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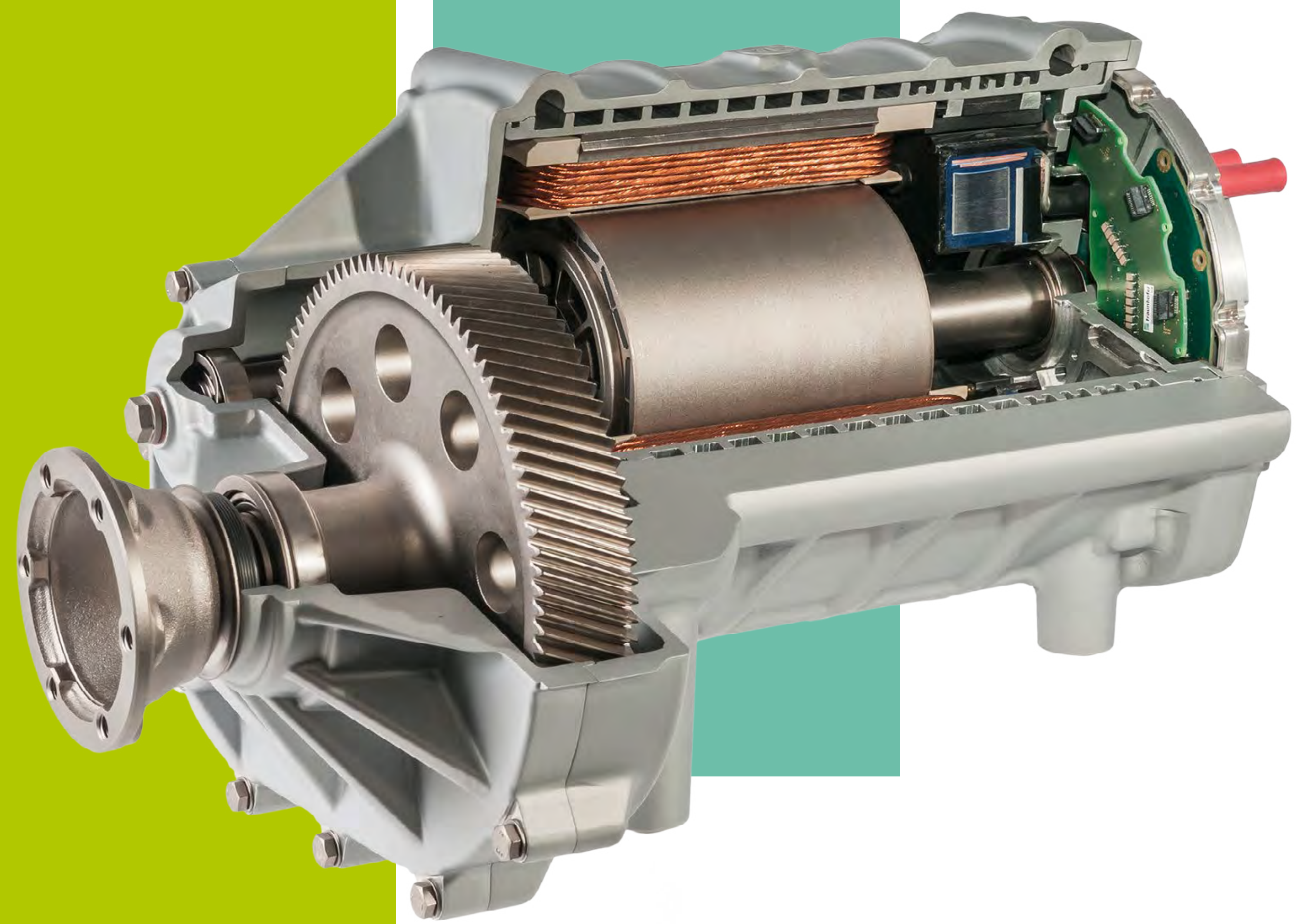
FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

Content

Annual Report 2016

Fraunhofer Institute for Integrated Systems and Device Technology IISB



ANNUAL REPORT 2016

Content

Imprint

Published by:
Fraunhofer-Institut für Integrierte Systeme und Bauelementetechnologie IISB
Schottkystrasse 10
91058 Erlangen, Germany

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Printed by:
Frank UG Grafik – Druck – Werbung, Höchstadt

Cover Photo:
Multiphase drivetrain system with Smart Stator Teeth (SST).
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ACHIEVEMENTS AND RESULTS
ANNUAL REPORT 2016

Content

FRAUNHOFER INSTITUTE FOR

INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

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PREFACE

1 *Prof. Dr. rer. nat. Lothar Frey, director of Fraunhofer IISB, during the groundbreaking ceremony for the next extension building of the institute. © K. Fuchs / Fraunhofer IISB*

Content

Growth once more characterized the development of Fraunhofer IISB in the past year. This, includes the commencement of construction work for our next institute building, new research setups, and strengthening the ties to our partner universities.

In June 2016, the foundation stone for our second extension building in Erlangen was set. The new labs will be available from summer 2018 for enhanced R&D on highly efficient power electronic systems in power grids, energy storages, industrial drives, electric cars and aviation. The premises will also be used as a demonstration and testing platform for a sustainable energy infrastructure on an industrial scale.

Since September 2016, our deputy director Professor Martin März is heading the new Chair of Energy Electronics (LEE), at the Friedrich-Alexander-Universität Erlangen-Nürnberg, our close partner, focusing on power electronics for electrical energy supply in mobile and stationary applications. Also, Professor Johannes Heitmann from our partner TU Bergakademie Freiberg joined the IISB branch lab THM in Freiberg by leading our THM working group on material synthesis.

Our newly established large cold storage from the Bavarian energy project SEEDs and our new LOHC storage container solution combined with an efficient DC grid from the Leistungszentrum Elektroniksysteme visibly express our scientific progress in energy research. From the economic viewpoint, Fraunhofer IISB has increased its annual budget to 24 million Euros with a staff of more than 260.

Fraunhofer IISB combines both proven traditional and emerging paths. As a long-time contributor to the International Conference on Simulation of Semiconductor Processes and Devices (SISPAD), we had the honor of organizing this event on its 20th anniversary in 2016. Also the IISB Symposium on Ion Implantation, which was held on the occasion of the 75th birthday of our former director, Professor Heiner Ryssel, focused on classical IISB topics.

For entering new ways of R&D cooperation, IISB launched its brandnew flexible battery management system foxBMS in a free and open-source manner, in order to establish a vivid industrial and academic network of battery electronics research.These are just examples of a very long 2016.

I would like to thank all my colleagues at IISB for their successful work in the past year. I also thank our partners in industry and our funding authorities, especially the Bavarian Ministry of Economic Affairs and Media, Energy and Technology, and the Federal Ministry of Education and Research (BMBF) for their support.

Prof. Dr. Lothar Frey Lothar Frey Erlangen, Februar 2017

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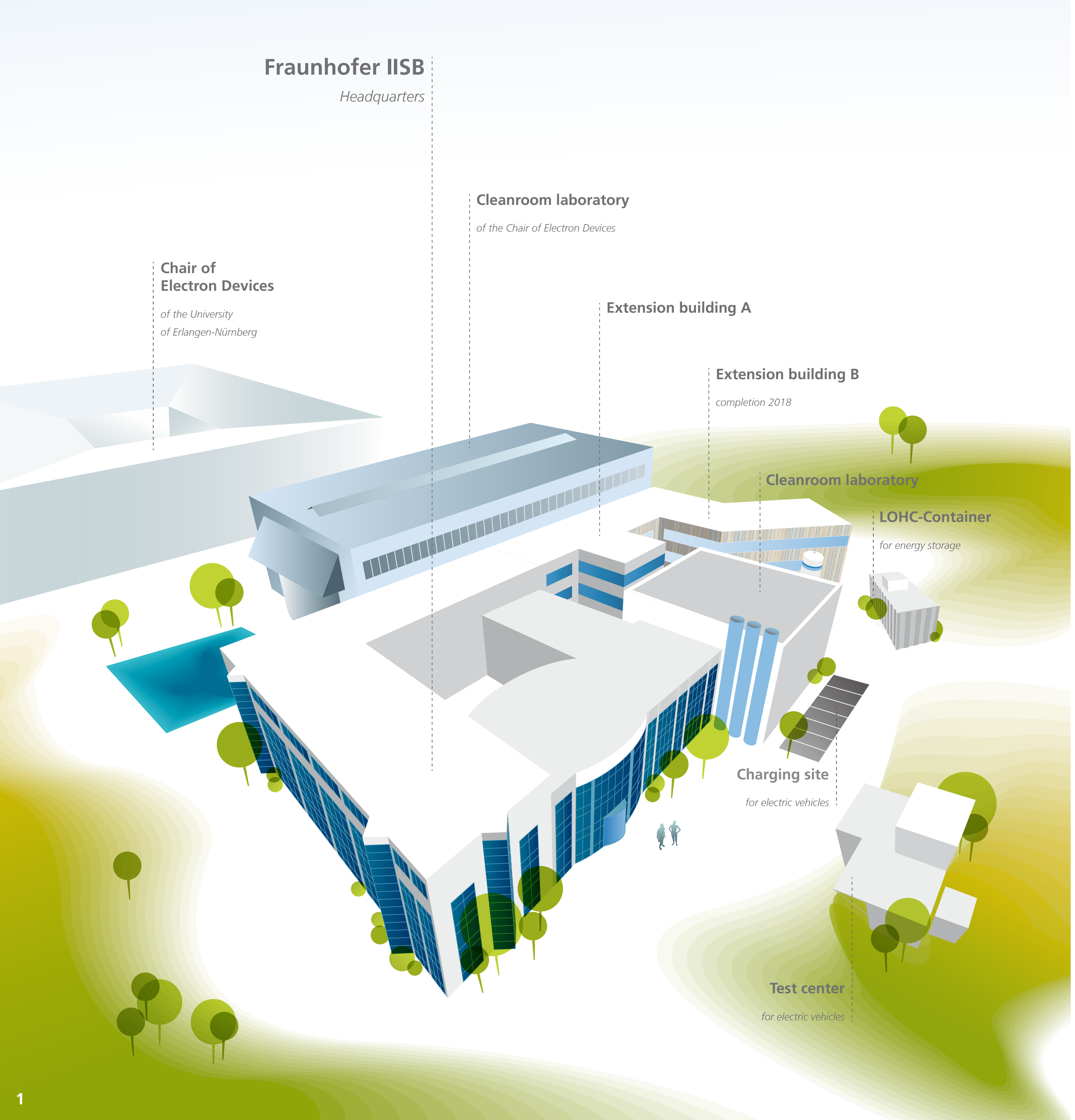

Content

Profile

The Fraunhofer Institute for Integrated Systems and Device Technology IISB conducts applied research and development in the field of electronic systems for application in, e.g., electric vehicles or energy technology. In this connection, the IISB extensively covers the complete value chain from basic materials to entire power electronic systems. With its two business areas, semiconductors and power electronics, the institute provides innovation and solutions in materials development, semiconductor technology and manufacturing, devices and modules, as well as in system development for vehicle power electronics, energy electronics, and energy infrastructures. This is supplemented by broad activities in reliability, simulation, characterization, and metrology.

The headquarters of the IISB is located in Erlangen, Germany. The institute has branches in Nuremberg, Freiberg and Chemnitz. As one of the 69 institutes of the Fraunhofer-Gesellschaft, the IISB does contract research for industry and public authorities. Moreover, it closely cooperates with the University of Erlangen-Nürnberg. The IISB has more than 250 employees plus numerous students working as research assistants. The institute is equipped with high-class laboratories, such as a test center for electric cars and an application center for DC grid technology. Together with the University, it operates 1500 m² of cleanroom area for semiconductor technology on silicon and silicon carbide.

The IISB is a close partner of national and international industry. Its main objective is to provide excellent research to its customers and to set technological benchmarks as one of the leading research institutions in electronic systems. Cooperation includes research and development projects, prototyping, consultancy, licensing, and studies.

History

The Fraunhofer Institute for Integrated Systems and Device Technology IISB in Erlangen is an important center of applied R&D for 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 sibling 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 his retirement in 2008, Prof. Heiner Ryssel was the head of the IISB. Since 2008 Prof. Lothar Frey has been director of the institute. From the beginning, the institute has been closely cooperating with the University of Erlangen-Nürnberg (FAU). In 2015, IISB together with Fraunhofer IIS and FAU founded the "Leistungszentrum Elektroniksysteme" (LZE).

