is ideally suited for aerospace and energy efficiency, and where Fraunhofer IISB stands with its research on aluminum nitride.

What exactly makes AlN such an interesting ultrawide-bandgap semiconductor?

»Technically well proven, lower-cost solutions with Si reach their physical limits when faced with more demanding requirements. Wide-bandgap materials such as SiC or GaN cover a number of these applications. But for example, Si, and at low temperatures also SiC, are not ideal for electronics for extreme temperatures. If radiation exposure is also an issue, nitrides are currently the best option. Here, we already use 2DEG devices based on GaN, more precisely aluminum gallium nitride (AlGaN). However, for these 2DEG devices, the electrical conductivity of the GaN substrate is a major drawback. As a physical consequence, a base material with an even larger bandgap is required, such as AlN, which is inherently insulating. It is one of the ultrawide-bandgap materials. AlN is considerably more resistant to radiation and temperature fluctuations than WBG materials.«

Can you please explain in more detail how GaN and AlN differ in their suitability for 2DEG components?

»With all nitrides used to make a two-dimensional transistor - i.e., a 2DEG device - a functional barrier is formed, including AlGaN on a GaN substrate. The downside to GaN is the electrical conductivity of the material. To prevent the current from simply dissipating downward and causing losses, we need to compensation-dope the GaN-based 2DEG devices with great effort. Physically, our hope is that we can achieve these components on an AlN substrate, since AlN itself is insulating. So we increase the AlN content of the alloy in the next step. The big advantage here is that we are already familiar with the AlGaN alloy and basically stick with this technology. With a totally new UWBG material, we would not yet have production lines or epitaxy plants on hand, which would obviously lead to a different time-to-market scenario than we can achieve with AlN.«

Elke, what is the task of your Nitride Materials group at Fraunhofer IISB?

»My group is organized around the topic of nitrides, starting with crystal growth of gallium nitride and aluminum nitride. After growing them, we trim and polish the AlN crystals in-house and produce wafers. We also perform epitaxy, for example to qualify the surfaces of the prepared wafers. In addition, we also check the material using test devices we manufacture ourselves, such as transistors. It is important to me to link the ends of our technological value chain across all business areas, that is, semiconductor materials and power electronic systems. One focus is on defect analysis. For our own substrates as well as for customer wafers from chip manufacturers, we investigate the structural defects in the material and how they later influence the final performance of the devices.«

In which specific application area, for example, does AlN have benefits?

»For instance, in aerospace applications, AlN brings decisive physical advantages. In vertical SiC or Si MOSFETS, charge carriers no longer flow below a certain temperature. The two-dimensional electron gas of AlN-based 2DEG devices, on the other hand, would prevent charge carriers from «freezing«, so to speak, at these low temperatures. In the extreme conditions in aviation and also in space, with severe temperature fluctuations and radiation exposure, AlN is ideally suited.«

Saving resources by increasing energy efficiency is currently an important topic with significance for society as a whole. How can AlN support this issue?

»We could replace technology currently used in data centers, for example, and achieve enormous energy savings. That is not because high voltages have to be switched there, but because of the high energy density and the large number of individual processors. For each of these CPUS, the input voltage must be converted. This means that there are many conversion steps that cause energy losses. Point-of-load (POL) converters could make the conversion steps more efficient and reduce the number of conversions overall. AlN is from a physical point of view the best semiconductor for the POLs and would allow the last conversion steps to be combined into one. This means an energy saving of approx. 25 % for the energy conversion. Data centers can be the size of a soccer field - so this would be a huge saving, not only in Germany, but world-wide.«

Will aluminum nitride become the new, universal semiconductor?

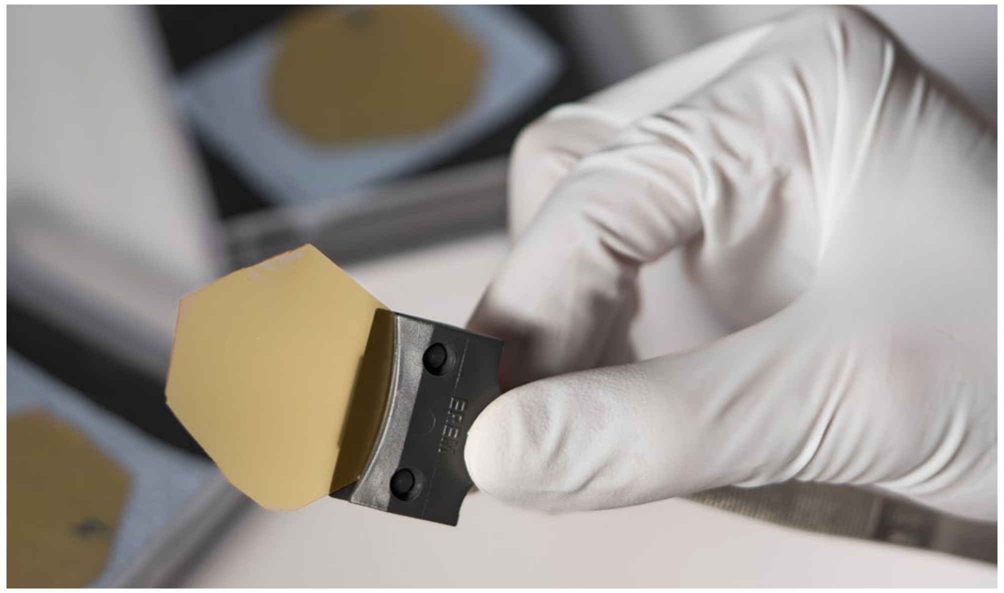
»To sum it up: AlN definitely narrows down GaN and SiC and could take over a large part of the application areas. The type of crystal growth process is also relevant here. We assume that an approach similar to the physical method used for SiC growth can be established for AlN. This would be less complicated than growing GaN and would therefor be another advantage of the material.«

Installation of a PVT (Physical Vapor Transport) reactor suitable for AlN crystals of 4 inches and larger © Elisabeth Iglhaut / Fraunhofer IISB

AlN

– The next generation ultrawide-bandgap semiconductor material?

35 mm diameter with AlN – a major breakthrough



First 35 mm AlN crystal slice made by IISB © Elisabeth Iglhaut / Fraunhofer IISB

Where do you stand on your journey to the two-inch AlN wafer?

»We expect to realize a two-inch wafer in the first quarter of 2023. The big goal of my Nitride Materials group is to develop first a two-inch and then, in the next step, a four-inch AlN wafer. We are already on the right track. We would like to push AlN for Germany and Europe so that great applications can be realized here with AlN. Going forward, I envision the IISB as the technological point of contact for AlN. This is how we can fulfill our Fraunhofer-typical mission of conducting applied research for industry and for the benefit of society.«

So, what's next for aluminum nitride at Fraunhofer IISB?

»In 2022, we initiated three projects on AlN that have already been approved: Green ICT, Nitrides for 6G and AlN-EMotion. The exciting thing about all these projects is that, together with us, our colleagues from system development are also on board. This brings our crystal growth all the way to application level. Part of Green ICT is also Dr. Stefan Zeltner, a specialist in AC/DC converters, who will be developing a POL converter based on our AlN for data centers. In the Nitrides for 6G project, we are likewise responsible for the material manufacturing of the AlN and the chip will be manufactured at the Ferdinand Braun Institute (FBH). Then, Florian Hilpert and his aviation electronics group at the IISB will build power modules for future satellite communication via the 6G mobile communications standard. We also manufacture AlN substrates for AlN-EMotion, which should then be somewhat larger, because they are to be used for integrated circuits (ICs) for automotive applications. Dr. Stefan Matlok and his DC/DC Converters group are also part of the project. Based on the AlN ICs and transistors, Stefan then is going to develop another outstanding DC/DC converter. With this AlN converter we aim to continue our record-breaking path in power density of converters, which started with Si and now leads via SiC and GaN to AlN.«

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Dr. Elke Meißner on Aluminum Nitride

Florian Hilpert, Head of the Aircraft Power Electronics Group
© Elisabeth Iglhaut / Fraunhofer IISB

Florian Hilpert on the Possibility of Hybrid-electric Flying

»We should reach the point where we can fly domestic, and European aircrafts CO_2 free and completely from renewable energies. I cannot imagine that we will give up flying, and that's why I'm doing everything I can to make sure that it no longer causes harm to the environment. Flying has such a high value. I think it's important to use it in an appropriate way. It brings people closer together, which for me is the most precious thing about flying.«

»Failure handling in aviation is challenging - you can't simply shut everything down and pull over.«

Due to the progress with new WBG activities and the resulting reduction of the power-to-weight ratio, there is a new research potential in aviation. The IISB is researching and developing in this field in various funded projects as well as in direct research cooperations with the industry. The projects aim to address society's overall need for sustainable mobility. Florian Hilpert, Head of the Aircraft Power Electronics group, talks about his vision to fly inner-European airplanes completely from renewable energies. He gives an insight into the challenges of failure handling in aviation, what all-electric planes might look like in the future, and the importance of semiconductor materials as the foundation for the power electronic system.

How did you come to work in power electronics for aviation?

»In 2016, we completed some major projects in high power density automotive drivetrains utilizing new WBG power devices. In parallel, first concepts for hybrid-electric and electric aircrafts were discussed in the scientific community. We realized that the requested and assumed power densities for these future concepts were far below what we already had achieved. Hence, we wanted to contribute our expertise addressing high power density systems for aviation. Together with Bernd Eckardt, Head of the Vehicle Electronics department, we developed the concept for an aviation electronics workgroup at the IISB.«

As you first started working in power electronics for automotive, can you tell us more about the differences between power electronics for aviation versus automotive?

»One important difference is the type of power density. It's kilowatts per liter for cars and kilowatts per kilogram for airplanes, meaning system weight is the key driver in aviation, not volume.«

Another major difference is the failure handling. A safety mode for cars is simply to switch off everything and roll over. This, obviously, does not work for planes. Therefore, we are quite intensively researching fault-tolerant concepts. For sure we build the plane as safe as possible. Nevertheless, we design the entire system in a way to ensure it still runs reliably, even if errors occur in one part of the system. In the case of vehicles, for example, a serious fault in some power electronics part often leads to the entire drive train being switched off. In the case of aircrafts, we have to manage the situation and make sure the rest of the system keeps running. There are various dependencies between the subsystems. An error in one subsystem must not affect the rest of the system.«

Can you tell us more about your Aircraft power elctronics group at the IISB?

»On one side, we are a working group with own projects. At the moment, it's mainly aviation drive trains, i.e., traction motors up to a few 100 kilowatts. For the next projects we are approaching megawatts.

On the other side, our group operates as a central point of contact for all aviation customers to the institute. The typical aviation client wants to understand the whole system at once. It's hard to channel that to a dedicated group. For individual projects we connect new partners with our specialized groups according to the given focus and often convert the expertise from automotive to aviation.

The whole team has really done an outstanding job in adapting our IISB developments to the new and challenging aviation requirements, the credit for our success belongs to everyone involved.«

Besides research in the field of failure handling, what are other key aspects of your work?

»For three years now I am working in the Clean Aviation technical committee as a technical consultant in Brussels and I was able to help shaping the Clean Aviation program. My job was to consult the EU with regards to technical aspects as an independent scientific advisor. I had this special opportunity thanks to my scientific background in hybrid-electric and electric issues. This fits perfectly with the focused research topics of the EU program.«

How do you envision larger aircrafts in the future: Will it be possible to fly them completely electric? Will they look like today´s airplanes or different?

»Battery-only electric aircrafts work in the pilot trainer field for two to four seaters and maybe up to 20 seaters in the near future. One company has already launched the first certified pilot trainer aircraft. The focus of the Clean Aviation program right now aims at larger all-electric airplanes with around 100 seats. But clearly with the scaling to the CS 25 Certification Specifications for Large Aeroplanes.