1 *Fraunhofer IISB in Erlangen*
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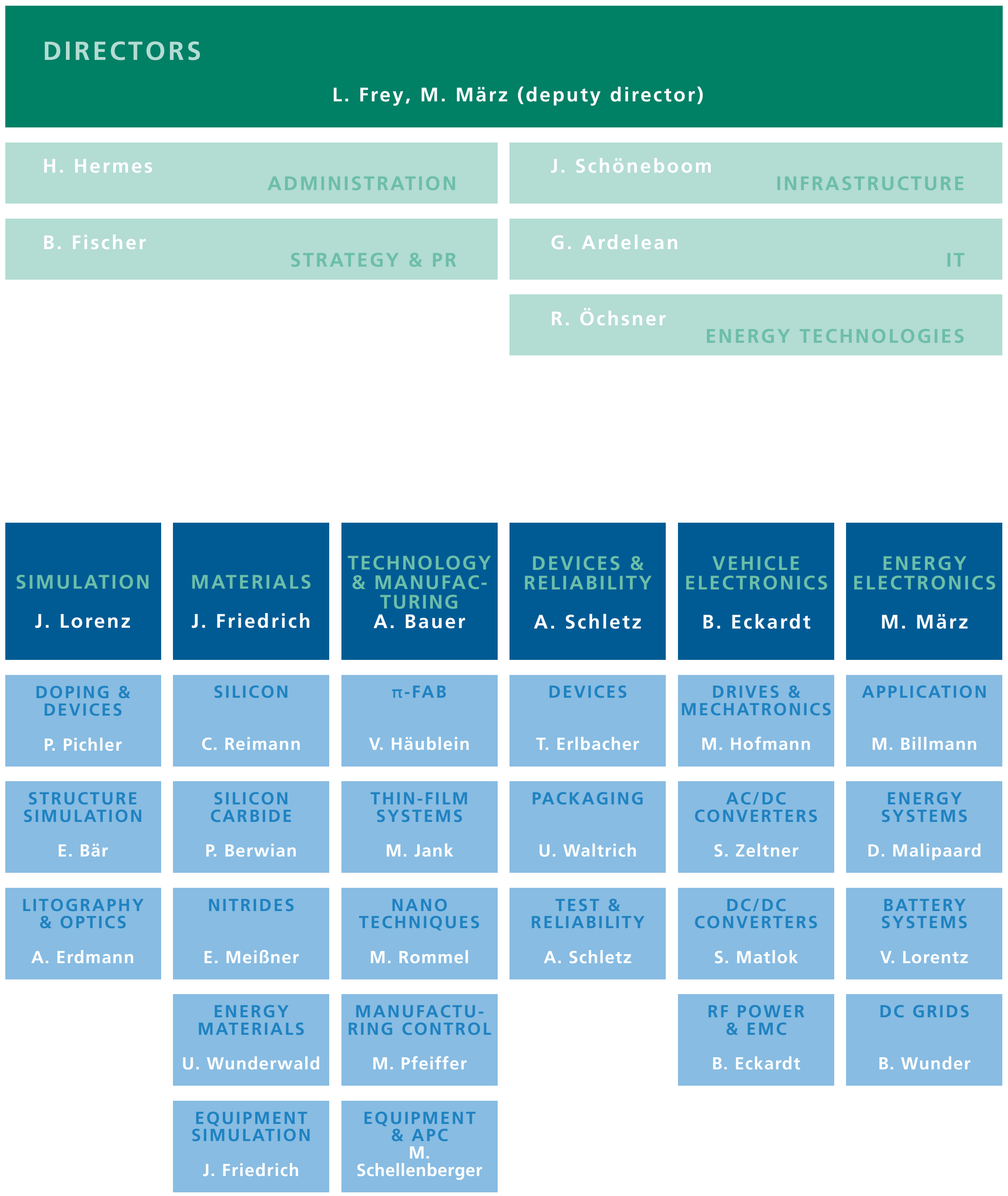
FRAUNHOFER IISB AT A GLANCE



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1 *Organization of Fraunhofer IISB 2016: The R&D activities of the IISB cover the complete value chain for electronic systems, from basic materials to devices and modules up to application, with power electronics as a continuous backbone of the institute.*
© Fraunhofer IISB

Research Areas and Organization

Materials

Together with its industrial partners, Fraunhofer IISB develops equipment and processes for the production of crystalline bulk and layer materials for electronics. This comprises silicon, wide-band-gap semiconductors (e.g., silicon carbide, gallium nitride), materials for optical applications, detectors, and energy technology.

Technology & Manufacturing

The IISB operates extensive semiconductor technology lines, cleanroom infrastructure, and metrology on silicon and silicon carbide for the development of custom-tailored processes and prototype devices in power electronics and microelectronics. Furthermore, IISB works on nanotechniques, particle and thin-film systems. Manufacturing aspects such as process and quality control, equipment optimization, automation, and efficiency are also considered.

Simulation

The research activities of the IISB and its customers are supported by extensive competencies in simulation, modeling, and software development in the fields of, e.g., process and device simulation in semiconductor technology, crystal growth simulation, or thermal simulation for designing power electronic systems.

Devices

The institute develops customer-specific active and passive electron devices on silicon and silicon carbide for application in power electronics, microelectronics, and sensors. This includes novel device concepts and the development of cost-efficient processes tailored towards implementation and realization of customized products.

Packaging & Reliability

New methods and materials for packaging, cooling, lifetime and failure analysis, and reliability play an important role. At IISB, packaging and reliability research are closely combined with each other. By analyzing the exact failure mechanisms after lifetime and reliability tests, the joining technologies, materials, concepts and mechanical designs are further improved. On the other hand, new packaging designs have a direct impact on the test methodologies and accelerating factors.

FRAUNHOFER IISB AT A GLANCE

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1 *In addition to its headquarters in Erlangen, Fraunhofer IISB has two branch labs in Nuremberg and one in Freiberg, as well as a laboratory for industrial power electronics in Chemnitz. © K. Fuchs / Fraunhofer / Fraunhofer IISB*

Vehicle Electronics

Efficient, compact, and robust power electronic systems for all kind of vehicles are in the focus of the IISB. This comprises electric drives, battery systems, and the charging infrastructure of electric cars. Benchmark values for energy efficiency and power density are regularly set for the work of the IISB. Further fields of application are shipping and aviation.

Energy Electronics

Power electronic systems are indispensable for realizing a modern energy supply and the transition to predominantly regenerative energy sources. The developments of the IISB contribute to this on all levels of the power grid through, e.g., electronic components for HV DC transport, local DC micro grids or the integration of electrical storages and regenerative sources in the power grid.

Energy Infrastructure Technologies

The goal of this field of activity is the coupling of electric and non-electric energy and the development of the necessary interfaces for implementing a sustainable energy infrastructure, especially for industry-size environments.

Locations

Headquarters of Fraunhofer IISB Erlangen

Schottkystrasse 10, 91058 Erlangen

The headquarters of Fraunhofer IISB in Erlangen are located close to the University of Erlangen-Nürnberg. About 7000 m² of laboratories and office area allow research and development on a broad range of power electronics, semiconductor technology, and materials development. A test center for electric cars and 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, are part of the available infrastructure.

Fraunhofer IISB Nuremberg-EnCN

Fürther Strasse 250, "Auf AEG", 90429 Nuremberg

As a member of the "Energie Campus Nürnberg", the IISB operates a 450 m² branch lab on megawatt power electronics for energy supply in the joint EnCN building in Nuremberg.

FRAUNHOFER IISB AT A GLANCE

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Locations

Technology Center for Semiconductor Materials THM Freiberg
Am St.-Niclas-Schacht 13, 09599 Freiberg

The THM is a joint department of Fraunhofer IISB and Fraunhofer ISE. It supports industry in technologies for the production of innovative semiconductor materials to be used in microelectronics, optoelectronics, and photovoltaics. The IISB part of the THM comprises 650 m^2.

Chemnitz Laboratory
Reichenhainer Strasse 29a, 09126 Chemnitz

In Chemnitz, the IISB operates a laboratory of 160 m^2 for the industrial application of power electronics

Network and Partners

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

- Since its foundation, the IISB has been closely cooperating with the University of Erlangen-Nürnberg. The institute is directed by the head of the Chair of Electron Devices of the University. The joint operation of infrastructure as well as the exchange in education and training create extensive synergies.
- The IISB is a core member of the "Leistungszentrum Elektroniksysteme" (www.leistungszentrum-elektroniksysteme.de, www.lze.bayern) .
- The IISB is the coordinator of the Bavarian energy research project SEEDs (www.energy-seeds.org).
- The IISB is a member of the "Energie Campus Nürnberg" (www.encn.de).
- The IISB is the coordinator of the Bavarian Research Cooperation for Electric Mobility (FORELMO, www.forelmo.de).
- The IISB is the coordinator of the Fraunhofer Innovation Cluster "Electronics for Sustainable Energy Use".
- The IISB is a partner of the excellence projects at the University of Erlangen-Nürnberg (www.eam.uni-erlangen.de, www.aot.uni-erlangen.de/saot/).
- 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 Association DGKK e.V.
- The IISB is the coordinator and partner, respectively, of numerous European research projects.
- Together with the Federal Ministry for Education and Research (BMBF), the IISB initiated and operates the joint student program of BMBF and Fraunhofer for electric mobility, DRIVE-E (www.drive-e.org).
- The IISB is a close partner of the "Förderkreis für die Mikroelektronik e.V."

The IISB is member of the following 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 Nanotechnology Alliance (www.nano.fraunhofer.de)

Chair for Energy Electronics (LEE), University of Erlangen-Nürnberg

Since September 1, 2016, Prof. Dr. Martin März, deputy director at Fraunhofer IISB, is heading the newly established Chair of Energy Electronics (LEE). The chair conducts research on current topics in the field of power electronics for the electric power supply. Beside stationary decentralized electrical power systems, the addressed application fields also include the power-nets in vehicles, ships, railways, and airplanes. LEE is part of Energy Campus Nuremberg (EnCN) on the former AEG company grounds in the Fürther Straße in Nuremberg, and the first chair grown out of the EnCN.

Chair of Electron Devices (LEB), University of Erlangen-Nürnberg

The Fraunhofer IISB and the Chair of Electron Devices (German abbreviation: LEB) of the University of Erlangen-Nürnberg are both headed by Prof. Lothar Frey.

Within the framework of a cooperation agreement, the two institutions not only jointly operate the University's cleanroom hall and other laboratories but also work closely together with regard to teaching and research.

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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, the vocational training as a "microtechnologist" has been offered jointly by IISB and the Chair of Electron Devices. Employees of IISB assist in courses and internships at the University.

The following staff members of Fraunhofer IISB regularly give lectures at the University of Erlangen-Nürnberg:

Dr. Andreas Erdmann
- Optical Lithography: Technology, Physical Effects, and Modeling

Dr. Tobias Erlbacher
- Semiconductor Power Devices

Prof. Dr. Lothar Frey
- Semiconductor Devices
- Process Integration and Components Architecture
- Nanoelectronics
- Technology of Integrated Circuits

Dr. Jochen Friedrich
- Fundamentals and Technology of the Growth of Semiconductor and Optical Crystals

Dr. Michael Jank
- Introduction to Printable Electronics
- Nanoelectronics

Dr. Jürgen Lorenz
- Process and Device Simulation

Prof. Dr. Martin März
- Power Electronics in Vehicles and Electric Powertrains

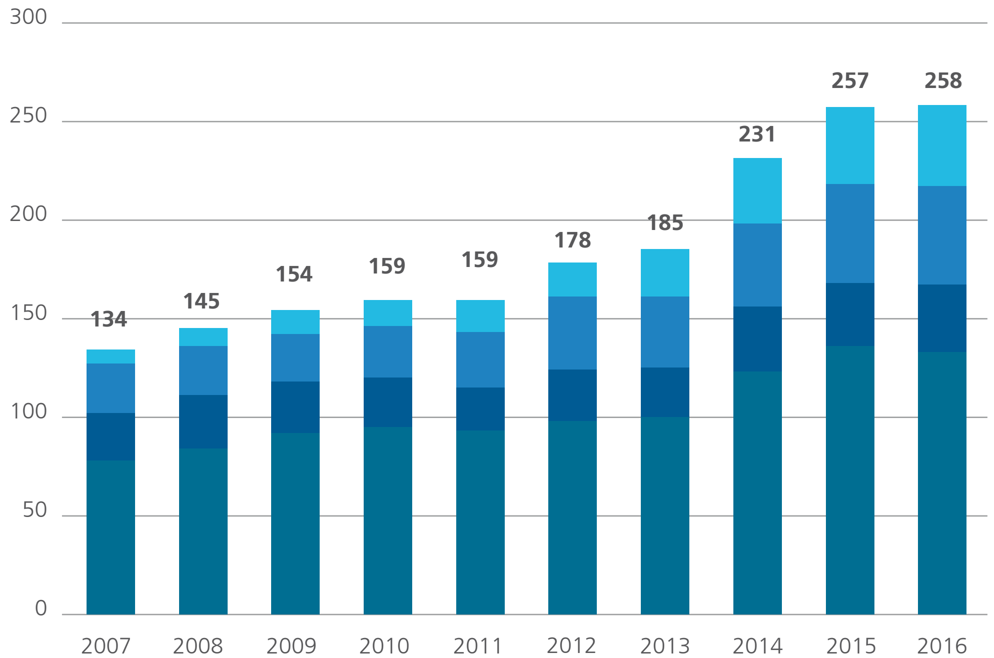
Prof. Dr. Lothar Pfitzner
- Semiconductor Equipment Technics

Priv.-Doz. Dr. Peter Pichler
- Reliability and Failure Analysis of Integrated Circuits

1 *Chair of Electron Devices of the University of Erlangen-Nürnberg: main building and clean room laboratory. © LEB*

Content

Staff Development, Investments, and Budget



1 *Staff development 2007 - 2016.*
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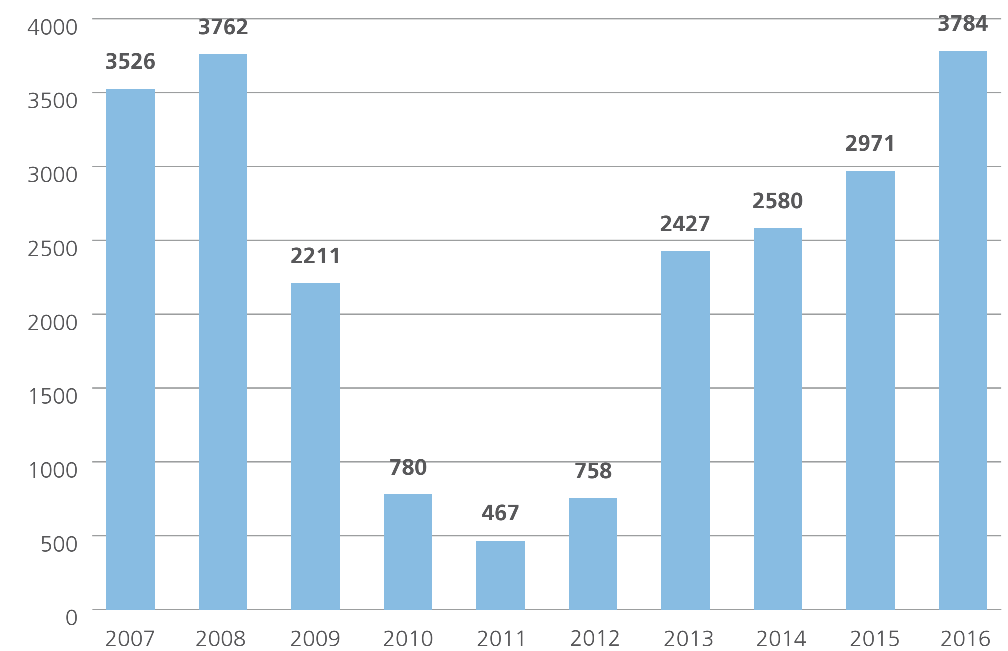
Student Assistants equivalent
Office Staff and Others
Technicians
Scientists



2 *Capital investment (without basic equipment and special funds) 2007 - 2016 (in T€).*
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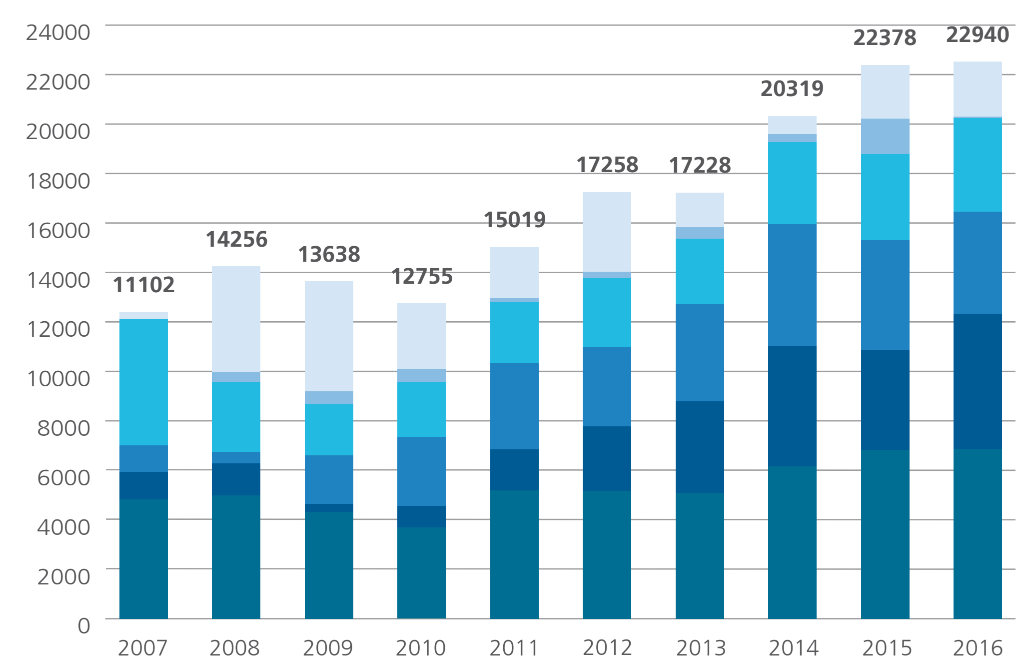
Capital Investment



3 *Operating budget according to financing domains 2007 - 2016 (in T€).*
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Basic Funding
Int. Programs
EU + Others
Federal
Bavaria + Saxony
Industrial Partners

Content

Advisory Board (December 2016)

IISB is consulted by an Advisory Board, whose members come from industry and research:

Dr. Stefan Kampmann (Chairman of the Advisory Board)
OSRAM Licht AG

Dr. Helmut Gassel
Infineon Technologies AG

Thomas Harder
European Center for Power Electronics (ECPE)

Prof. Dr. Reinhard Lerch
University of Erlangen-Nürnberg

Markus Lötzsch
Nuremberg Chamber of Commerce and Industry

MinR Dr. Stefan Mengel
Federal Ministry of Education and Research (BMBF)

Dr. Andreas Mühe
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Dr. Martin Schrems
ams AG

Dr. Karl-Heinz Stegemann
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Dr. Thomas Stockmeier
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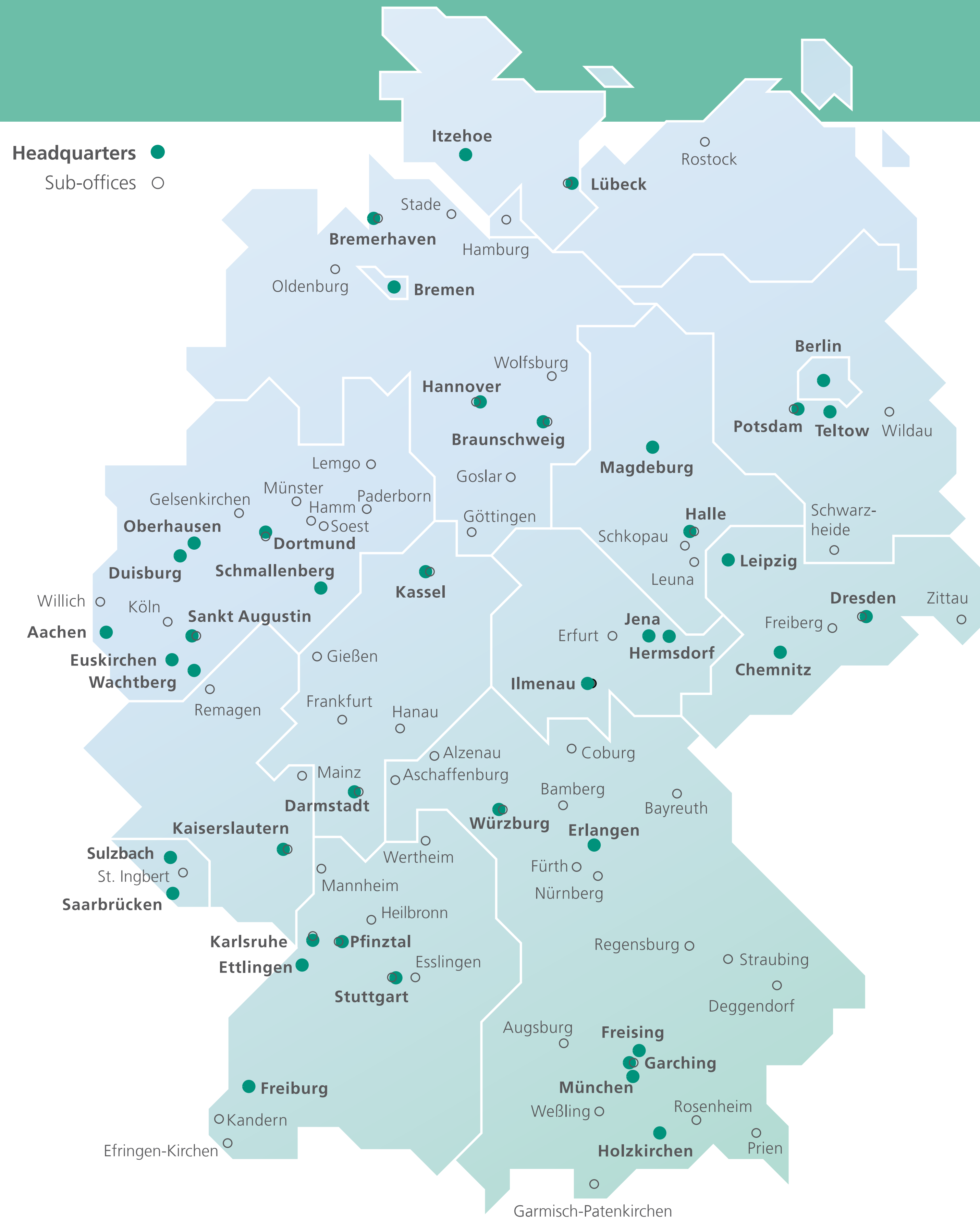
FRAUNHOFER-GESELLSCHAFT



Content

The Fraunhofer-Gesellschaft

1 *Locations of the Fraunhofer-Gesellschaft in Germany. © Fraunhofer*

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 69 institutes and research units. The majority of the nearly 24,500 staff are qualified scientists and engineers, who work with an annual research budget of more than 2.1 billion euros. Of this sum, more than 1.9 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