The design of the airplanes will be different. They will not be able to take off and land vertically, as cool as that would be. The current generation of aircraft has evolved because large gas turbines are needed for efficiency. On four-engine airplanes, such as Boeing 747 or Airbus 380, two big gas turbines would run more efficient than several small ones. That changes with electric engines. You don't necessarily need large electric motors, instead you can achieve the same efficiency with several smaller ones. Therefore, it is possible to arrange any number of motors and propellers of different sizes on the wing, providing aerodynamic advantages as well. This creates completely new possibilities in aircraft architecture. These architecture approaches have a strong impact on aviation electronics. You can spread the DC network in a different way, as it will be possible to have multiple independent drive trains. Therefore you don't lose all drives, if a DC line from multiple buses goes down. This increases safety. For now, though, a classic fuselage and wing design will stay. A delta wing would be nice, but it's hard to integrate windows. And I have heard passengers wouldn't like that.

The engine still needs an energy source. One development is a gas turbine, which uses kerosene, but with aerodynamic advantages due to electric propellers.

Deep mechatronic system integration enables system advantages - like on this 15 kW multiphase inverter, fully integrated in the aerodynamic nosecone of an electric motor nacelle © Elisabeth Iglhaut / Fraunhofer IISB

Deep system knowledge is one of the key advantages at the IISB.

Florian Hilpert on the Possibility of Hybrid-electric Flying

Test of a GaN half bridge in liquid nitrogen © Elisabeth Iglhaut / Fraunhofer IISB

»When it comes to cryogenics, we rely on **WBG** material.«

Other developments are multi-megawatt fuel cell systems with liquid hydrogen to achieve real CO_2-free flight.«.

How do you use WBG materials in developing power electronics for aviation?

»There are two development directions in which we use WBG materials for aircraft.

One research direction is a high-voltage powertrain system around 1 kV, with a conventional cooling circuit. We mainly use silicon carbide (SiC) in this case.

The second important material we work with is gallium nitride (GaN). Currently, it is used in planes for secondary systems with lower power and voltage levels. GaN will become even more interesting when we move to cryogenics. In other words, very cold power electronics. Therefore, we foster a close cooperation with our colleagues in the Materials department, in particular Dr. Elke Meißner, manager of the Nitride Materials group.

Together with Elke, we are addressing two challenges.

On the one hand, we are dealing with radiation. Of course, here on earth our cars are not exposed to space radiation. At altitudes where large airplanes fly, up to 10.000 meters and more, cosmic radiation is significant. To make sure that the components still work, we have to reduce the usable voltage on our semiconductors. How much we have to reduce it so that it is statistically safe, however, is still an unresolved question. Together with Elke, it is exactly about researching radiation resistance WBG semiconductors.

On the other hand, we are dealing with cold temperatures. Imagine a liquid hydrogen tank in an airplane, it's freezing cold, -250 °C. The liquid hydrogen has to be warmed up so that it can enter the fuel cell. Wouldn't it be great if we could cool our electronics, which we have to cool anyway, with the liquid hydrogen? Then we wouldn't have to use a big heat exchanger and in addition we could introduce superconducting cable systems, using the same cooling circuit. We have to make sure the electronics even run at this low temperature. SiC stops working efficiently when it gets too cold. GaN does work even more efficient at lower temperatures, but then has challenging dynamic effects, that we currently explore, together with additional challenges in packaging and thermal management.«

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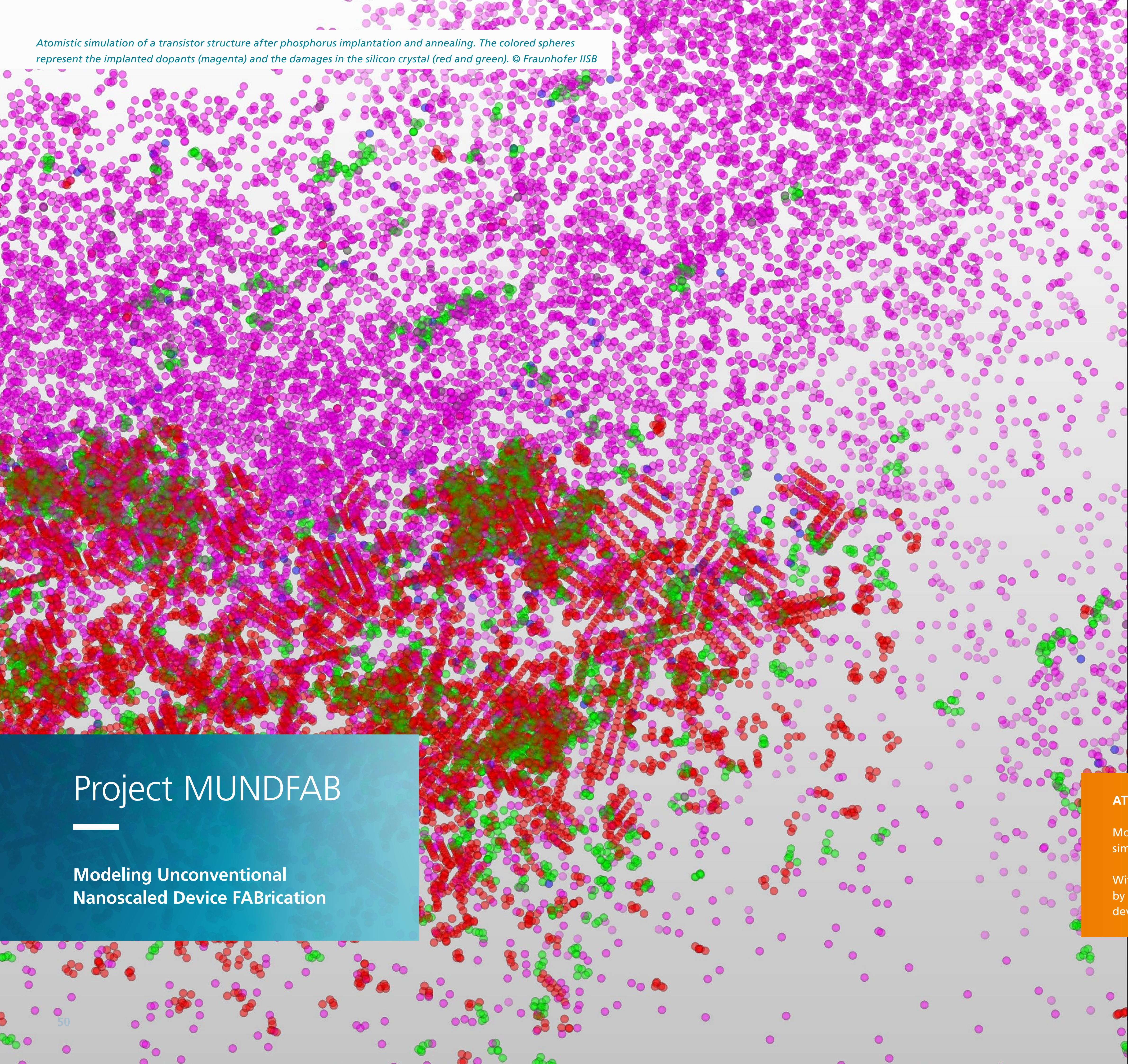

Atomistic simulation of a transistor structure after phosphorus implantation and annealing. The colored spheres represent the implanted dopants (magenta) and the damages in the silicon crystal (red and green). © Fraunhofer IISB

Project MUNDFAB

Modeling Unconventional Nanoscaled Device FABrication

Development of simulation software for the virtual fabrication of next generation nanoelectronics

For the last 50 years, shrinking transistors have enabled more and more processing capacity to be put on the same size chips, following Intel co-founder Gordon Moore's predictions in the 1960s. Moore's law is now reaching its physical and economic limits – our future virtually unlimited inter-connectedness will depend on a paradigm shift. Much as high-rises are a solution to urban growth, emerging 3D sequential integration could alleviate the problems faced by 2D CMOS transistor technology. Bringing this architecture down to the nanoscale could additionally enhance the benefits. Building on experimental work and development of simulation models, the EU-funded MUNDFAB project has developed the requisite software tools that will foster innovation via virtual fabrication of the next generation of nanoscale electronic devices. This article provides an overview of the project's focal topics and illustrates its achievements by means of an example – the simulation of a nanowire field-effect transistor.

AT A GLANCE

Modeling of nanoelectronic devices requires advanced simulation tools.

Within the European MUNDFAB project coordinated by the IISB, leading research institutions worked on the development and application of such tools.

Project MUNDFAB

The Approach of MUNDFAB: Development and Integration of Advanced Physical Models for Device Fabrication

Advanced physical models for various process steps

The project structure consists of different work packages devoted to the development of advanced physical models on the one hand side, as well as to the integration of the new models into process simulation chains based on commercial standard software on the other hand side. This allows one to simulate complete device processing flows and the electrical behavior of the devices to study their characteristics and its dependence on the manufacturing processes.

Si or SiGe epitaxy using chemical vapor deposition is the method of choice to produce high quality layers in many industrial applications such as CMOS transistors or heterojunction bipolar transistors. For the fabrication of nanoscale devices, this method is particularly important. Within MUNDFAB, the partners developed advanced atomistic 3D models relying on the lattice kinetic Monte Carlo method to simulate epitaxial growth of Si and SiGe layers. These models consider various process parameters, such as the nature of the chemical precursors and their mass flows, the temperature, the pressure, or the crystal orientation of the surface on which the growth takes place.

One work package focuses on fabrication processes related to dopant implantation and activation, solid phase epitaxial regrowth, and silicidation of metal contacts. Through a better understanding of these processes at the atomic scale, the predictivity of classical models was improved and new state-of-the-art modelling tools have been developed which consider the constraints imposed by the nanosized SiGe-based devices and processes at very low temperatures.

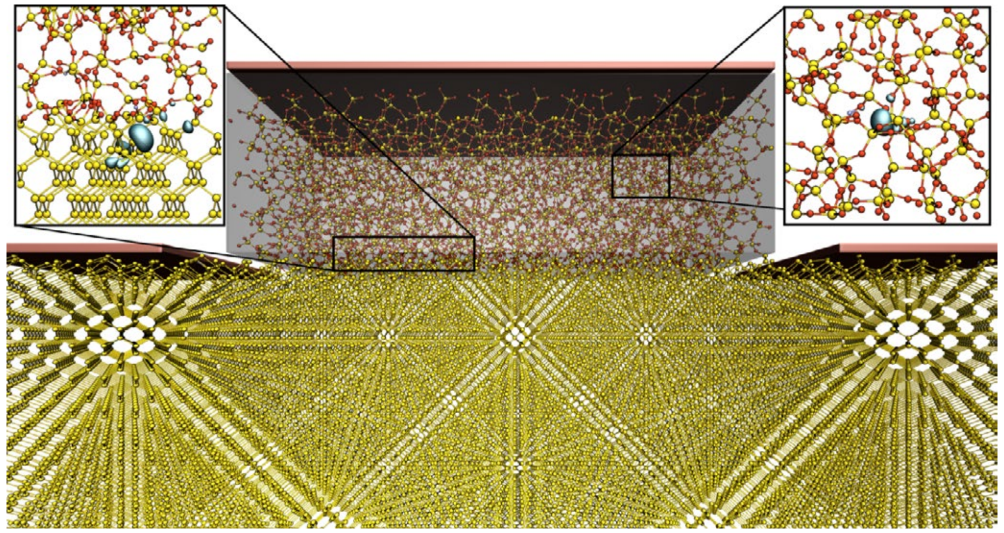

Fig. 1: Schematic atomistic representation of a field-effect transistor with an amorphous silicon oxide insulator (upper center part of the figure). The variety of interface defects (left inset) and oxide defects (right inset) are serious issues for the reliability and variability of modern ultra-scaled devices © Institute for Microelectronics, TU Wien

Laser annealing with space uniform beams and nanosecond range pulses is an extraordinary resource for the fabrication of advanced devices. The work package on laser annealing aims at developing simulation models for the process of laser annealing, extending the current understanding of the physical phenomena occurring during this process. In addition, dedicated experiments have been conducted to investigate the thermal and optical properties of materials during laser annealing, their structural modification, and the dopant activation under different laser annealing regimes.