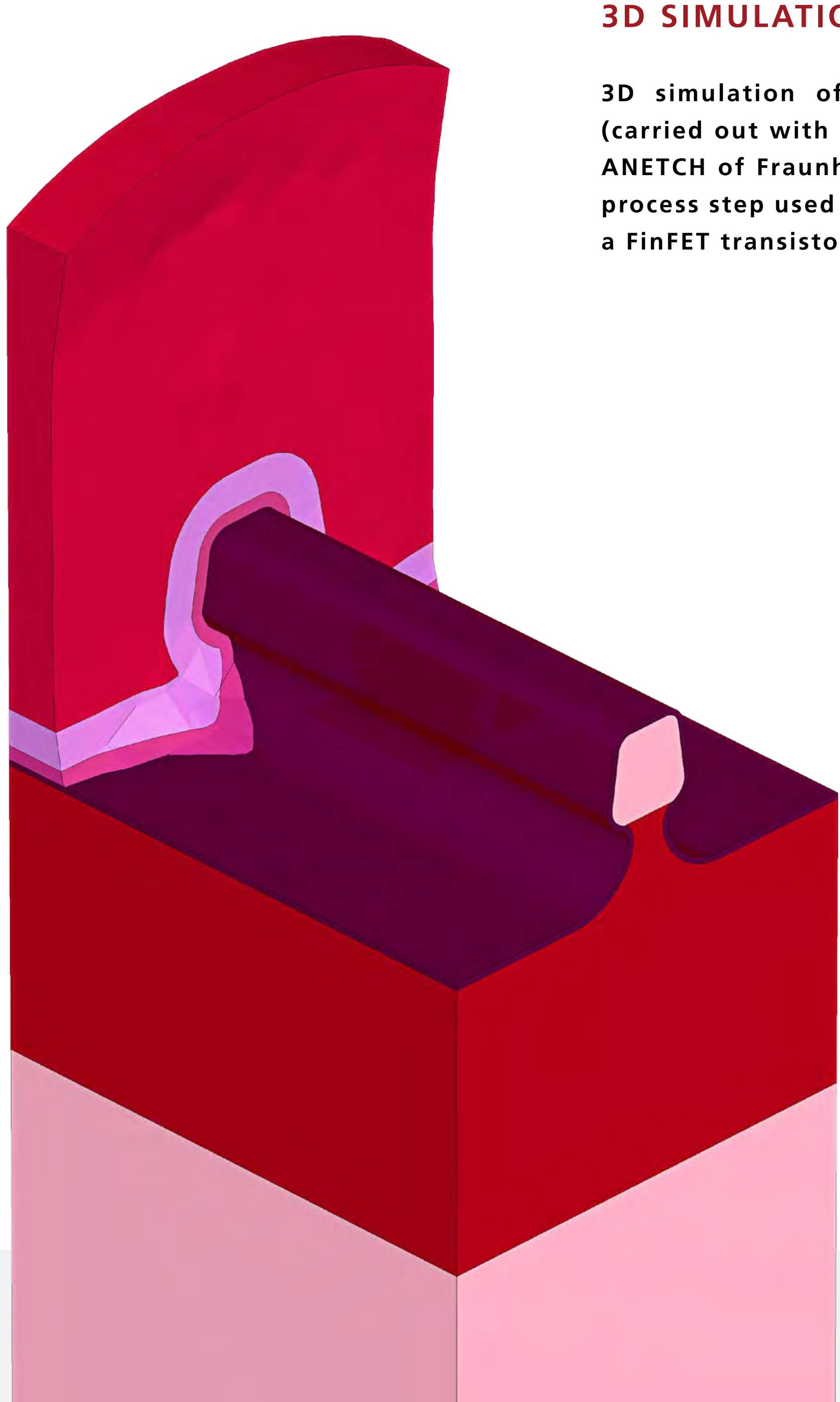
International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

SIMULATION



3D SIMULATION

3D simulation of gate stack etching (carried out with the etching simulator ANETCH of Fraunhofer IISB), which is a process step used for the fabrication of a FinFET transistor structure.

1 *Dr. Jürgen Lorenz, head of the Simulation department. © K. Fuchs / Fraunhofer IISB*

Content

The simulation of semiconductor fabrication processes, devices, circuits, and systems greatly contributes to reducing development costs in the semiconductor industry. Among others, this has been confirmed for micro- and nanoelectronics in the International Technology Roadmap for Semiconductors (ITRS). The Simulation department contributes to this by developing physical models and programs for the simulation and optimization of semiconductor fabrication processes and equipment. Furthermore, it supports the development of processes, lithography (incl. masks, materials, and imaging systems), devices, circuits, and systems by providing and applying its own and third-party simulation and optimization tools.

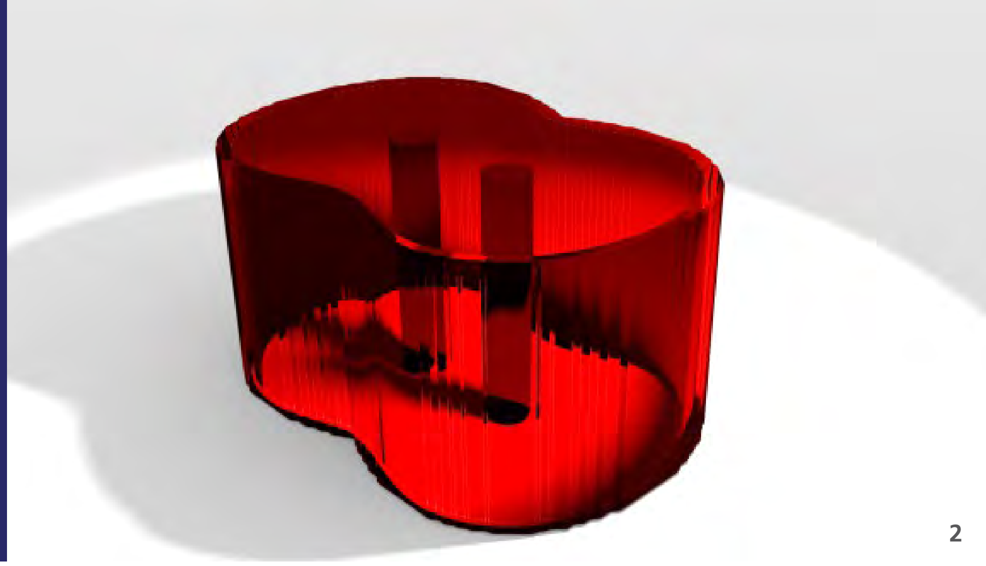
While process and device simulation has meanwhile become largely established in industry as an indispensable tool for the development and optimization of highly scaled devices ("More Moore"), the area of "More than Moore", which consists of fields such as analog / RF, low-power electronics, power electronics, and microsystems technology, offers a large variety of additional applications. On the other hand, these new fields of application in particular often require the combination of heterogeneous competencies, because thermal, mechanical, optical, and chemical effects also occur in addition to electronic effects. This gives rise to an additional demand for research. In consequence, about half of the activities of the Simulation department now deal with the application of its own and third-party simulation programs to support the development of technologies, devices, and systems in various "More than Moore" fields, especially regarding power electronics.

Nevertheless, the department also continues to make important contributions to support the further scaling of advanced nanoelectronic devices. These activities have been mainly carried out in four cooperative projects on the European level: The EU Horizon 2020 project "Stability Under Process Variability for Advanced Interconnects and Devices Beyond 7nm Node" (SUPERAID7) coordinated by the department deals with the simulation of the impact of process variations on advanced transistors and circuits. SUPERAID7 started at the beginning of 2016 as a follow-up project to the FP7 project SUPERTHEME, which was successfully completed at the end of 2015.The EU FP7 project "Computational Lithography for Directed Self-Assembly: Materials, Models and Processes" (CoLiSA.MMP) coordinated by the department dealt with a very promising material-driven resolution enhancement method for the patterning of small structures and was successfully completed in October 2016. The traditionally optics-driven resolution improvements through extreme ultraviolet (EUV) lithography are addressed in the ECSEL KET pilot lines "Seven Nanometer Technology" (SENATE) and "Technology Advances and Key Enablers for 5nm" (TAKE5) by large consortia of companies, research institutes, and universities, coordinated by ASML (the German part by Zeiss), the leading vendor of lithography steppers. Here, the department contributes with the extension and especially with the application of its leading-edge lithography simulator Dr.LiTHO. Furthermore, the department also earns license fees for software developed within "More Moore" projects. Our solid expertise gained in the field of "More

Moore", for instance regarding tailored numerical methods for model implementation, provides a sound basis for the development and application of simulation in other fields, such as "More than Moore". Our department has been correspondingly involved in several recent cooperative projects funded by German or European authorities, including three EU FP7 projects: In the project ATHENIS_3D ("Automotive Tested High Voltage and Embedded Non-Volatile Integrated System on Chip platform employing 3D Integration"), the department investigates and simulates the distortion of integrated capacitors due to fabrication and reliability problems that occur with the 3D integration of ICs with power devices. In the project "Multi Sensor Platform for Smart Building Management" (MSP), the department applies its own and commercial third-party software for the optimization of the three-dimensional integration of sensor systems, especially via so-called "through silicon vias" (TSVs). Within the project "Large Area Solid State Intelligent Efficient Luminaires" (LASSIE), the department employs its lithography simulator Dr. LiTHO for the optimization of advanced LED-based lighting systems. Lithography simulation is used not only for the development of advanced lithography technology but also for metrology and inspection. Software engineering techniques are provided and applied in other areas of the institute, among others for smart battery management, which is an important area in power electronics. Multiphysics simulations that include electrical, mechanical, and/or thermal effects on a case-by-case basis are employed for applications especially in the power electronics area. In both the areas of "More Moore" and "More than Moore", the expertise gained or expanded in publically funded cooperative projects also provides the foundation for several research and development projects directly commissioned and financed by industry, e.g., for the optimization of lithography masks, the simulation of platinum diffusion for power devices, or inductive coupling.

Besides the project work in 2016, members of the department also organized the international conference "Simulation of Semiconductor Processes and Devices" (SISPAD) held in September 2016 in Nuremberg, Germany, around 20 km from Erlangen, with more than 130 international participants.

The department will continue its approach to performing focused work on physical models and algorithms in order to develop the necessary skills and tools on the one hand and to transfer these results to applications in industry on the other. Here, a close and trustful cooperation based on sharing work according to the individual competencies and requirements of the partners has been a key element of the success achieved for many years.



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Content

2 *3D visualization of a simulated double cylinder, which was created in a contact multiplication process. © Fraunhofer IISB*

Computational Lithography for Directed Self-Assembly: Materials, Models and Processes

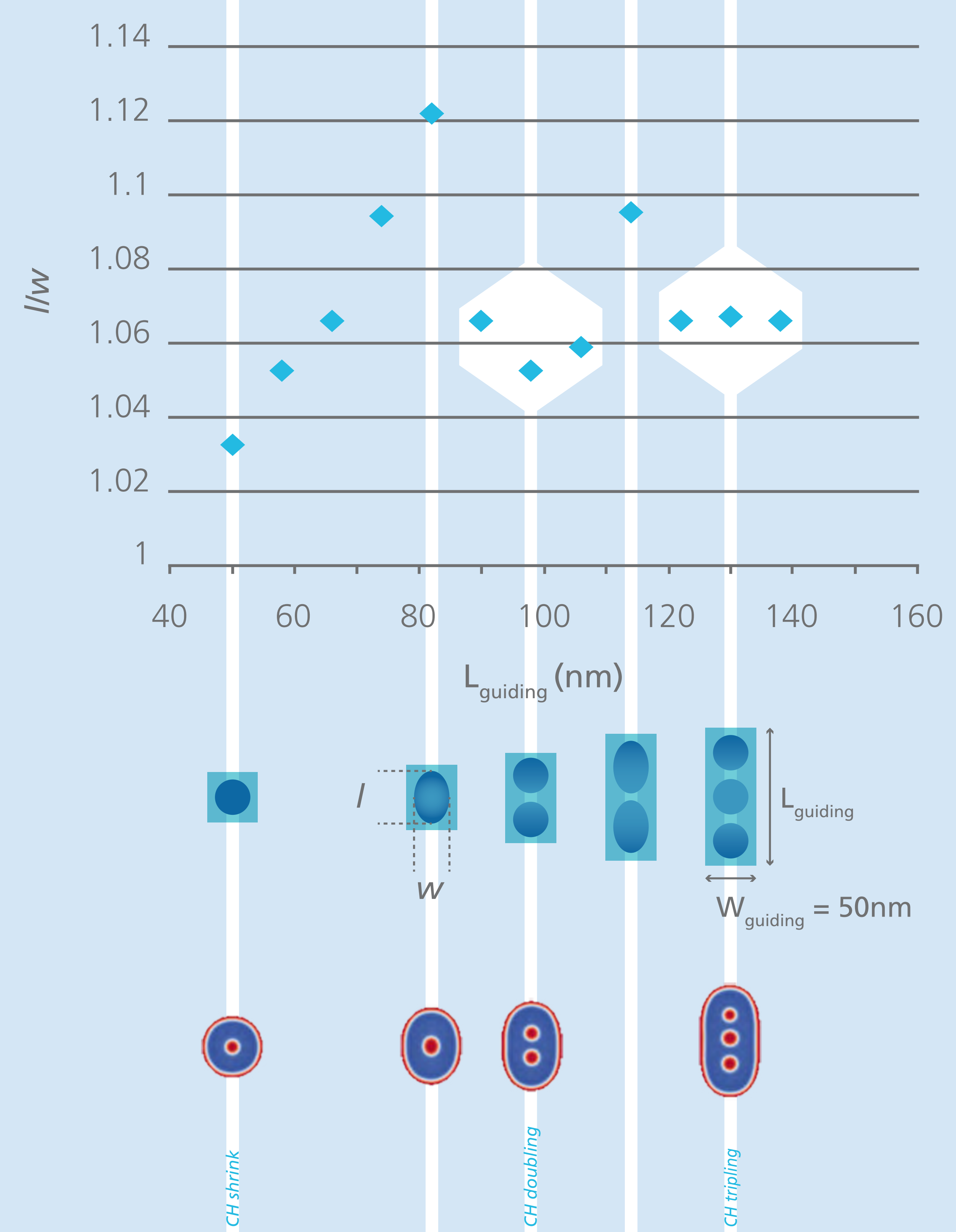
Directed self-assembly (DSA) of block copolymers is one of the most promising techniques to enable the continued miniaturization of integrated circuits. It combines top-down photolithography to create guiding patterns with engineered new materials and processes to facilitate cost effective bottom-up techniques for pattern-density multiplication and defect rectification. Block copolymers (BCPs) are macromolecules that consist of two (or more) covalently bonded chemically distinct polymer chains, the so-called blocks. Just as most polymer mixtures will separate due to unfavorable interactions, the blocks of the copolymer tend to demix, but only on a nanometer scale, as the constituting blocks are linked together. This segregation leads to spatially organized periodic nano-domains with different structural configurations, such as lamellae, cylinders, spheres, and other more complex geometries. Guiding patterns are employed to achieve the required long-range order and position control for semiconductor applications. These guiding patterns can involve a pre-patterning of the substrate surface with chemical functionality (chemical epitaxy) or a surface topography (graphoepitaxy). The guiding patterns are fabricated by conventional top-down lithographic methods such as optical/EUV projection lithography or e-beam lithography.

An industrial-scale application of DSA still faces several challenges: i) Geometry and surface affinities of the guiding patterns for self-assembly heavily impact the DSA. The resulting pattern formation must be well understood and modeled in order to optimize its efficiency and avoid defects. ii) The specific properties of DSA must be considered early in the design process. iii) Generation of sub-20-nm patterns requires new so-called high-chi block copolymer materials.

CoLiSA.MMP has combined European expertise in soft matter physics, block copolymer chemistry, lithographic process, and computational lithography to develop new material and process models and a computational lithography framework for DSA. Atomistic models were developed to compute important physical material parameters such as the Flory Huggins parameter and surface properties for given molecular structures and helped to identify the most promising block copolymer materials that enable sub-10-nm feature sizes. Coarse-grained models were applied to study the kinetics of self-assembly, the formation/annihilation of DSA typical defects, and to predict appropriate processing conditions for defect reduction.

Specially designed atomistic and coarse-grained models were combined with experimental data to develop and calibrate efficient predictive reduced models, such as special forms of the Ohta-Ka-

SIMULATION



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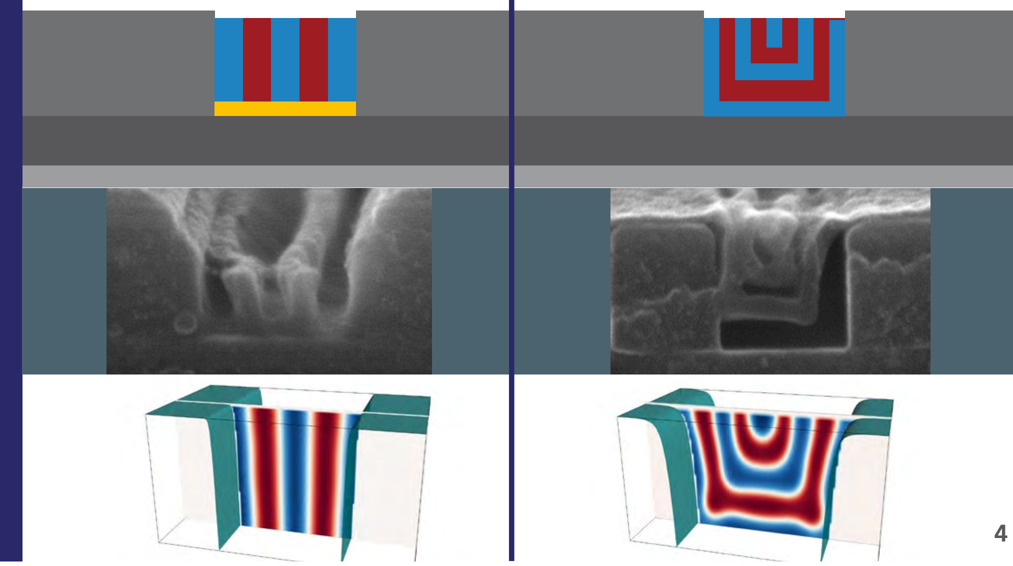

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wasaki model and Interface Hamiltonians. Figure 3 shows experimental and simulation results for a so-called contact multiplication process. For this purpose, elliptically shaped guiding patterns are created by established lithographic methods. The width or the semi-minor axis of the ellipses was 50 nm. The aspect ratio between the semi-major and semi-minor axis varied between 1.0 and 3.0. Self-assembly of appropriate block copolymers results in the formation of 1 - 3 almost rotationally symmetric cylinders with diameters in the order of 16 - 18 nm. These cylinders can be transferred to contacts that connect different layers in a semiconductor chip. Figure 2 shows a 3D visualization of a double contact. The strong impact of the chemical affinity of the surfaces of the guiding pattern on the resulting morphology of the BCP is demonstrated in Figure 4.

To tightly integrate the computational DSA components with Dr.LiTHO, an extension module called Dr.Seal (Development and research self-assembly lithography) has been developed. This module, which not only includes the reduced DSA models but also encompasses topology, metrology, visualization and evaluation routines, is seamlessly integrated into the research and development lithography simulator Dr.LiTHO of Fraunhofer IISB. The new modeling capabilities were used to establish new design flows that include the lithographic generation of guiding patterns and the resulting patterns after DSA and to demonstrate a fully functional source/mask/DSA optimization approach.

The model development was supported by a comprehensive characterization of synthesized polystyrene-b-poly(methyl methacrylate) (PS-b-PMMA), the implementation of dedicated chemoepitactical and graphoepitactical processes, and extensive process metrology. The developed modeling and processing techniques were applied to new high-chi materials. The transition from PS-b-PMMA to other materials such as PLA-b-PDMS-b-PLA turned out to be more challenging than expected at the beginning of the project. Nevertheless, as targeted within the CoLiSA project, block copolymers have been obtained and characterized to demonstrate a pitch < 15 nm by SAXS in bulk and resolution ("critical dimension" CD < 7 nm) by CD SEM measurements on a patterned surface on a CEA-Leti line.

3 *Experimental and simulation results for a contact multiplication process. Top views of simulated and measured patterns. Lguiding , Wguiding – size of the long / short axis of the guiding pattern, l/w – ratio of the long / short axis of the created cylinders.*
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4 *Experimental and simulation results for the investigation of the impact of surface affinities a line multiplication process. Cross section views of schematics (top row), SEM measurements (center row) and simulation result (bottom row), Left column: A neutral surface of the bottom of the guiding pattern helps to create vertical lines, right: preferential affinity of this surface result in onion-like geometries, which cannot be transferred in an etch process.*
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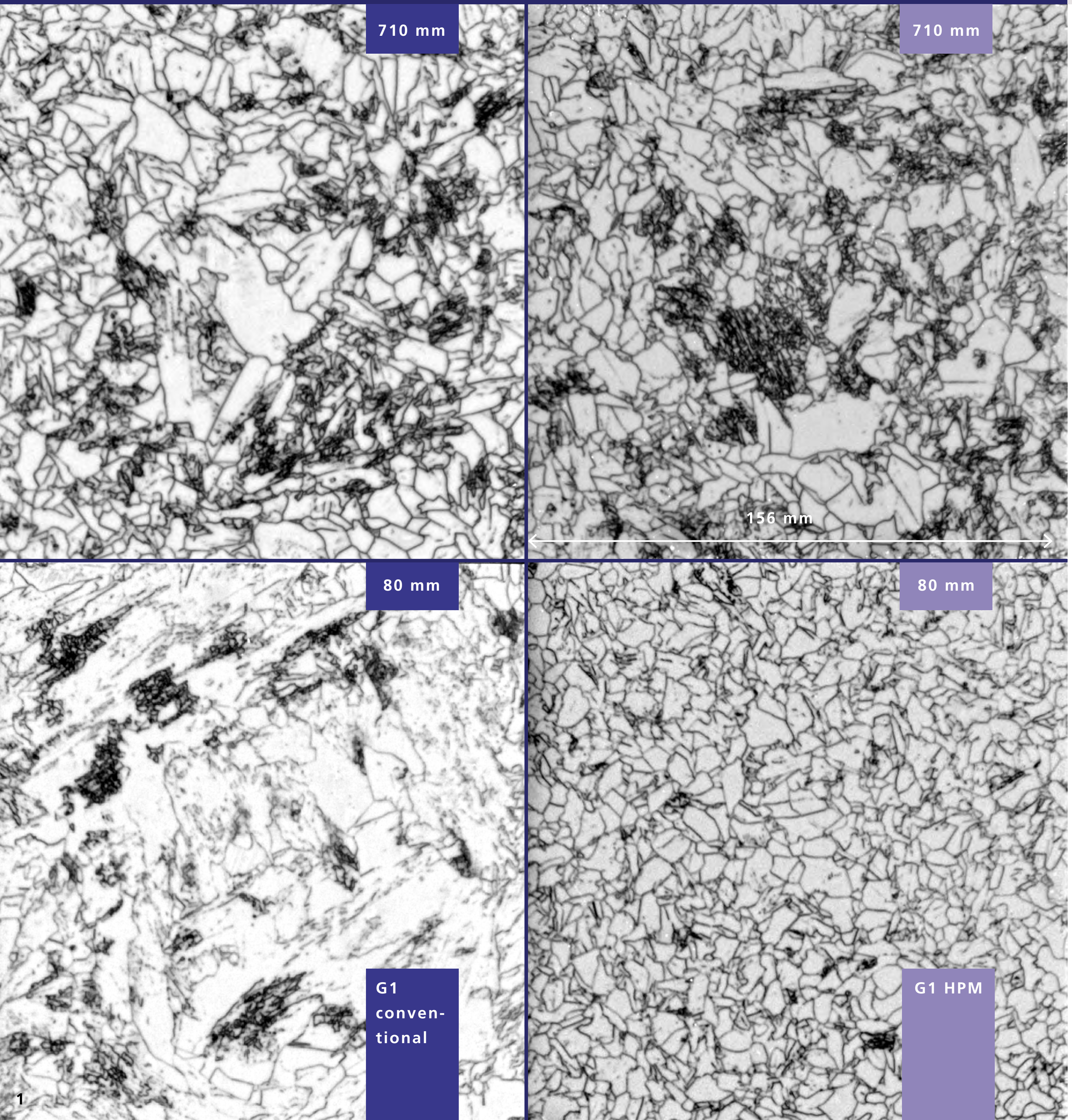
MATERIALS



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We provide scientific and technological solutions for the development and characterization of semiconductor materials and their production processes.

Our driving force is to enable novel applications through the commercialization of these materials. Special emphasis is placed on silicon and compound semiconductors (SiC, GaN, AlN) for electronic applications, energy saving, and optical systems. The main aim is to support material, device, and equipment manufacturers and their suppliers in the areas of crystal growth and epitaxy. Our materials are further processed into devices and integrated in system demonstrators in-house or at partner sites. The investigation of the relationship between the microstructure of the semiconductor material and the performance and reliability of a respective device gives us the best input for further development of the materials and their production processes.

The strategy of IISB, together with its branch lab in Freiberg/Saxony, the Fraunhofer Technology Center for Semiconductor Materials (THM), is a combinatory approach composed of thorough experimental process analysis, tailored characterization techniques, and numerical modeling. These efforts are supported by a well suited infrastructure consisting of R&D-type furnaces, epitaxial reactors, other thin film technologies, state-of-the-art metrology tools for the investigation of physical, chemical, electrical, and structural properties of materials, as well as powerful and user-friendly simulation programs. These programs are especially suitable for heat and mass-transport calculations in high-temperature equipment with complex geometry.

The Materials department gains its competences based on an interdisciplinary team of materials scientists, physicists, chemists, as well as electrical, mechanical, chemical, and computer engineers. They have extensive expertise in the areas of crystal growth, epitaxy, thin film deposition, and synthesis of functional materials including characterization and modeling. Multiple national and international research awards within the last several years underline the scientific and technological achievements of the Materials department. These awards were granted for outstanding scientific and technological results, as well as for excellent contributions to the education of students and engineers. In collaboration with the University of Erlangen-Nuremberg, the Technical University Georg-Simon-Ohm Nuremberg, and the Technical University Bergakademie Freiberg, the Materials department supervises students carrying out research projects as well as bachelor's, master's, and PhD theses.

During 2016, the majority of research topics at the Materials department were in the areas of silicon, silicon carbide, gallium nitride, and energy materials.