For modern ultra-scaled electronic devices, electrically active defects are particularly critical, as they impact variability and reliability at the channel-oxide interface and within the oxide layer (Figure 1). The formation of these intrinsic defects, however, is inevitably linked to various manufacturing steps such as oxidation, forming gas anneal, plasma nitridation and atomic layer deposition of high-k materials. To break grounds, the MUNDFAB researchers studied the formation and implication of different defect types at the process level. State-of-the-art multiscale atomistic simulation approaches – ranging from molecular dynamics to density functional theory – were employed to identify the relevant reaction kinetics of defect formation and transformation within the important low-temperature processing steps.

Software for the simulation of complete process flows

In industry, Sentaurus Process and Sentaurus Device of Synopsys are often considered the gold standard of process and device simulation world-wide. Part of the models developed in MUNDFAB can be implemented and used directly within the Sentaurus software. Other models require the use of own tools, such as the open-source kinetic Monte Carlo super-lattice tool MulSKIPS from the partner CNR-IMM or the physics-based deposition simulator and geometry editor DEP3D of Fraunhofer IISB. Integrating them into the Sentaurus workflow enables accurate simulations of advanced process steps as required by next generations' devices and structures.

MUNDFAB

The MUNDFAB Project

The duration of the project MUNDFAB (Modeling Unconventional Nanoscaled Device FABrication) is from January 1, 2020, to June 30, 2023. Project partners are Fraunhofer IISB (coordinator), CEA-Leti (France), CNR-IMM (Italy), CNRS-LAAS (France), Lukasiewicz (Poland), STMicroelectronics (France), TU Wien (Austria). The MUNDFAB project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 871813.

mundfab.eu

Application Example: Simulation of a Nanowire Field-effect Transistor

The gate-all-around nanowire field-effect transistor (GAA-NW-FET), see Figure 2, represents one of the most promising candidates for the Power-Performance-Area-and-Cost scaling that replaced Moore's law. GAA-NW-FETs show excellent performance and, thanks to their 3D layout configuration, can enhance integration and overcome physical limitations resulting from 2D layout, such as contact placements and interconnect routing congestion. Vertical GAA-NW-FETs can be fabricated using a top-down approach with conventional processes and particularly good control on dimensions and localization.

Thermal oxidation is a key process for the nanowire fabrication. It is used to shrink the diameter, remove residual damage from the etch process, and to grow the gate oxide. For a nanowire, some phenomena of the oxidation process are aggravated compared to the oxidation of a planar surface. As a result, the oxidation process leads to a strong decrease of the doping concentration in the nanowire. Since the doping distribution in the nanowire strongly affects the electrical characteristics and performance of the transistor, an accurate prediction of the doping profiles after the oxidation processes is paramount. Oxidation is therefore one of the most crucial steps for process simulation of GAA-NW-FETs.

Within the MUNDFAB project, we have developed a full toolchain for the simulation of GAA-NW-FETs, including process and device modeling. Simulation results have been compared with experimental data of devices fabricated by the project partner CNRS-LAAS. The initial nanowire structure, after a first reactive ion etching step, is presented in Figure 3 (a).

3D simulation of transistor structures

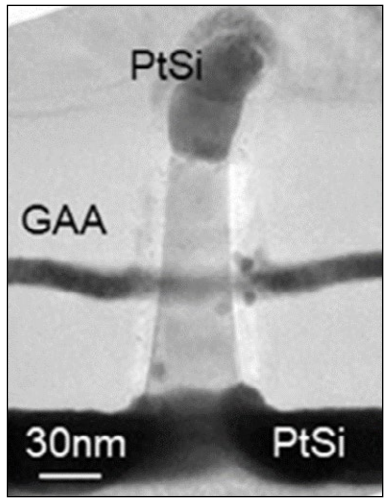

Fig. 2: Microscopic image of a vertical gate-all-around (GAA) silicon nanowire field-effect transistor fabricated by the MUNDFAB project partner CNRS-LAAS © Larrieu et al., Nanoscale 5 (2013) 2437

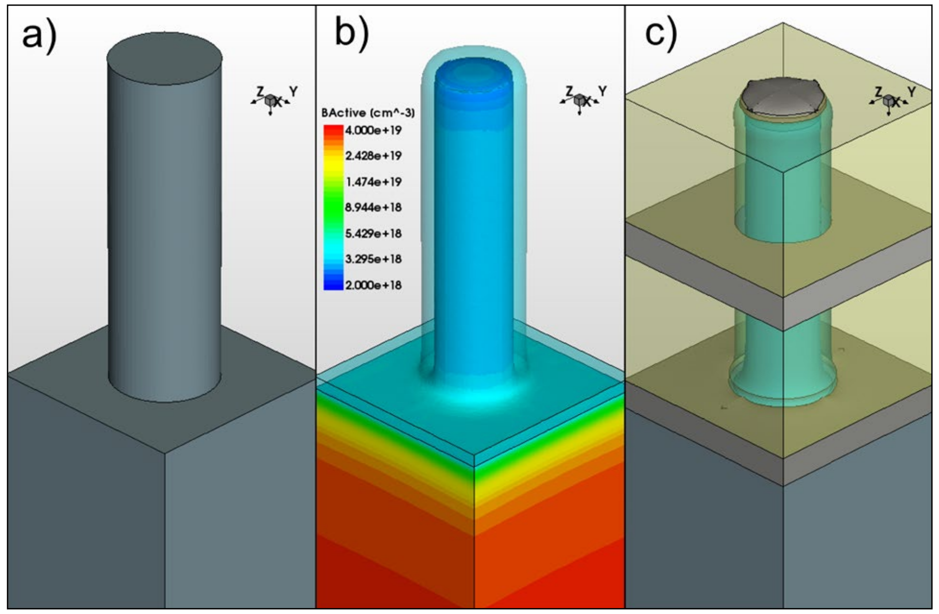

Fig. 3: Simulated silicon nanowire structure: after first reactive ion etching (a), after wet and dry oxidation, showing the doping concentration (b), after contact creation and deposition of spacers and metal gate (c) © Fraunhofer IISB

The geometry and the doping concentration after a sacrificial wet oxidation for nanowire thinning and subsequent dry oxidation are shown in Figure 3 (b). 3D simulation results predict a decrease of boron doping in the nanowire of about one order of magnitude, with the decrease being more pronounced for thinner nanowires. Figure 3 (c) depicts the final structure, after contact creation by silicidation and deposition of spacers and gate metal layer.

Using this structure, one can perform device simulations of the transistor. The experimental data agree quite well with the simulation (Figure 4 (a), black dots for the experimental data, red curve for the simulation). However, for the subthreshold slope a deviation is observed. To further investigate this, we artificially modified the doping distributions obtained from process simulation by multiplying the doping concentration with certain factors. The corresponding simulations are shown in Figure 4 (a) as well. The simulated threshold voltage and the subthreshold slope as a function of the doping multiplication factor are reported in Figure 4 (b). Lowering or increasing the doping considerably changes the threshold voltage and the subthreshold slope. This confirms the importance of a precise modeling of the doping evolution in nanowires during oxidation. For a multiplication factor of 1.5, we obtain a rather good agreement of the simulated and the measured subthreshold slope (147 mV/dec). Therefore, further study to improve the process simulation models for predicting doping evolution during oxidation is ongoing.

Oxidation processes require precise modeling

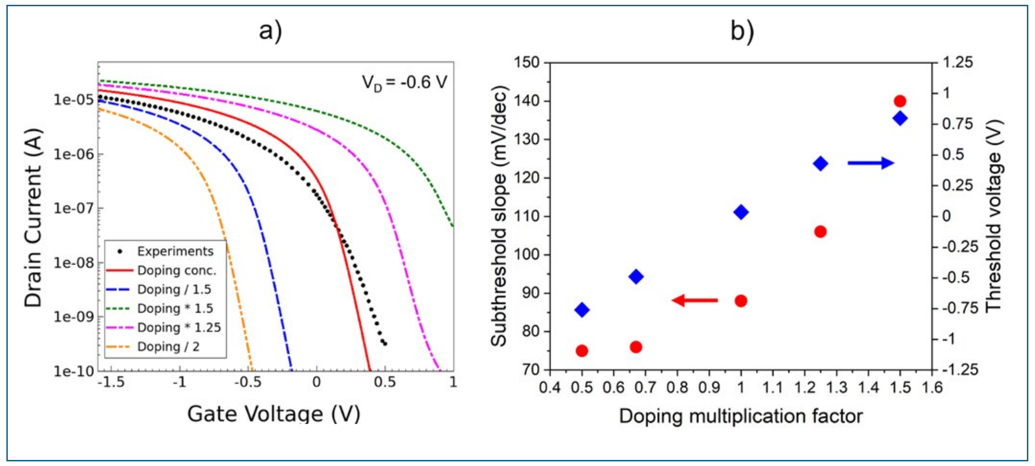

Fig. 4: Measured and simulated electrical characteristics for nanowires with different doping concentrations (a), simulated dependence of the electrical parameters on the doping concentration (b) © Fraunhofer IISB

Conclusion and Outlook

The models developed in the project have been looped into simulation workflows based on standard commercial software tools. Thus, one now has a complete calibrated tool chain on hand that can simulate the virtual fabrication of the 3D sequential integration of nanoscale electronic devices. This will allow continuing further the success story of the use of advanced semiconductor simulation tools for the early development of the next generation of nanoscale devices and their integration.

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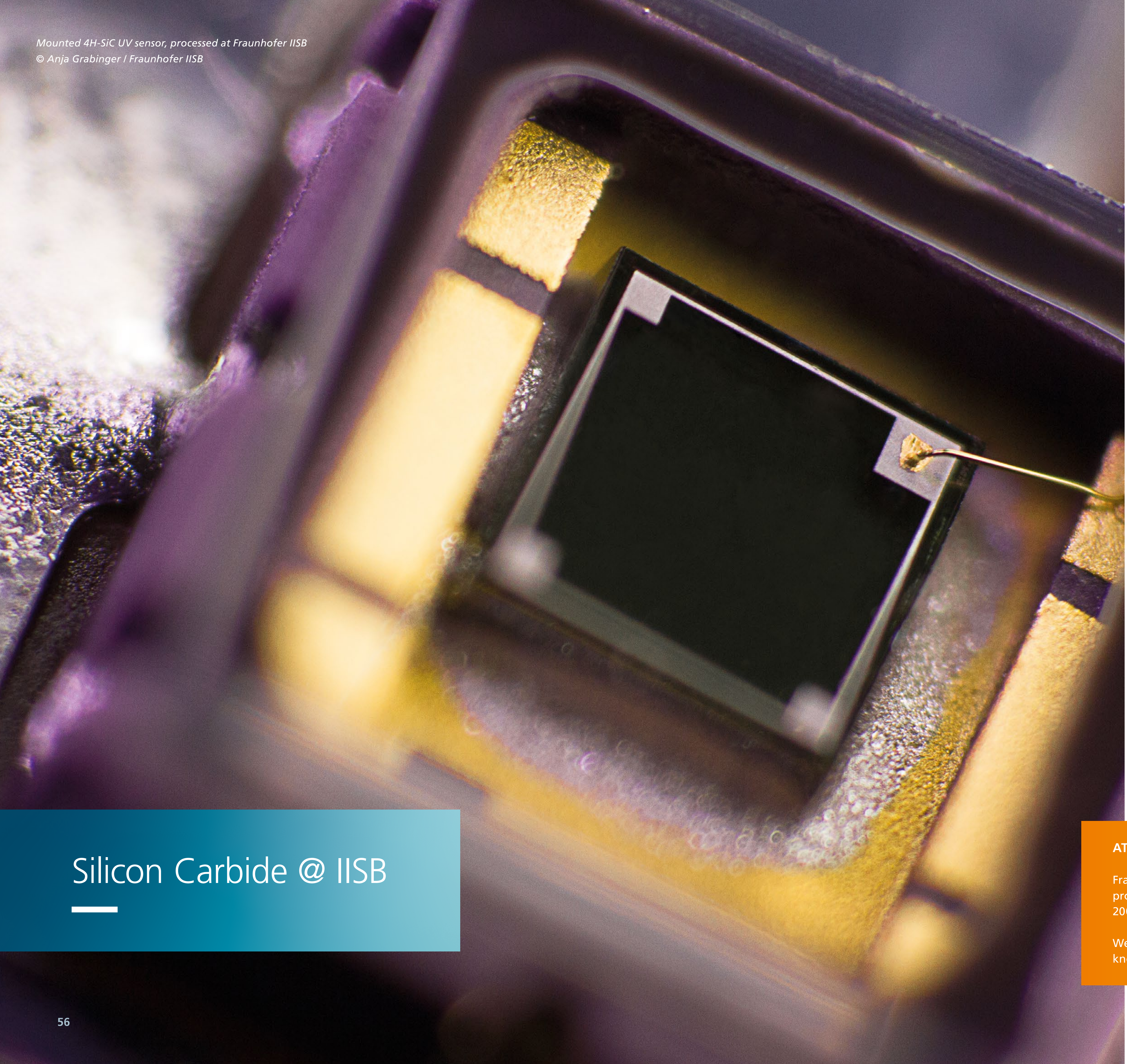