In the field of directional solidification of silicon, we continued our research on so-called high-performance multicrystalline silicon. Our expertise in producing such material, which is characterized by a fine-grained structure along with a high amount of random grain boundaries and thus a low

1 *PL images of the 710 mm G1 conventional (left) and HPM ingot (right) for 80 mm and 710 mm total ingot height. Dark, non-line shaped areas represent the recombination active dislocations.*
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2 *Dr. Jochen Friedrich, head of the Materials department.*
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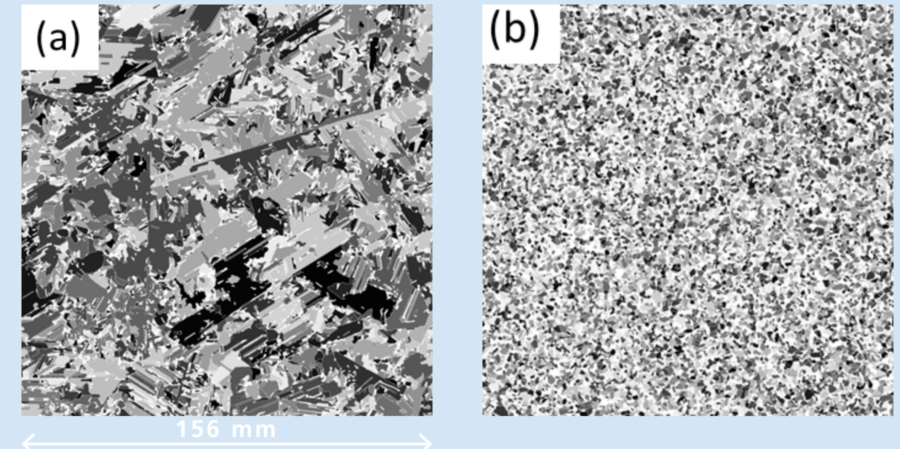
density of dislocation clusters, has meanwhile become part of products that are offered by our industrial partners. In order to achieve these technological solutions, we have intensively used a so-called sessile drop furnace that was specially developed to investigate the wetting and nucleation behavior between silicon and different substrates. For a photo of this sessile drop furnace, we received the Best Photo Award 2016 from the International Organization of Crystal Growth and Epitaxy (IOCGE).

In the field of Czochralski-grown silicon, we grew our first 2 m long Czochralski crystal with a 200 mm diameter. We set up a numerical model of an industrial Czochralski process for photovoltaic applications based on our special 2D-3D coupling approach and started to validate the modeling results with data originating from production runs. For heavily doped silicon, we extended our investigations on the causes of the higher probability of so-called structure loss during crystal pulling for heavily phosphorous-doped silicon with a 300 mm diameter. These investigations also allowed us to obtain some new insights into the behavior of point defects in this heavily doped material.

In the field of nitride semiconductors, we started to develop AlN substrates for the production of efficient and stable UVC-LEDs. We began to set up the infrastructure and equipment to synthetize pure AlN powder and to grow AlN boule crystals by the sublimation method. Furthermore, we brought a MOCVD reactor into service that is used for functionalization and qualification of the surface of native substrates with regard to device epitaxy. Our work towards the optimization of the HVPE GaN boule growth continued, and we were able to upscale the process to a 3" diameter. Our investigations about the correlation of structural defects in the nitride device layer stack with the electrical performance of HEMT devices continued as well. Both topics will be further investigated in a number of nationally and European-funded projects in the next three years.

In the field of silicon carbide, we received the Semikron Innovation Award 2016 for our correlation of structural defects in epitaxial layers with the electrical performance of bipolar high-power SiC devices. For our analysis of the impact of the epitaxial process as well as post-epitaxial processes such as annealing, implantation, and oxidation on the Z1/2 defect in SiC, which is related to carbon vacancies and which determines the minority carrier lifetime, we received the Best Paper Award of the German Crystal Growth Association in 2016.

In the field of energy materials, we showed in a small system demonstrator that pyroelectric crystalline materials can be used to produce hydrogen through a cyclic temperature change. For these outstanding results, we received the Best Poster Award at the EMRS Symposium W "Materials and Systems for Microenergy Harvesting and Storage". We also achieved initial promising results in the field of secondary aluminum ion batteries. We were able to show the electrochemical reversibility and the active potential range of such aluminum ion battery systems. We will



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3 *Typical grain structure images at 20 mm height of G1 HPM (a) and conventional (b) mc silicon bricks grown at Fraunhofer IISB.*
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continue these research activities in order to evaluate the commercial potential of such future battery systems further.

HPM-Silicon: Small Grains for Large Efficiencies

Nowadays, multi-crystalline (mc) silicon is used roughly for 50% of all produced silicon solar cells in the world. It is produced by the directional solidification technique, where the silicon feedstock is melted in a square-shaped fused silica crucible that is coated with a silicon nitride powder on the inner surfaces. By extracting the heat in a downwards direction, an mc silicon ingot is solidified from bottom to top. As a result, the initial nucleation of the silicon melts at the coated crucible bottom leads to the typical mc grain structure, which consists of unregularly shaped grains including a lot of dendrites and twins (compare figure 3a). Today, ingots with a weight of 600 - 800 kg and an edge length of 840 - 1000 mm are typical.

A few years ago, a new silicon material, so-called "high performance mc silicon" or "HPM" silicon, has entered the PV market. This HPM material, which is typically obtained by nucleation on a non-melted silicon feedstock layer at the crucible bottom, exhibits a very fine grain structure (see figure 3b) in contrast to conventional mc silicon and results in $\sim 0.5\%_{abs}$ higher solar cell efficiencies.

At Fraunhofer IISB, a lot of research and development activities have been done in the past years in order to investigate the development of the grain structure as well as the crystal defects over the ingot height and finally to further improve the material quality and the yield of high quality wafers per ingot.

One research topic was the influence of the feedstock type used within the seeding layer on the grain structure and material properties of the HPM ingots. It was found that the microstructure of the used feedstock determines the initial grain size of the HPM grain structure. If single-crystalline silicon feedstock particles in the mm range are used, the resulting mean grain size decreases with decreasing feedstock particle size, because each particle represents one seed and for small diameters more seeds can be located on the crucible bottom area. On the other hand, if poly-crystalline feedstock (e.g., from the Siemens process (SIE) or Fluidized Bed Reactor (FBR)) is used, one feedstock particle provides more than one seed due to its microstructure, which is characterized by an inner grain size in the 200 - 800 µm range. As a result, the achievable mean grain size is slightly lower than for the single-crystalline feedstock.

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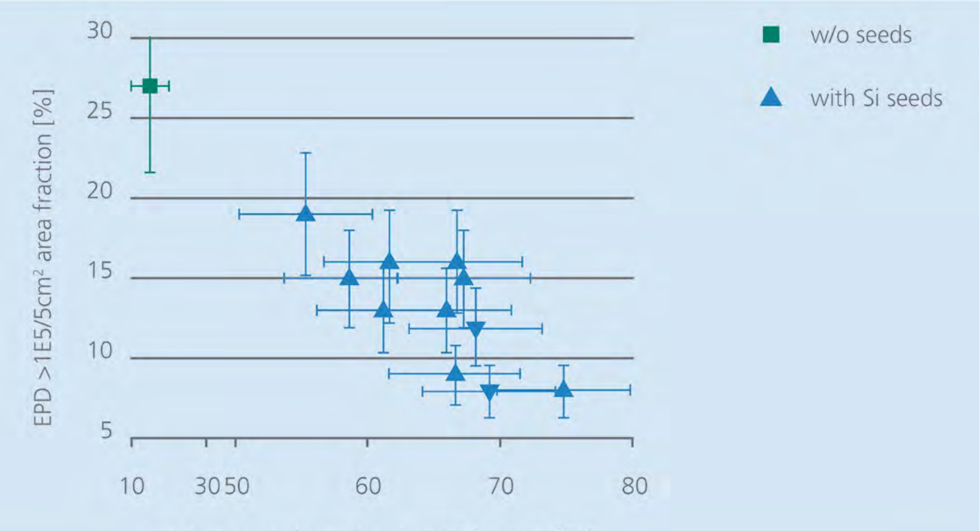
A further key parameter in HPM silicon besides the small grain size is the amount of random grain boundaries, because this grain boundary type prevents the movement and multiplication of harmful crystal defects (dislocations) inside the material. Investigations at Fraunhofer IISB have shown a clear correlation of the dislocation content in HPM material to the amount of random grain boundaries (see figure 4). Explicitly, the higher the length fraction of random grain boundaries, the lower the dislocation content (etch pit density – EPD). This means that a smaller initial grain size results in a higher random grain boundary fraction and finally in a lower dislocation content in the HPM material.



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Studies on the grain structure development over the ingot height reveal that the initially high random grain boundary fraction of 60 - 70% decreases during the growth of the ingot. Additionally, the mean grain size becomes larger towards the top of the ingots. For detailed investigation of this grain growth behavior, extraordinarily tall HPM and conventional silicon ingots up to 710 mm height were grown at Fraunhofer IISB. The extraordinary ingot height was obtained by the successive growth of eight G1 ingots (each of 130 mm height) whereas a 20 mm horizontal cut from the top region of the former ingot was used as a seed plate for the subsequent ingot. The results show that the grain structure properties as well as the amount of dislocations of both material types, which are quite different at the ingot bottom, align with each other with an increasing ingot height. However, at an ingot height of about 300 mm, the properties become equal and remain constant until the top of the ingots at 710 mm (see figure 1). The reason could be identified as different grain boundary annihilation and formation mechanisms taking place during growth. From this observation, it was concluded that the growth of even higher HPM silicon ingots has no advantage the industrial producers in respect to the benefit of HPM versus conventional mc silicon.

The main advantage of the above-described method including the seeding on a non-melted silicon particle layer is the high reproducibility in industrial production. However, there are also some economic drawbacks, namely the more time-consuming melting process and some yield losses in the bottom region of the ingot due to the non-usability of the seeding layer. Therefore, industrial wafer producers are greatly interested in finding alternative seeding methods to overcome these drawbacks. The main aspect of these methods is to provide foreign nucleating agents at the crucible bottom and to solidify the silicon melt directly on them to achieve a fine-grained HPM structure.

Fraunhofer IISB investigated the potential of a functional coating based on silicon dioxide (SiO_2) and silicon carbide (SiC) particles. The coating was applied at the bottom of G1 crucibles on top of the standard silicon nitride coating either by spraying a particle/water suspension or embedding particles in an additional wet silicon nitride layer. Whereas the SiC coating did not show a positive effect, it could be demonstrated that using small SiO_2 particles (3 µm in diameter, an initial grain structure with mean grain sizes of 1 - 4 mm² and a random grain boundary fraction of about 60%) could be obtained, independently of the coating procedure, which is nearly the same as for HPM silicon seeded on a silicon feedstock layer.

Overall, Fraunhofer IISB has done a lot of research and development activities in the field of HPM silicon growth over the last five years. It has been possible to successfully support several industrial partners by improving their HPM growth process, resulting in an improvement of the HPM material and a reduction of the wafer production costs.