Mounted 4H-SiC UV sensor, processed at Fraunhofer IISB

Silicon Carbide @ IISB

As a unique center of excellence in Europe for the semiconductor material silicon carbide (SiC), Fraunhofer IISB is a pioneer in the development of highly efficient power electronics. The research activities are deeply embedded in the institute's strategy of offering outstanding services along the entire value chain – from semiconductor base materials to power electronic systems. The technological foundation for this is a continuous and industry-compatible CMOS process line for silicon and SiC wafers up to 150 mm and 200 mm in diameter, respectively. With its process line, the IISB also has access to advanced nanoscale heterointegration and patterning technologies. In addition, the technological portfolio covers assembly and connection technology as well the reliability of electronic components and modules. The extensive know-how in the field of wide-bandgap semiconductor technology flows directly into the development of power electronic systems. Here, the institute primarily addresses the key areas electromobility, aviation, aerospace, and also sustainable energy supply. With its solutions, the institute has been setting benchmarks in energy efficiency and performance, even for extreme operating conditions. In this way, the IISB offers low-threshold access to high-tech infrastructure and know-how in the field of wide-bandgap semiconductor technology as well as power electronics system development.

AT A GLANCE

Fraunhofer IISB operates an industry-compatible CMOS process line for Si and SiC wafers up to 150 mm and 200 mm in diameter.

We offer access to high-tech infrastructure and unique know-how in the field of semiconductor technology.

SiC goes Europractice

The commercialization of SiC power devices is in full swing. Processing technology has matured to a point where highly reliable device fabrication with significant yield is available. In contrast to introduction of silicon power devices, which heavily relied on the efforts following Moore's Law in silicon integrated circuits, silicon carbide technology now also enables integrated SiC CMOS technology development.

Adding a PMOS transistor to a planar device technology (from VDMOS power transistors) constitutes to a straight-in approach to SiC CMOS technology. This technology benefits from ultra-low pn-junction leakage and enables applications for integrated circuits and semiconductor sensing opportunities beyond 200 °C. This SiC CMOS technology is not considered as a competitor to silicon CMOS circuits with its plentiful highly integrated and high performance solutions. Instead, it extends the applicability of conventional semiconductor sensing principles of temperature, light, magnetic field, and pressure to operating conditions silicon circuits cannot satisfy.

Semiconductor sensors combine miniaturization, high performance, low power consumption, and high reliability compared to mechanical sensor solutions. Moreover, multiple sensors can be integrated in the same chip, thus further reducing the effort and cost to provide integrated sensor solutions, e.g., temperature sensing for magnetic field and pressure sensor calibration.

Availability of semiconductor manufacturing technology at an early stage is imperative for matching device performance (Technology Push) with different possible device applications (Application Pull). Moreover, the immersion of fabricated devices in relevant applications supports the technology development towards reliable and performant devices and integrated circuits. Combined with a combination of different circuits in a single fabrication technology, this ensures timely development cycles towards manufacturable technologies.

In order to enable these prototyping efforts at Fraunhofer IISB, we have launched an early-access to our 2 µm 1P2M SiC CMOS technology through the Europractice-IC platform at www.europractice-ic.com. Similar to commercial multi-project wafer (MPW)offers, this MPW-centered approach is aiming towards universities and research centers to enable SiC CMOS circuit development at low manufacturing cost for evaluation and optimization. Customers will allocate a portion of the available wafer area with their circuits and receive approx. 30 fabricated chips for measurement and evaluation. By offering up to two tape-out dates per year, customers enjoy the opportunity for rapid circuit development even at this early stage of technology adoption for SiC CMOS technologies. Within the available process flow, additional devices besides MOS transistors like diodes, capacitors, and resistors can also be implemented.

The availability of a preliminary cadence-based Process Design Kit (PDK) ensures easy integration of circuit design and modelling into the standard development workflow of fabless companies and universities. The models in the PDK are calibrated to temperatures up to 500 °C. The PDK can be obtained after providing a signed standard NDA available from the Europractice-IC website.

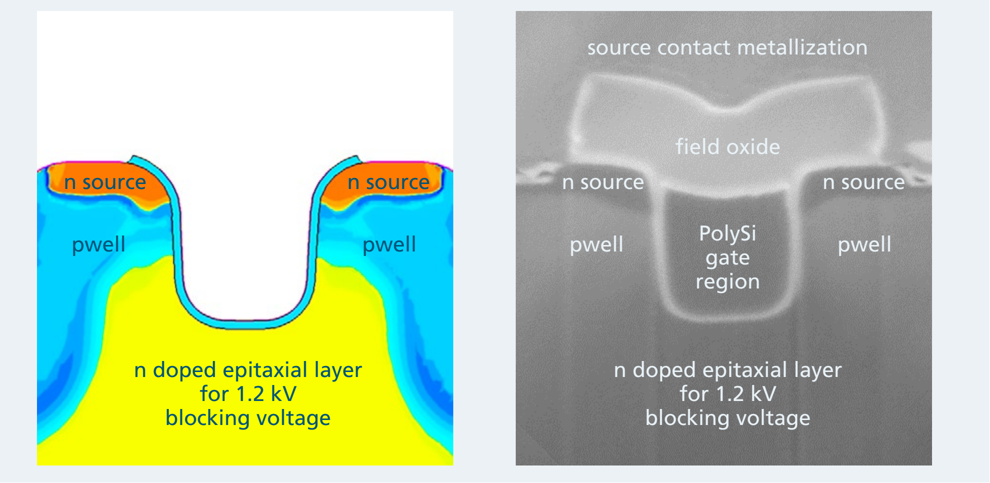
Besides the integration sensors and integrated circuits, e.g., signal conditioning at elevated temperature using operational amplifiers, optional processing modules towards integrated power devices (bipolar junction transistors and RESURF-LDMOS transistors) are also available on request.

We are looking forward to including your SiC circuit solution in the upcoming Europractice-IC run at the IISB!

CMOS
technology through the Europractice-IC platform

iisb.fraunhofer.de/europractice

Development of 4H-SiC 1.2 kV TrenchMOS Power Devices



Comparison of TrenchMOS device unit cells: TCAD simulation after trench formation, implantation, and gate oxide deposition (left) and cross-sectional SEM image after device fabrication (right) © Matthias Kocher / Fraunhofer IISB

Power semiconductor devices based on 4H-SiC, like planar SiC MOSFETs (metal-oxide-semiconductor field-effect transistor) are widely established on the market. Due to its physical properties, 4H-SiC power devices allow the fabrication of fast switching devices with simultaneously reduced power losses compared to their silicon counterparts.

Further improvements of the MOSFET device properties can be achieved by increasing the integration density, which results in a reduction of the on-state resistance. One common way to realize this is to introduce a vertical channel instead of a horizontal one in the device structure. Doing so reduces the cell pitch size and additionally increases the channel mobility by using the trench sidewalls. In addition, the high integration density of the cells enables a reduction and savings in chip area and thereby chip costs. To fabricate these vertical channels, a trench topography is introduced into the SiC surface via plasma etching. However, as the device architecture becomes more complex, additional manufacturing risks arise. In addition, it is crucial to achieve a high-resolution and precise alignment for a maskcompliant structure, which comes with significant lithograph systemrelated constraints that impose further costs. Therefore, a suitable fabrication process with a self-aligned approach for the formation of the n-source and p-well regions has been successfully developed at Fraunhofer IISB.

In order to extend the portfolio of 1.2 kV power devices, 4H-SiC TrenchMOS power devices were developed and processed at Fraunhofer IISB. During this development, TCAD simulations were performed to predict suitable processing parameters as well as the electrical characteristics in advance of device fabrication. The figure shows a comparison between the TCAD process simulation and the corresponding cross-sectional SEM image in the gate trench region of a fabricated device, where the contrast the n- and p-doping regions is visible.

As a result, devices with a specific on-resistance between 3 – 4 mΩcm² were fabricated, being normally off between 2 and 5 V. As expected, the narrowest cellpitches exhibit the lowest resistances due to the highest integration density, but with compromises in yield. Furthermore, the leakage current decreases with a reduced cellpitch width due to a more efficient shielding of the electric field in the

1.2 kV
4H-SiC TrenchMOS power devices

gate oxide. This made it possible to achieve leakage currents below 10 µA at nominal breakdown voltage.

However, in order to obtain further improvements in device characteristics, development will continue in respect of device design and process integration. One major factor to increase the device performance is the optimization of the trench geometry in terms of depth, width, and corner rounding. Furthermore, optimizations regarding the stability and homogeneity of the individual process steps aim at improving the robustness und reliability of the fabricated power devices. This enables the IISB to establish TrenchMOS prototype manufacturing on a small scale.

SiC-based High-performance Traction Inverter for Electric Drives

Fraunhofer IISB provides highly efficient, compact and reliable power-electronic solutions based on SiC semiconductors for mobile applications.

Together with the Porsche AG, the institute designed and realized a modular and SiC-MOSFET based traction inverter. The system is designed for the characterization of future electric drives on the motor test bench. It operates without derating up to a maximum DC-link voltage of 865 V and can provide a continuous phase current of up to 1000 A_{rms}. The switching frequency of the system can be set to values between 4 kHz and 30 kHz.

These performance parameters, together with the modular internal power-stage design, result in a flexible testbench setup for a wide range of electric drives. Single subcomponents of the inverter can be exchanged for specific testing purposes. The flexibility of the inverter control setup is achieved by using a rapid prototyping controller platform with model-based algorithm development, wich enables rapid adaption to different electrical machine types and control strategies.

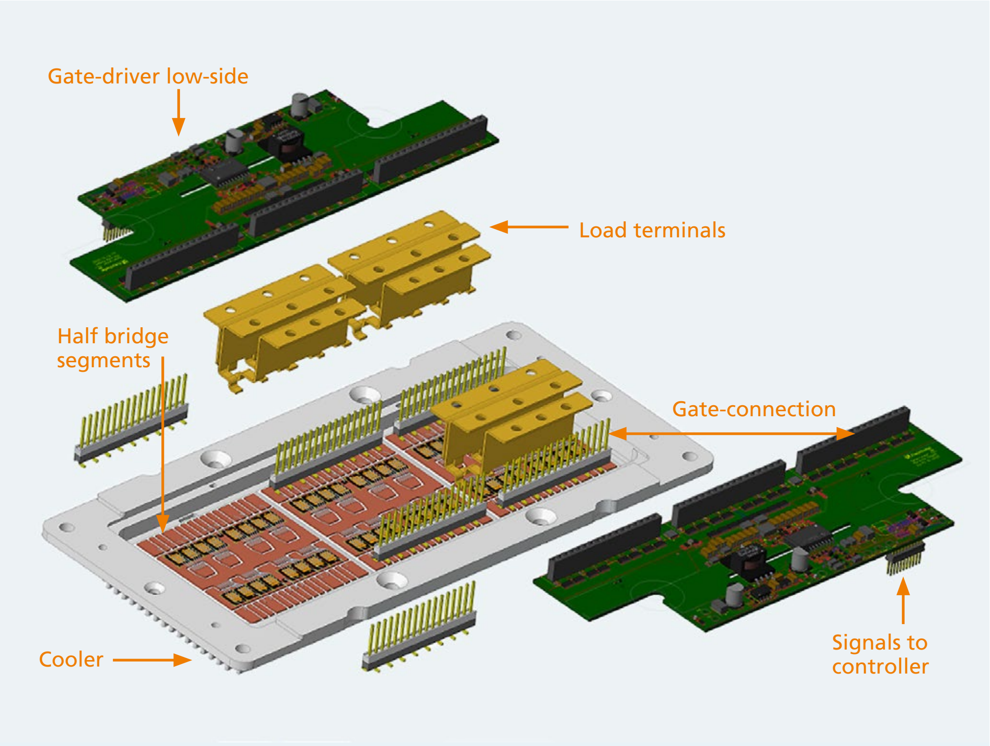
Key element of the inverter power-stage is a half-bridge power-module with 24 parallel 1200 V SiC MOSFETs for each switch of the B6-topology. The module was developed and realized as part of the project with the Porsche AG. A symmetrical and low-inductance design for the commutation loop, but also for the gate-drive connection of each chip, was the focus of the optimizations. A combination of common and single gate serial resistors as well as a binning process allow homogeneous switching of all parallel chips without oscillations or ringing caused by uneven switching on and off of the individual semiconductors.

With these measures, a maximum switching speed of up to 20 kV/µs (10 % - 90 %) could be achieved with the high-current inverter design, providing high efficiency and realistic dU/dt stress of the electric machine.

The system was successfully tested on a power HiL (Hardware in the Loop) system before it was now applied for targeted use to test prototype e-machines in operation.

SiC-MOSFET based 800 V inverter system with continuous output current of 1000 A_{rms}
© Porsche / Fraunhofer IISB

1000 A
continuous phase current at 865 V DC-link Voltage



Half-bridge inverter power module with 24 SiC MOSFETs in parallel per switch
© André Müller / Frauhofer IISB

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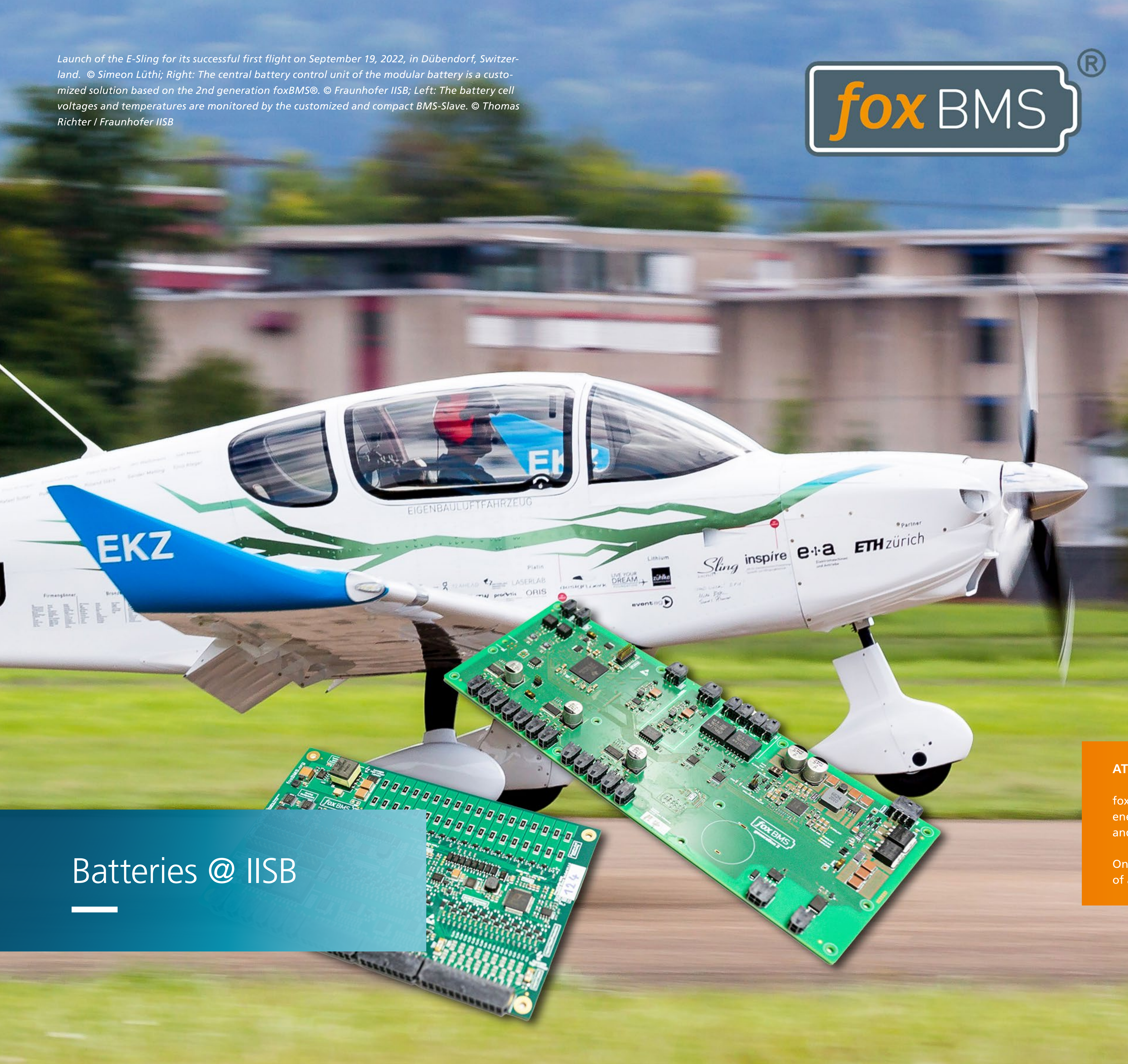
Batteries @ IISB



Launch of the E-Sling for its successful first flight on September 19, 2022, in Dübendorf, Switzerland. © Simeon Lüthi; Right: The central battery control unit of the modular battery is a customized solution based on the 2nd generation foxBMS®. © Fraunhofer IISB; Left: The battery cell voltages and temperatures are monitored by the customized and compact BMS-Slave. © Thomas Richter / Fraunhofer IISB

The development work at Fraunhofer IISB on electrical energy storage systems was originally motivated by electromobility, with stationary electrical storage systems soon being added, as they are needed in particular for the energy transition. Consequently, the Energy Systems department at the IISB released its own highly successful battery management system called foxBMS®, as well as its successor foxBMS2®. In order to meet the rapidly growing demand in more and more sectors and the need for alternative and application-oriented battery technologies, the institute now also conducts its own cell development, primarily under cost and sustainability aspects. At the same time, research on cell condition and state of health has been intensified, especially using smart electronics, which at the IISB is referred to as Cognitive Power Electronics (CPE). Against this background, the recent expansion of the application areas in e-mobility to large-scale propulsion systems for marine and aerospace applications is only logical. Today, Fraunhofer IISB is able to offer R&D services along the entire value chain for battery systems.

AT A GLANCE

foxBMS® aims to control modern and complex electrical energy storage systems, like lithium-ion battery systems and hybrid systems (e.g., fuel cell systems).

One of the highlights for us was the successful first flight of an electric E-Sling aircraft with foxBMS® on board.

Novel Li-free Al-ion Battery Pouch Cells

With the aim of reducing the drastically increasing demand for critical raw materials used in electrochemical storage, the activities in developing alternative battery materials were intensified at Fraunhofer IISB. The novel Li-free Al-ion battery, which is based on cost-effective electrode materials and a non-flammable electrolyte, achieves high charging currents of up to 10 A per gram of active mass, and good rapid charging capability with high cycle stability > 20,000. It can be regarded as a promising high-performance cell for stationary and hybrid mobile applications. In perspective, such batteries can be used for highly dynamic grid requirements, power peak booster, or industrial energy recovery.

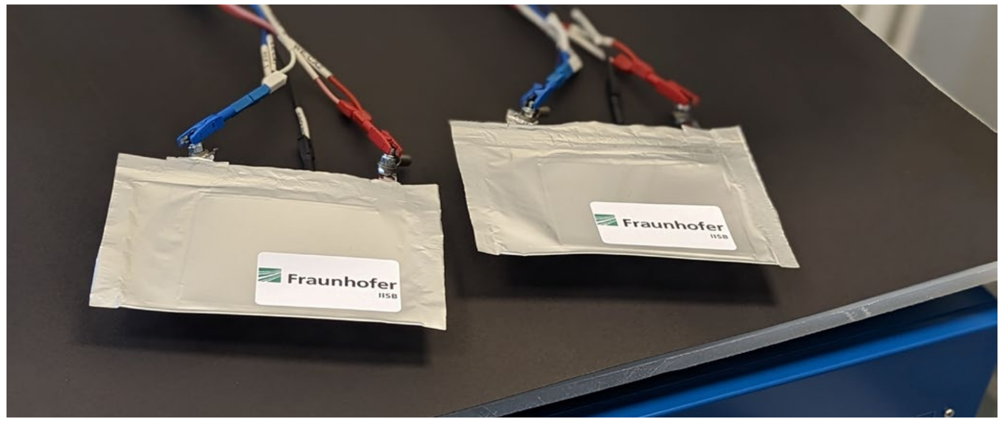
AIBs use an aluminum anode and typically a graphite cathode. The electrolytes are molten salts that are liquid at room temperature. They belong to the group of deep eutectic solvents (DES) or ionic liquids (IL). A glass fiber fleece is used as a separator. The aluminum-graphite dual-ion battery (AGDIB) can be regarded as the most mature secondary Al battery technology.

To improve the basic understanding of the AGDIB cell chemistry, self-discharge effects are currently investigated. It turns out that these processes in the AGDIB are reversible and the cell can be recharged almost completely after self-discharge. Also, the influence of contaminations within the electrolytes on the electrochemical performance was analyzed. Initial results indicate that impurities, such as iron, do not cause a reduction of specific capacities. Currently, in-operando analysis methods are developed to further elucidate structural changes in the active materials during charging and discharging processes of the battery employing powder XRD and Raman spectroscopy.

A particular challenge in the development of application-relevant AIB cell designs is the strong corrosivity of the $AlCl_3$-containing electrolytes. Long-term stable casing materials must be evaluated to enable future use of the cells in AIB battery systems. Using corrosion-resistant polymer foils, hermetically sealed pouches containing the active and passive materials of the AGDIB are manufactured with an electrode area of 4 x 6 cm^2. During cycling tests at various current densities, the electrochemical properties of the developed single-layer AIB pouch cells corroborate well to small lab test cells. More than 7000 cycles could be achieved using high charging current densities of 2.5 A per gram of active mass. As a next step, the manufacturing technology for electrodes and pouch cells need to be further improved to produce multi-layer cells with a higher power and energy density. Future post-mortem failure analysis of the pouch cells will allow for an improved cell design.

2.5 A

charging current densities per gram of active mass



Prototypes for aluminum-ion pouch cells, developed at Fraunhofer THM in Freiberg © Martin Eckert / Fraunhofer IISB

Condition Monitoring with Cognitive Power Electronics

To achieve a higher efficient and safer operation of batteries than usual, the application of artificial intelligence methods is a promising option. Keeping this in mind, Fraunhofer IISB now successively expands the functionalities of its own in-house developed battery management system called foxBMS®. The foundation for these activities was laid with the new research field Cognitive Power Electronics (CPE) a few years ago. Through CPE, the IISB's core competences in the field of power electronic systems are combined with data analytics and artificial intelligence: This combination turns power electronics into »intelligent« power electronics!