4 *Fraction of areas with an etch pit density (EPD) >1E5/cm² versus the random grain boundary length fraction at 25 mm ingot height for lab scale HPM experiments performed without and with silicon seeds.*
© Fraunhofer IISB

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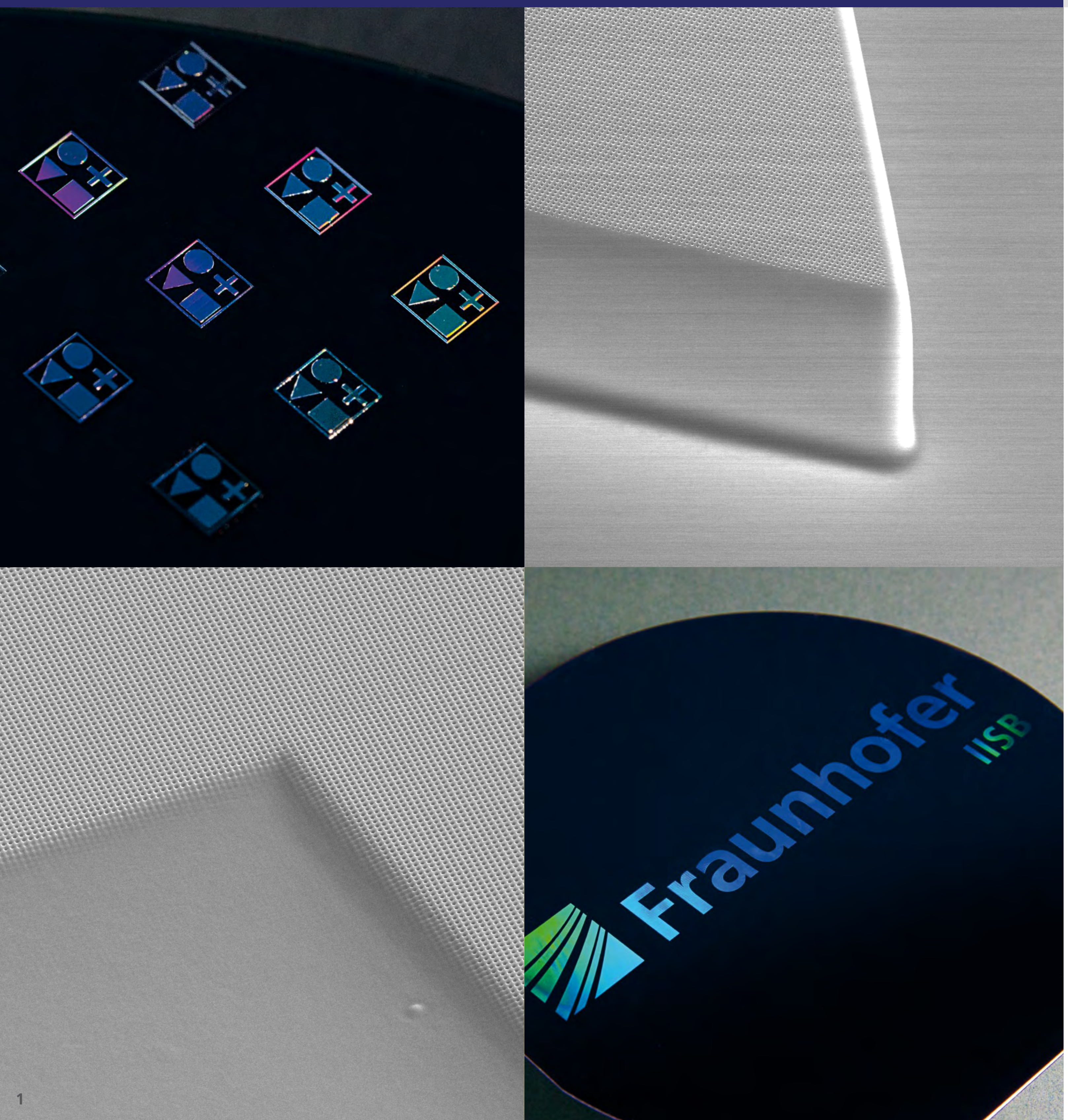
TECHNOLOGY AND MANUFACTURING



Technology and Manufacturing at Fraunhofer IISB means above all research and development in the field of electronic devices on a micro- as well on a nano-dimensional scale. In particular, to meet the requirements of our customers better, the service sector is arranged in a separate organizational unit called π-Fab. The purpose of π-Fab is the fabrication of custom-tailored prototype electron devices, and it is ISO 9001:2008 certificated for this. Furthermore, from nanotechnology to printable macro-electronics, the Technology and Manufacturing department is your contact for the realization and characterization of single process steps up to prototype devices. Based on comprehensive clean-room facilities, silicon and silicon carbide processing form the backbone of the department. Examples of current activities are high-resolution nano-imprints on a large scale, low-temperature depositions of inorganic materials using printing techniques, and especially the fabrication of advanced integrated power devices on SiC as well as on Si. In addition, the heterogeneous integration of various technologies is becoming more and more important. For this purpose, IISB and the Chair of Electron Devices of the University of Erlangen-Nürnberg operate joint clean room facilities of 1500 m^2 (primarily class 10) with CMOS-compatible equipment. This allows the implementation of important process steps on silicon wafers with diameters of up to 200 mm and on SiC wafers with diameters of up to 150 mm. An industrial CMOS process transferred to IISB and constantly adapted for research and development purposes is used as a reference and as the basis for developing advanced process technologies.

The main activities focus on the fields of Si power semiconductors, passives, and silicon carbide electronics. IISB has increased its commitment to these fields by implementing new equipment and processes to meet special requirements for Si and SiC power device processing. This above all concerns the etching and refilling of deep trenches and the high-temperature processing of SiC. A smart-power IGBT technology on Si with integrated trench isolation has been successfully realized too. All of this allows the department to strengthen its competence in manufacturing smart-power or high-voltage devices. By now, IISB has developed its resources and expertise to the point where it can perform nearly all manufacturing steps on SiC substrates according to an industrial standard. The devices currently under development include diodes and merged pin diodes in the voltage ranges from 1.2 kV up to 4.5 kV, as well as MOSFET devices such as vertical or lateral DMOS. A trench technology for vertical diodes and MOSFET as well as sensor and high-temperature CMOS devices are in progress.

For the development of novel process steps in the field of dielectrics and metallization, IISB operates advanced sputter and chemical vapor deposition tools on the basis of ALD that are used for the deposition of high-k and metallic layers. Furthermore, special activities focus on ion implantation technologies. At IISB, implantation tools with acceleration voltages ranging from a few eV up to 800 keV are available. Special implantations for CMOS as well as for power semi-conductors have been established (for example, commercial tools have been modified to be able to implant several wafer diameters and manifold elements at elevated temperatures).

1 *Photograph (first row, left) and detail electron microscopy image of fabricated hierarchical structures (first row, right). Photograph (second row, right) and detail electron microscopy image of Fraunhofer IISB logo fabricated using the novel approach (second row, left). The color effect visible in the photographs is caused by diffraction effects due to the present nanostructures. © Fraunhofer IISB*

2 *Dr. Anton Bauer, head of the Technology and Manufacturing department. © K. Fuchs / Fraunhofer IISB*

TECHNOLOGY AND MANUFACTURING

The physical and electrical characterization of process steps and device structures is of the utmost importance for the manufacturing of semiconductor devices. Important steps in this respect are the determination of the topography, doping profile, and further physical and chemical parameters, as well as SEM & TEM investigations, energy-dispersive X-ray analysis, and AFM surface characterization of layers. The specific competence of the department consists of the combination of several methods for failure analysis during the processing of semiconductor devices and tracing the causes of failure. The spectrum for electrical characterization has been further increased (e.g., lifetime measurements and high voltage measurements especially for SiC).

Another focal area of the department's work is the processing of structures in the range of a few nanometers as well as the repair and analysis of electronic device prototypes by means of focused ion beam (FIB) techniques and electron beams. In addition to that, UV nano-imprint lithography, a cost-effective fabrication technique that allows the transfer of nano-sized features to photoresist without the use of advanced optical lithography by applying small rigid stamps and, most importantly, by applying large-area (up to 150 mm) flexible stamps as well, is now well established.

The field of thin-film systems ranges from materials to device exploration to the development of TOLAE (thin, organic, and large-area electronics) applications. Based on a carefully targeted selection from solution processing/printing, spray coating, or vapor deposition of inorganic layers, novel devices are planned and optimized for their respective environment. Printed electrolyte sensors integrated with read-out and data handling electronics allow physical strain to be monitored in wearable sports trackers and can also be utilized in the chemical industry, water quality assessment, or several agricultural tasks. Capacitive and temperature sensing in combination with high performance TFTs enable the realization of smart integrated thin-film systems.

The core competence of the Semiconductor Manufacturing Equipment and Methods groups is multidisciplinary research and development for manufacturers of equipment, materials, and semiconductor devices. The decisive factor for this is the expertise in process development, metrology, analytics, software, simulation, and device integration combined to develop tailor-made solutions together with customers. The scope of developments ranges from lead research for novel processes and measurement methods to the application of new research results in cooperation with corporate industrial partners and the assessment and optimization of equipment in an industry-compliant environment. The IISB analysis laboratory for micro- and nanotechnology with various chemical, physical-chemical, and physical test methods is essential for a conclusive and comprehensible assessment. Two working groups at Fraunhofer IISB contribute their expertise in advanced process control, manufacturing science, productivity, contamination control, and yield control aspects to the ENIAC project "EPPL", which aims to combine research, development, and innovation to demonstrate the market readiness of power semiconductor devices fabricated in leading European 300 mm pilot lines.

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A Simple Approach for Complex Structures

So-called "hierarchical structures" combine features of different size regimes (e.g., the micro- and nano scale). One of the most famous examples can be found on the surface of the leaves of the lotus plant. Here, the combination of micrometer-sized papillae and nanometer-sized wax structures create the well-known water repellant properties of the surface. Beyond exhibiting hydrophobicity, hierarchical surface patterns can also be of interest, e.g., in the area of photonics.

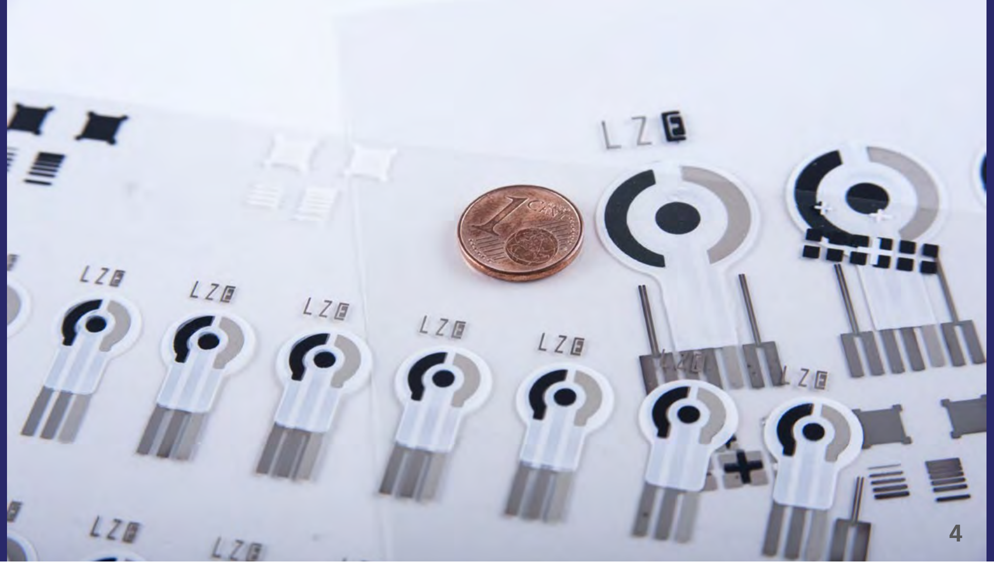
However, the controlled fabrication of such double structures is usually quite challenging and laborious, since the micro- and nano features have to be created in separate process steps. A new single-step approach, developed at the IISB, could facilitate this task significantly. The approach is based on the combination of two existing fabrication methods, namely Direct Laser Writing (DLW) and Substrate Conformal Imprint Lithography (SCIL). While a laser is used to write the desired micro structures into a UV-curing resist material, the nano features are transferred simultaneously by mechanical contact with a transparent mold. As a result, the resist outside the area irradiated by the laser remains uncured and can be washed away in a following development step. Therefore, only the hierarchical structures are left behind on the substrate. The height of the fabricated micro patterns is determined by the thickness of the initial resist layer and is therefore easy to adjust.