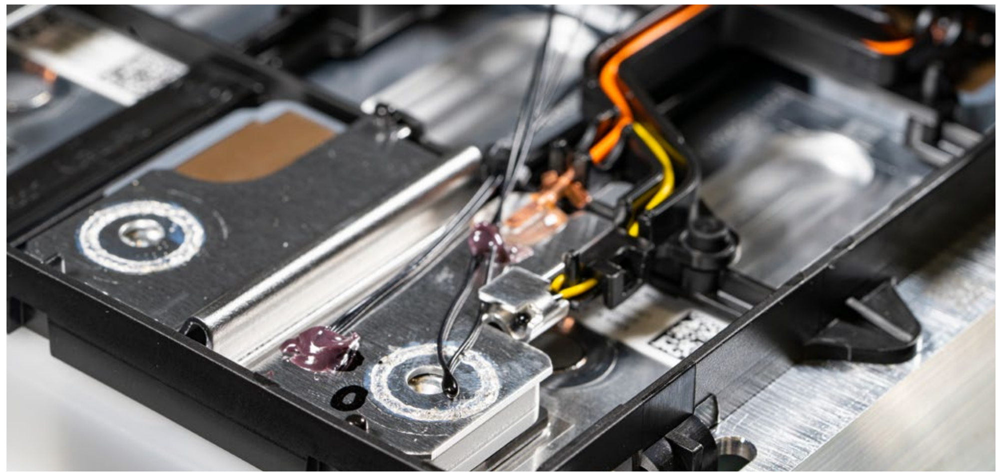
CPE records electrical parameters such as current, voltage, and their variation over time. To save costs, the integration of additional sensors into power electronic systems is avoided as much as possible. The obtained data allows the training of AI-based algorithms, e.g., for the detection of anomalies, specific faults, or the prediction of maintenance events. Depending on the application, the algorithms are used »on site« in the power electronic system (the »edge device«) and/or in a data cloud and enable the innovative use of intelligent power electronics.

As an example, in the European joint project AI4CSM (AI for Connected Shared Mobility), methods to monitor the condition of temperature sensors installed in batteries are investigated. In this context, continuous temperature measurement is the basis for fast battery charging and safe operation under changing load profiles. A failure or even a gradual degradation of the sensors would be very critical. With CPE it is possible to use data, that a battery management system already collects, to detect degradation and faults in the temperature sensors during operation.

Another example is the joint European project AI4DI (AI for Digitizing Industry). The project addressed one of the biggest challenges for the reuse of end-of-life vehicle batteries in second-life applications: The combination of batteries with heterogeneous performance characteristics in an autonomous reconfigurable battery system. For this purpose, novel data-driven algorithms were developed to accurately estimate the state parameters of individual battery cells. Based on the estimated state parameters and the user-specific load requirements, an optimal reconfiguration is performed. To ensure a safe and economically valuable second-life use, specific battery cells are dynamically activated or bypassed.

CPE

turns power electronics into »intelligent« power electronics



Experimental setup for monitoring the condition of temperature sensors installed in batteries © Thomas Richter / Fraunhofer IISB

The application of CPE makes it possible to continuously monitor the health of batteries and, beyond that, also of motors and the connecting DC networks. Furthermore, CPE detect faults at an early stage and makes sure, that the desired efficient and safe operation of battery and drive systems is achieved.

Electric Aircraft Takes Off with Fraunhofer IISB's Open Source Battery Management Platform foxBMS®

One of the highlights in the year 2022 was the successful first flight of an E-Sling aircraft with Fraunhofer IISB's own-developed foxBMS® battery management system on board.

At ETH Zürich, students of mechanical and electrical engineering equipped a 4-seat Sling-TSi Sling Aircraft with a battery electric powertrain as part of a student focus project. The E-Sling completed its first flight in Dübendorf, Switzerland, on September 19, 2022. To electrify the Sling-TSi, the combustion engine was removed and replaced by a modular battery system that stores 44 kWh of energy and achieves a range of up to 200 km. The modular battery system is monitored and controlled with the foxBMS® battery management system developed by Fraunhofer IISB. The safe and well documented architecture of foxBMS® enabled the Swiss student team to reach flight approval from the Swiss federal office of civil aviation (Bundesamt für Zivilluftfahrt).

With foxBMS®, the IISB developed a free, open and flexible research and development battery management system platform that offers a high level of functional safety and advanced edge cloud capabilities. Now available in its 2nd generation, foxBMS® allows developers to implement and validate their individual solutions and proof-of-concepts. IISB's services also cover customer-specific and certification ready adaptations of foxBMS®, for example for the automotive, marine, industrial, renewables and even the aerospace sector. The institute is continuously expanding its range of products and services for highly reliable and highly efficient power electronics for use in extreme environmental conditions, such as those encountered in the aerospace industry.

foxBMS® enabled a Swiss student team to reach flight approval from the Swiss federal office of civil aviation

Project SEABAT: Battery System Concepts for Fully Electric Vessels

Worldwide, the transportation sector is turning to electrification to reduce emissions and increase efficiency. Accordingly, the International Maritime Organization (IMO) wants to reduce annual greenhouse gas (GHG) emissions from maritime transport by 50 % by 2050 compared to 2008, and even pursues efforts towards phasing them out entirely. Electrification is one of the key solutions to reach this target. In this context, the european consortial project SEABAT is developing a modular full electric maritime hybrid battery concept to substantially reduce the costs of large waterborne battery systems for over 1 MWh. Within SEABAT, Fraunhofer IISB is one of the fifteen partners from eight different EU and associated countries.

The new full-electric maritime hybrid concept is essentially based on a combination of modular high-energy batteries and high-power batteries, novel converter concepts and production technology solutions derived from the automotive sector. The modular approach will reduce component costs (battery, converter) so that unique ship designs can profit from economies of scale by using standardized low-cost modular components. The concept is suitable for future battery generations and high-power components that may have higher power densities or are based on different chemistries.

The expected results of project SEABAT are an optimal full-electric hybrid modular solution, a minimized battery footprint and a reduced oversizing from up to 10 times down to 2 times max. Further milestones are the validation as a 300 kWh system including full battery system test at TRL (Technology Readiness Level) 5, and a virtual validation of a battery system with a storage capacity of 1 MWh and above by using 300 kWh system P-HiL (Power Hardware-in-the-Loop) tests. Additionally, a roadmap for type approval and a strategy towards standardization for ferries (among other types of vessels) and short sea shipping will be developed. The end results are savings of approximately 35-50 % lower total cost of ownership (TCO) of maritime battery systems, including 15-30 % lower CAPEX (capital expenditures) investment, 50 % lower costs of integration at the shipyard and a 5 % investment cost recuperation after the useful time of life in the vessel.

The SEABAT consortium unites all the necessary expertise for developing the hybrid topology and implementing it in the industry. Fraunhofer IISB focuses in particular on the electrical architecture of the battery system, the thermal sensing and modelling of the battery, and the development of advanced algorithms for aging and rest value prediction to optimize for TCO.

In addition to the results of the project SEABAT, the IISB successfully received funding from the European Commission for a follow-up project called FLEXSHIP. The institute will extend its technology portfolio in the maritime domain through the development of a maritime battery management system (BMS) based on the IISB's own open source BMS platform foxBMS®. The overall goal of FLEXSHIP is to develop and validate safe and reliable, flexible, modular, and scalable solutions for electrification in the marine industry. First of all, this includes the reliable design and the development of modular battery packs as well as the safe on-board integration including the battery system and its associated electrical distribution grid into the vessel's existing power grid. Furthermore, the design of the energy management system (EMS) is optimized with focus on maximum operational flexibility and energy efficiency of both full-electric and hybrid solution. Last but not least, smart control improves the life of the battery system and critical power electronics components.

In FLEXSHIP, this is demonstrated on two vessels. One is an all-electric vessel that will operate on routes from 50 to 100 nmi (90 – 185 km), and the other is an electric-hybrid vessel that will operate on routes from 100 to 300 nmi (185 – 555 km). These different ships and operation conditions place different demands on the battery system, energy and power management, and ship integration in general. All this aspects are addressed in the project's design, development, and testing. At the end of FLEXSHIP, the project technology will reach TRL 7.

50% reduction of greenhouse gas emissions from maritime transport by 2050

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Fraunhofer IISB: One institute, many opportunities
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IISB Science Stars

Energy Award 2022 of the Energie Campus Nürnberg (EnCN) for Master Thesis at the LEE

Markus Meindl, a master's student in the Electrical Engineering - Electronics - Information Technology (EEI) course of study at FAU Erlangen-Nürnberg, has been awarded the EnCN Energy Prize 2022 for his master's thesis.

The thesis is entitled «Reverse Engineering of the Hydrogen System of a Commercial Fuel Cell Vehicle« and was written at the Chair of Power Electronics (LEE). The holder of the LEE chair is Prof. Martin März, who is also head of the Power Electronic Systems Division at Fraunhofer IISB. The award was presented on Dec. 16, 2022, by Dr. Michael Fraas, appointed city council member and business and science officer of the city of Nuremberg, in his role as board member of EnCN e.V. A total of nine students from FAU Erlangen-Nürnberg and Nuremberg Institute of Technology Georg Simon Ohm (TH Nuremberg) received an EnCN Energy Award 2022 for their outstanding contributions to energy research and the Energiewende (energy transition). The subject matter of the award-winning theses includes new energy technologies, efficient energy use and efficiency enhancement, as well as the development of realizable applications.

As part of his master's thesis, Markus Meindl analyzed all non-destructively accessible components of the hydrogen system of a commercial fuel cell vehicle. This includes the analysis and communication with the software-based vehicle interface as well as the extraction of operating parameters. In addition, Markus Meindl was able to successfully operate the fuel cell system outside the vehicle in a hydrogen laboratory at the IISB for more detailed investigations. Particularly noteworthy is the comprehensive documentation of the knowledge gained about the individual components as well as the overall system, including the software controls. This valuable knowledge base now serves as a starting point for further research and development activities for sustainable mobility solutions.

Dr. Michael Fraas (left), appointed City Councilor and Economics and Science Officer of the City of Nuremberg, presents the certificate for the Energy Award 2022 of the Energie Campus Nürnberg (EnCN) to Markus Meindl, Master's student in the EEI study course at FAU Erlangen-Nürnberg © Kristin Zeug / EnCN e.V.

Fraunhofer IISB Award for Research and Development 2022

With the Research and Development Award, presented by IISB director Prof. Jörg Schulze, Fraunhofer IISB honors outstanding research and development work by its employees. This year's prize went to Dr. Ulrike Wunderwald, Dr. Maximilian Wassner, Dr. Franziska Jach, and Mirko Gerlach from the Battery Materials Group at Fraunhofer IISB.

The team, led by Dr. Ulrike Wunderwald, succeeded in substantially increasing the energy density, the number of charging cycles, and the charging efficiency of low-cost aluminum-ion batteries (AIB). Aluminum-ion batteries offer a great development potential as a high-performance, safe, cost-effective, and sustainable alternative to the established lithium battery technology.

Two of the award winners, Dr. Franziska Jach and Mirko Gerlach, received the award on behalf of the team on site at Fraunhofer IISB during our Christmas party.

Mirko Gerlach and Dr. Franziska Jach with the Fraunhofer IISB Research and Development Award 2022 © Elisabeth Iglhaut / Fraunhofer IISB

First Place for Team Evolonic at the New Flying Competition NFC 2022

The student research group Evolonic, which cooperates closely with the IISB, won the first prize at the international flight contest New Flying Competition NFC 2022. The NFC 2022 took place from September 22 to 26 in Hamburg. Team Evolonic was already able to beat the international competition at the last NFC in 2020.

The interdisciplinary group was awarded for the development of the «Night Fury V3 eVTOL UAV« aircraft. Night Fury V3 showed to be the most reliable and efficient aircraft in the competition.

Evolonic is an interdisciplinary project team at the University of Erlangen-Nuremberg FAU and is headquartered at Fraunhofer IISB, where it is supported with laboratory equipment and technical expertise. Among others, the team is developing innovative electric air vehicles that take off and land vertically, so-called »eVTOLs«.

evolonic.de

Winner at the New Flying Competition NFC 2022 in Hamburg: Team Evolonic with its newly developed eVTOL Night Fury V3 © Adrian Sauer / Evolonic

Prof. Roland Nagy is Awarded Funding in the BMBF »Quantum Futur« Program

Prof. Roland Nagy, junior professor at the Chair of Electron Devices (LEB) at FAU Erlangen-Nürnberg, succeeded with his project «SiC Quantum Memory Nodes for a Distributed Quantum Computing Network« in the funding program »Quantum Futur« of the German Federal Ministry of Education and Research (BMBF). The funding serves to establish an independent junior research group through which Roland Nagy realizes new interdisciplinary research approaches in quantum technology at the LEB and the IISB.

In his research project, Prof. Roland Nagy focuses on the realization of a quantum computer network based on solid-state quantum devices in the semiconductor material silicon carbide (SiC). The core problem of all current approaches for quantum computers is the scaling of the required qubits, because with each additional qubit the technical effort increases disproportionately. Instead of a single, large quantum computer, Nagy's approach relies on the networking of several smaller quantum computers. In such a quantum network, the number of available qubits could be scaled by simply adding further quantum computers.

The novel quantum devices required for this purpose are designed and manufactured based on silicon carbide (SiC). Major advantages of the wide bandgap semiconductor material SiC for quantum electronics are its comparatively good technological handling combined with excellent physical properties and compatibility with established microelectronics. In this context, Fraunhofer IISB provides its comprehensive expertise for the manufacturing and processing of WBG semiconductor materials and integrated devices, especially those based on SiC.

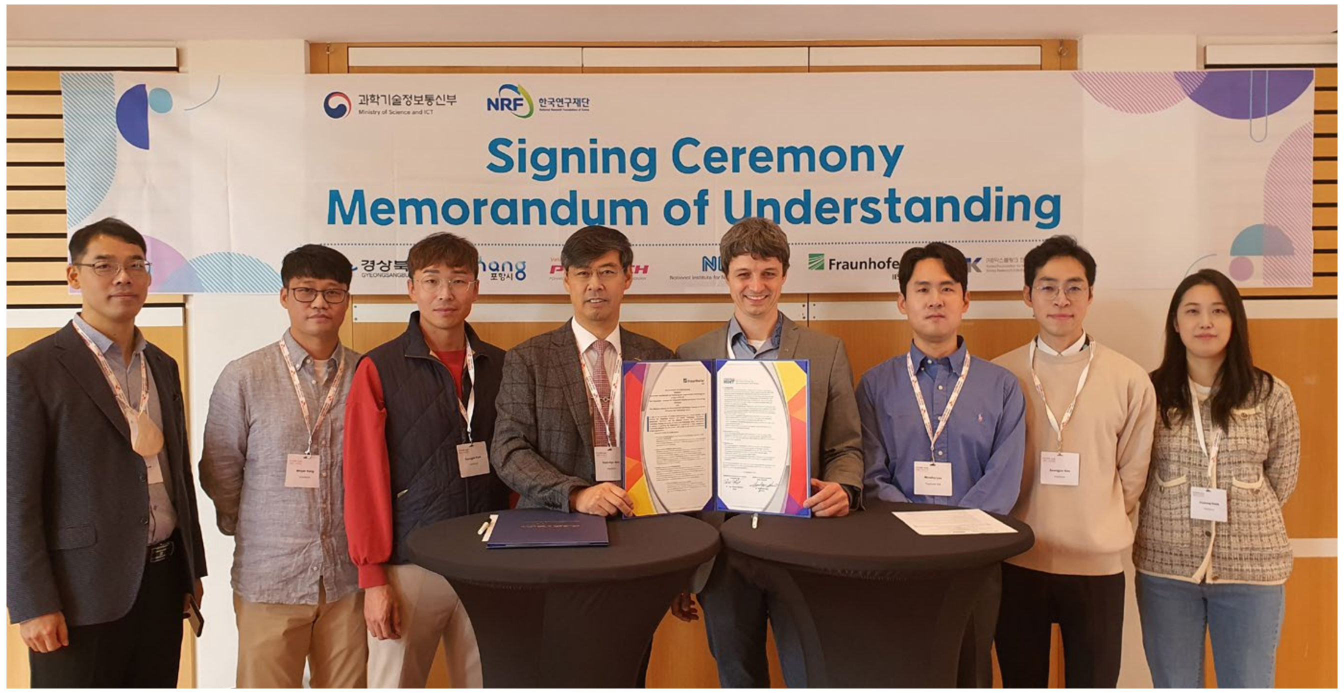
The establishment of a research group for SiC quantum devices at the Chair of Electron Devices is an important milestone for Fraunhofer IISB on the way to industry-compatible quantum computers and another example of the successful cooperation between our institute and FAU.

Prof. Roland Nagy, Junior Professor at the Chair of Electron Devices (LEB) at FAU, impressed with his project »SiC Quantum Memory Nodes for a Distributed Quantum Computing Network« in the funding program »Quantum Futur« of the German Federal Ministry of Education and Research (BMBF) © Roland Nagy / private

Memorandum of Understanding Between Fraunhofer IISB and National Institute for Nanotechnologies (NINT) Pohang (Korea)

At the world's largest silicon carbide (SiC) conference, the »International Conference for Silicon Carbide and Related Materials (ICSCRM)«, Fraunhofer IISB again demonstrated its extensive expertise on SiC with technical presentations and an exhibition booth. The conference is regularly used as a platform for intensive discussions and negotiations by project partners and potential customers of the IISB. Especially pleasing is the continued high demand for material development, material characterization, process services, and device development.

Following the successful completion of a six-year development project with the National Institute for Nanotechnologies (NINT) in Pohang, Korea, a «Memorandum of Understanding« was signed at the conference for the continuation of cooperation for a further five years. The aim of the planned work, with a volume of around 700,000 euros, is the scientific investigation and technological expansion of IISB's SiC CMOS technology for integrated circuits and sensors in harsh environmental conditions.



Signing of the »Memorandum of Understanding« for the continuation of the cooperation between NINT and Fraunhofer IISB by Prof. Hoon-Kyu Shin (NINT, 4th from left) and Dr. Tobias Erlbacher (IISB, 4th from right) © NINT / Pohang University of Science and Technology

Prof. Vincent Lorentz Takes over the Chair of Electronics of Electrical Energy Storage at the University of Bayreuth

Prof. Vincent Lorentz, Head of the Intelligent Energy Systems Department at Fraunhofer IISB, has accepted an invitation to become a Full Professor at the University of Bayreuth, where he will hold the Chair of Electronics of Electrical Energy Storage at the Bavarian Center for Battery Technology (BayBatt).

The French-born engineer earned his first university degree at the Télécom Physique Engineering College in Strasbourg. This was followed in the same year by a master's degree in microelectronics at the University of Strasbourg. Lorentz then pursued his binational doctorate in electrical engineering at the Friedrich-Alexander Universität Erlangen-Nürnberg (FAU) and the University of Strasbourg, completing it in 2008. He started working on electronics for lithium-ion batteries at Fraunhofer IISB in Erlangen in 2003 and initiated the open source battery management system platform foxBMS® in 2015. In 2013, Vincent Lorentz earned an additional Master's degree in Business Administration and General Management at FAU Erlangen-Nürnberg.

Now, Vincent Lorentz wants to share his knowledge from almost 20 years of practical experience in the field of electronics and battery systems with the next generation of scientists and also make it easier for his students to later step into the professional world. However, Vincent Lorentz is not leaving Fraunhofer IISB altogether. He will continue to work one day a week for the Fraunhofer-Gesellschaft at Fraunhofer IISB in Erlangen and will promote collaboration with the University of Bayreuth.

Prof. Vincent Lorentz, Head of the Intelligent Energy Systems Department at Fraunhofer IISB, has accepted an invitation to become Full Professor of Electronics of Electrical Energy Storage at the University of Bayreuth © Anja Grabinger / Fraunhofer IISB

Christian Miersch, PhD Student at Fraunhofer IISB, Receives Best Student Presentation Award at 2022 GaN Marathon

The Best Student Presentation Award was presented to Christian Miersch for his talk «Low Damage Etching of Nitride Semiconductors« at the GaN Marathon in Venice, June 19-22, 2022. Christian Miersch is a PhD student in Fraunhofer IISB's Spectroscopy and Test Devices Group within our Materials Department. The group is located in the Fraunhofer Technology Center High Performance Materials THM in Freiberg, a research and transfer platform of Fraunhofer IKTS and Fraunhofer IISB.

Miersch explained an approach to optimize the ohmic contact on AlGaN / GaN heterostructure with reference to the resistance and annealing temperature. This has been achieved by recess etching into the AlGaN barrier of HEMT (high electron mobility transistor) structures. The main goals of reducing contamination, thermal stress, and degradation of the substrate material, as well as a low surface roughness, are reached by a low damage etching technology.

PhD student Christian Miersch presents the certificate for the Best Student Presentation Award of 2022 GaN Marathon at the THM in the clean room laboratory © Fraunhofer IISB

Hans-Wilhelm Renkhoff Foundation Honors Bachelor's Thesis by Michelle Fribance, Student Assistant at Fraunhofer IISB

Michelle Fribance, student assistant in the Data Analytics group at the IISB, was honored by the Hans-Wilhelm Renkhoff Foundation for her bachelor's thesis. In her thesis «Investigation of Surrogate Modeling to Optimize the Stability of DC Networks«, Michelle Fribance uses artificial intelligence to address the challenge of stability in complex microgrid networks.

Stability optimization of low-voltage DC (LVDC) microgrid networks is becoming increasingly significant in the development and utilization of efficient and sustainable energy supply systems worldwide. Grid stability must be established at the time of grid setup, and continuously monitored and maintained throughout grid usage. Artificial Intelligence can make a significant contribution to further increase the efficiency, stability, and general advantages of DC smart grids.

Every year, the Hans-Wilhelm Renkhoff Foundation honors particularly outstanding final theses from the Engineering and Economics Departments of the Hochschule für angewandte Wissenschaften Würzburg-Schweinfurt.

Michelle Fribance, student assistant in the Data Analytics group at IISB, was honored by the Hans-Wilhelm Renkhoff Foundation for her bachelor's thesis »Investigation of Surrogate Modeling to Optimize the Stability of DC Networks« © Michelle Fribance / private

IEEE Honors Paper by PhD Student at Fraunhofer IISB, Stefan Ehrlich, with Transactions on Power Electronics (TPEL) First Place Prize Paper Award 2021

Stefan Ehrlich, PhD student at Fraunhofer IISB, was honored with the outstanding Transactions on Power Electronics (TPEL) First Place Prize Paper Award 2021. Together with the co-authors Dr. Hans Rossmanith, Marco Sauer, Dr. Christopher Joffe, and Prof. Martin März, Stefan Ehrlich published the paper «Fast Numerical Power Loss Calculation for High-Frequency Litz Wires«.

It was announced at this years' IEEE Energy Conversion Congress & Expo (ECCE, from October 9-13, 2022) that the paper was selected for aFirst Place Prize Paper Award 2021. Each year, the IEEE Power Electronics Society recognizes the papers deemed best among those published in the IEEE Transactions on Power Electronics during the preceding calendar year - in 2021, that number was 1233 papers.

In the paper, the authors present a fast numerical calculation method of realistic power losses for high-frequency litz wires. Explicitly, the imperfect structure of litz wires is considered when calculating losses due to an excitation current (skin losses) and external magnetic fields (proximity losses). This method allows to select a suitable litz wire for a specific application or to design a litz wire considering realistic twisting structures. Calculations of litz wires with more than 1000 strands were performed on a personal computer and have been validated by measurements up to 10 MHz.

Stefan Ehrlich, winner of the Transactions on Power Electronics (TPEL) First Place Prize Paper Award 2021. The award was announced at the IEEE Energy Conversion Congress & Expo 2022 © Elisabeth Iglhaut / Fraunhofer IISB

IISB Science Stars

MINT (STEM) Project Week «Crystals« at the Montessori School Herzogenaurach

The relationship between sparkling crystals and an ordinary smartphone is not obvious at first glance. But without consciously noticing it, we are surrounded by crystals in our everyday lives: Digital mass media, LED lighting, electric cars - even the Internet wouldn't exist without crystals.

But what makes these materials so special and how are they made? To find out, the pupils of the fifth and sixth grades of the Montessori School Herzogenaurach were allowed to step into the role of researchers themselves. Equipped with lab coats, protective goggles, and gloves, the students grew their own alum crystals. Dr. Christian Reimann, crystal expert and head of the Silicon and Special Materials group at Fraunhofer IISB, provided them with expert knowledge and laboratory equipment.

The main objective of the project week was to promote young talents in the context of MINT (STEM) lessons. «MINT« stands for the subjects mathematics, computer science, natural sciences, and technology. The workshop on crystal growth marked the beginning of a school partnership between Fraunhofer IISB and the Montessori School in Herzogenaurach. It is planned to sustainably promote students' enthusiasm for MINT subjects through further cooperation.

The project week »Crystals« is the kick-off for a long-term cooperation between the Montessori School Herzogenaurach and Fraunhofer IISB to promote MINT (STEM) subjects. From left to right: Michael Lang, mener of Fraunhofer IISB's Silicon and Special Materials group, Sabine Kliem and Sandra Frankenberg, fifth and sixth grade teaching team, and Dr. Christian Reimann, head of the Silicon and Special Materials group © Amelie Schardt / Fraunhofer IISB

From Semiconductor Materials to Electric Flying: Fraunhofer IISB at PCIM Europe 2022

The PCIM Europe is the leading international exhibition and conference for power electronics, intelligent drive technology, renewable energies, and energy management. After a break, PCIM Europe opened its doors again at the Nuremberg exhibition center from May 10-12, 2022. Fraunhofer IISB presented the broad spectrum of its activities from semiconductor materials and devices to power electronic systems.

The IISB's special highlights were wide-bandgap (WBG) semiconductor materials and devices, particularly silicon carbide based power devices, reliable power modules for extreme demands, like high-temperature, cryogenic or corrosive environments, and high-performance power electronics with highest efficiency and power density, especially for aviation and automotive applications. Also at the booth was the student group Evolonic, which has already won international awards and cooperates closely with the IISB. Evolonic presented its latest design, the electric drone «Light Fury«. The visitors to the exhibition greatly appreciated the opportunity to talk to experts in person and to make new contacts. The IISB booth offered the best opportunity for this, with exhibits and presentations attracting great interest and leading to intensive exchanges with IISB staff.

The PCIM conference, which traditionally takes place at the same time every year, once again demonstrated the close links between industry and science within the framework of PCIM Europe. In top-class lectures on current research and development topics, the participants expanded their knowledge and were able to discuss scientific issues. The IISB demonstrated its comprehensive scientific expertise in technical contributions, e.g., on technological questions in packaging or various aspects of intelligent power electronics.

PCIM Europe 2022 was again a great success for the entire IISB team.

The team of Fraunhofer IISB presented the latest developments in the field of WBG semiconductor materials and WBG devices, high-reliability power electronics modules and high-performance automotive electronics at its booth at PCIM Europe 2022 in Nuremberg © Kurt Fuchs / Fraunhofer IISB

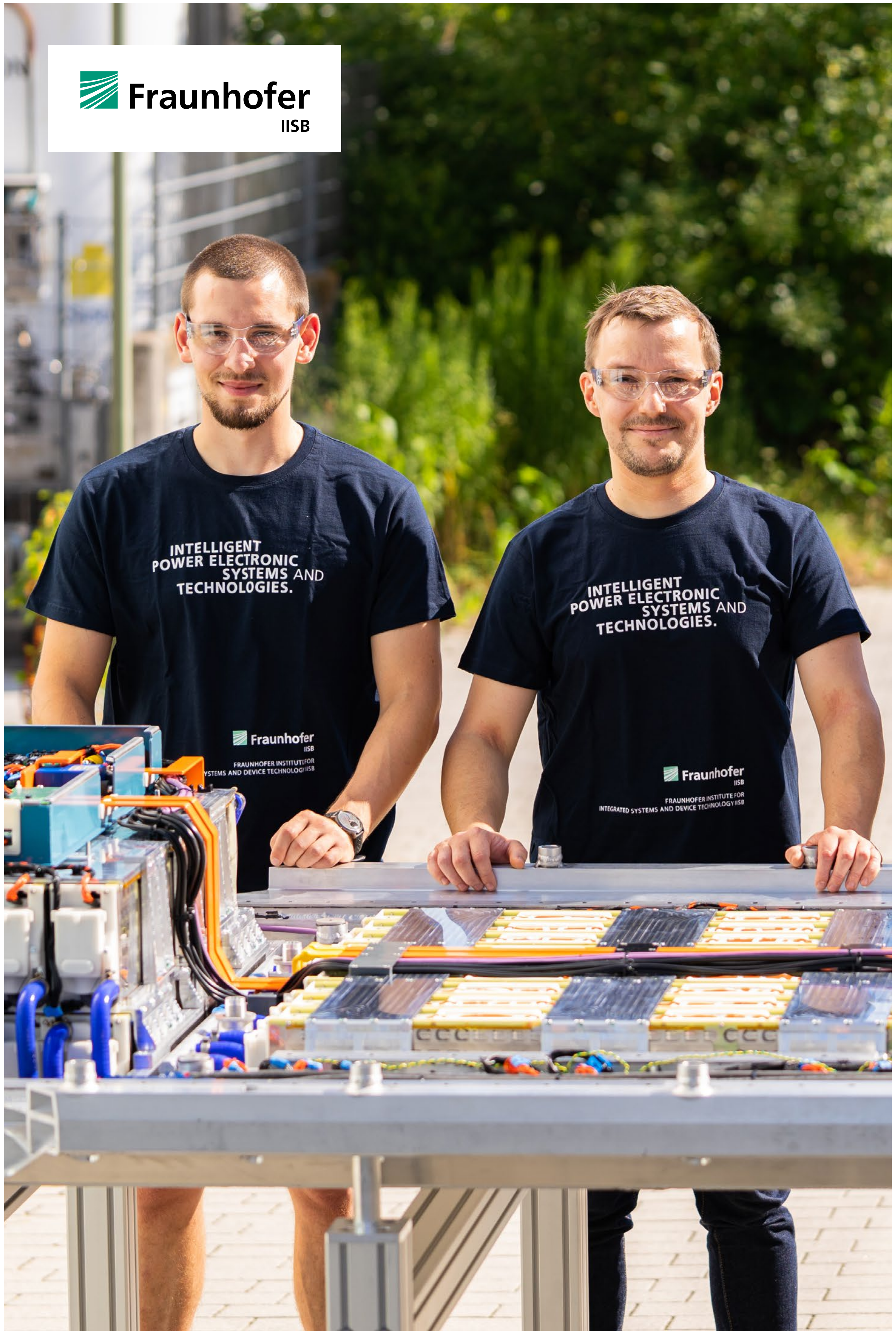
IISB Science Stars

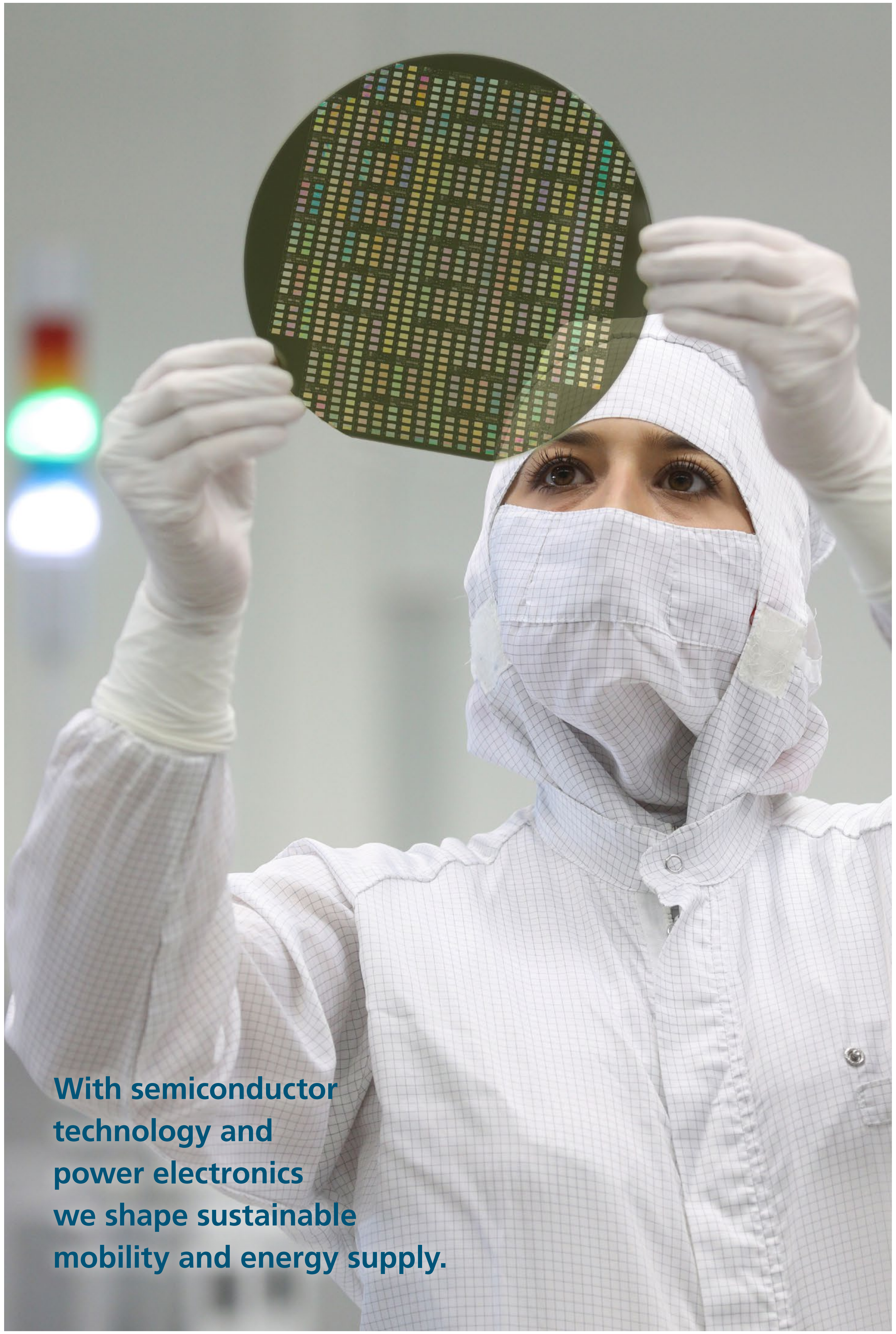
Paper on Historic Development of Crystal Growth and Epitaxy by Dr. Jochen Friedrich and Prof. Georg Müller Honored as Top Downloaded Article by Wiley Publisher

Dr. Jochen Friedrich is the head of the Materials Department at Fraunhofer IISB and co-author of the article «An Important Center of Crystal Growth and Epitaxy: Major Scientific Results and Technological Solutions of the Last Four Decades«. This paper, published in Crystal Research & Technology, is among the top 10 most downloaded articles published between January 1, 2019 and December 31, 2020.

The article describes the historic development of the Erlangen Crystal Growth Laboratory CGL. The CGL was founded by Prof. Georg Müller in 1974 at the chair of Materials of Electrical Engineering (Department of Material Science) of the FAU. Later, it became today's Materials Department of the Fraunhofer IISB. In the paper, essential developments and scientific achievements in the various fields of crystal growth and epitaxy are presented from the early period until now – an important piece of technology history.

Dr. Jochen Friedrich, Head of the Materials Department at Fraunhofer IISB, and Prof. Georg Müller, founder of the Erlangen Crystal Growth Laboratory CGL © Elisabeth Iglhaut / Fraunhofer IISB





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