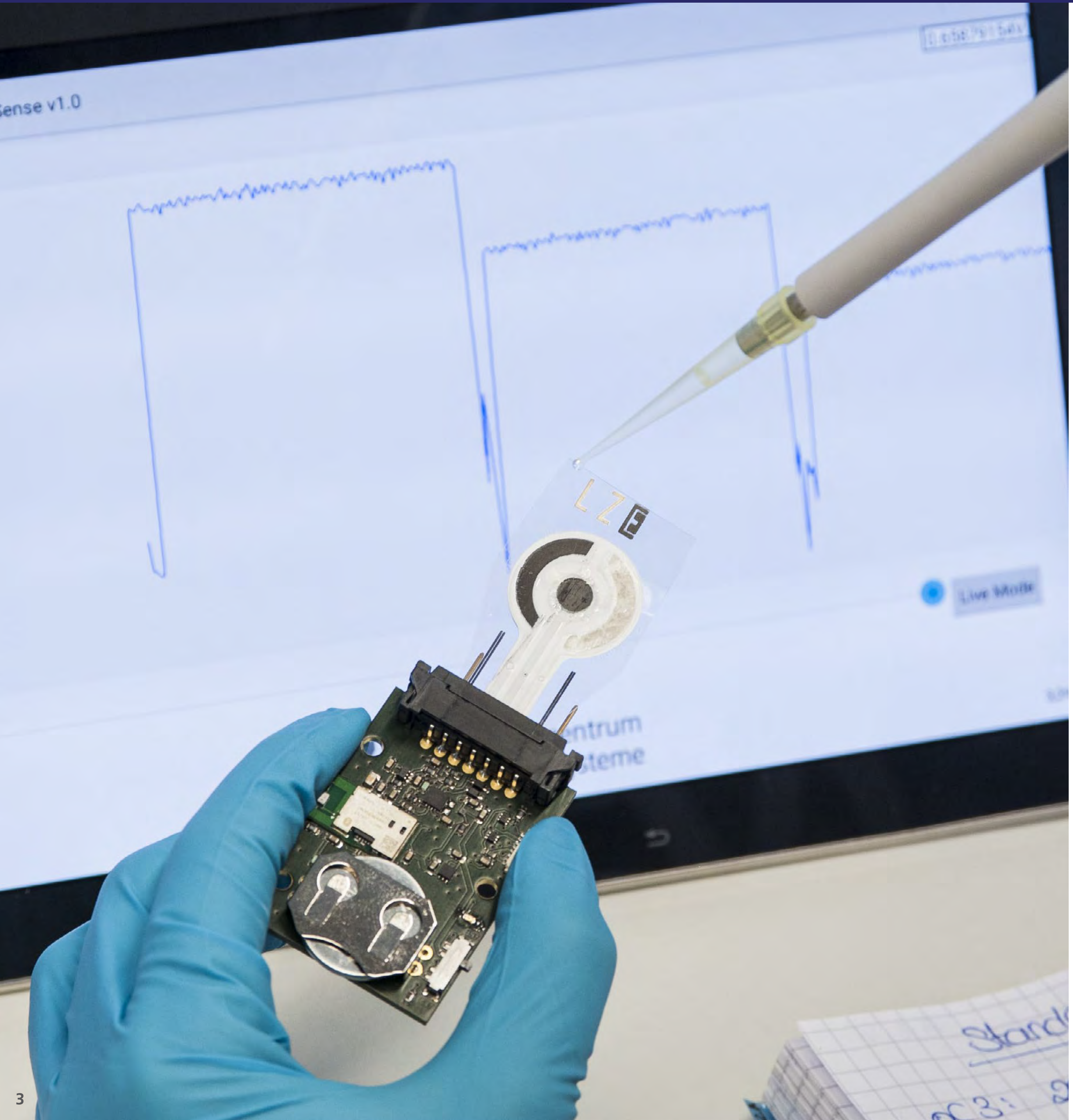
The invention of the new fabrication approach was also honored with the "Innovation Award" conferred by the "Erlangen Graduate School in Advanced Optical Technologies" to IISB scientist Maximilian Rumler in June 2016. Mr. Rumler has since used the prize money to push his research idea forward and determine the possibilities and limitations of the fabrication approach.

ELECSA® Printed Electrolyte Sensors for Wearables

Wearables evaluating vital parameters of the human body during sports activities meet the current trend of self-monitoring. Current systems obtain electrically or mechanically accessible data such as heart or breathing rates. The combination of these parameters with physiologically motivated, biochemical signals obtained from the analysis of sweat improves the assessment of the body status in sports performance diagnostics for leisure and professional athletes.

The developed electrolyte sensor is fully printed on flexible substrates, e.g., foils and textiles, and is able to analyze and monitor biomarkers such as ammonium ions and electrolytes such as potassium and sodium ions in liquid media. Increased ammonia expression in sweat is known as a





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key parameter for the detection of muscular overstrains, as it is directly related to the metabolic degradation of proteins in the muscles.

The sensor uses an ion-selective working electrode and a reference electrode for potentiometric measurement of the electromotoric force, EMF. An adapted mixture of specific ion acceptors in a polymeric matrix is drop-casted on top of a suited metal to form the working electrode. The ELECSA® electrolyte sweat analysers are calibrated using ammonium standard solutions at a working range between 10 - 5 M to 0.1 M, which corresponds to the range of physiological levels of ammonium in sweat at rest and during physical strain. The potentiometric characterization of the ion-selective sensor shows a linear behavior of the EMF versus pC values at higher concentrations and delivers a specific variation of about ~60 mV per decade of ammonia ion concentration, meeting the theoretical prediction according to Nernst. Furthermore, artificial sweat solutions were tested to characterize the device under realistic conditions. The deviation between the EMF values measured in ammonium standard solution (NH_4Cl dissolved in DI water) and a corresponding solution in artificial sweat are less than 10%, proving the robustness of the sensor against environmental distortion.

For integration in wearables, electronics were co-developed with the LZE partner Fraunhofer IIS. The application can be used by itself, or it can define the interface for further integration in the IIS FitnessSHIRT system. The heart of the device is a system on a chip (SOC) that contains a microcontroller (MCU) for data acquisition and processing as well as wireless connectivity. The EMF is stabilized and related to the MCU's ground potential by a high-impedance unity gain preamplifier. After analog-to-digital conversion, the measured EMF values are transmitted to a mobile device by a Bluetooth low-energy protocol. Monitoring and recording of the sensor signal are realized by a specifically developed Android application that can be run on smartphones or tablets.

The combination of low-cost printed sensors, potentiometric sensing, and the integration, e.g., with textiles represents a very attractive approach for non-invasive monitoring of individual sports performance. The largest benefit of this kind of sensor device is to prevent overstrain during physical training and give a holistic view of body status with important vital parameters. The integration in mobile devices and the low-cost technology of the electrolyte sensors further show high potential for other markets, especially for medical technology, eldercare, agriculture, as well as the food and water industry.

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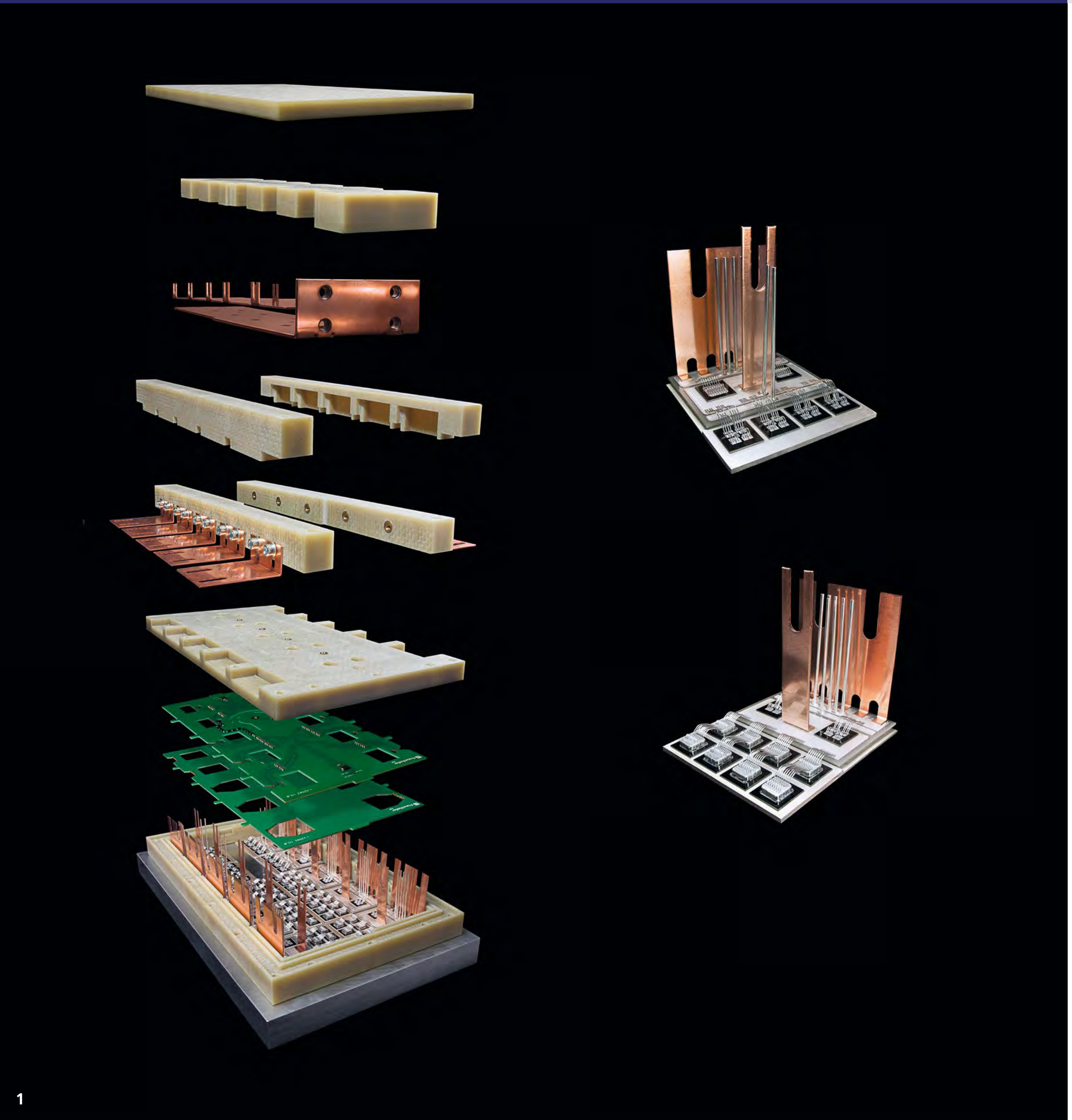
3 *Sensor system with circuit board and data acquisition/ transfer via Bluetooth 4.0. The mobile device shows system response to two consecutive concentration drops for one order of magnitude.*
© Fraunhofer IISB

4 *Shrinking of screen-printed electrolyte sensors for reduction of area and materials input.*
© Fraunhofer IISB

DEVICES AND RELIABILITY



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The department acts as a bridge between the "semi-conductor technology" business unit, which is focused on materials and processes, and the system-oriented "power electronics" business unit. The fields of research are active and passive devices, packaging technology and concepts, as well as lifetime testing, modelling, and reliability.

The development of silicon carbide devices has gained further momentum during this year at Fraunhofer IISB. Additional collaborations with several international partners has enabled the development of a gate oxide module for SiC VDMOS transistors that allows for normally-off device operation up to 175 °C, a high yield, and excellent reliability. Moreover, a channel mobility of 18 cm²/Vs was obtained. This module is part of a modular SiC process technology that will enable the fabrication of 1200 V VDMOS transistors with on-state resistance below 10 mOhm cm² at 150 °C. Even lower on-state resistance can be obtained by implementing trench gate technology. Further activities to this extent have also recently been started.

One of the institute's cutting-edge devices under development are solid-state circuit breakers using 4H-SiC bipolar injection field effect transistors. These devices are self-triggering, resettable electronic fuses that detect an externally defined overcurrent. The device concept used is based on thyristors employing dual JFET devices.

Finally, UV A/B sensitive, visible-blind 4H-SiC sensors were developed in an integrated project funded by the European Union. The derivation of a TCAD model for the optical properties of these 4H-SiC pin structures allows precise control of the device design regarding spectral sensitivity. Even more, 4H-SiC UV sensors with quantum efficiency tuned for a particular application can be realized.

For fast switching of power semiconductor devices such as GaN HEMTs and SiC VDMOS transistors, parasitic inductances in power modules must be handled. Silicon RC snubbers assembled directly on the DBC next to the power switches were identified as a promising alternative to developing low-inductive power modules. After the development of 200 V and 600 V RC snubbers was successfully completed over the last decade, 1200 V RC snubbers are now under investigation in two publicly funded projects. This latest class of high-voltage silicon RC snubbers could be paired with SiC power transistors in the 1200 V range.

In the field of packaging, new publically funded research projects were started in 2016. One of these is called "Vorsch". It is supported by the Bavarian Ministry of Economic Affairs and Media, Energy, and Technology. The aim is optimized thermal management with silver sintered semiconductor devices on organic printed circuit boards. A novel process is under development for a selective silver sintering step after the board is populated with common SMD devices.

1 *Novel Modular Multilevel Converter Submodule © Fraunhofer IISB*

2 *Andreas Schletz, head of the Devices and Reliability department. © K. Fuchs / Fraunhofer IISB*

DEVICES AND RELIABILITY

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The project EMiLE, which is sponsored by the Federal Ministry of Education and Research (BMBF), was successfully finalized with the application of a new type of power module concept. It is based on a lead frame approach. The semiconductors of the top and bottom switches were stacked for a very low parasitic inductance in combination with a very good EMC behavior. In addition to that, IISB's monolithic integrated silicon DC link capacitor was integrated into the new power module, enabling superior switching behavior. In addition, solutions were developed in the project for sintering on copper surfaces without pressure assistance. Advanced high-temperature insulation materials and measures were applied for these kind of double-sided module concepts.

The planning and the installation of a new clean room for new packaging concepts and technologies were finalized. The first tools arrived in the beginning of 2017 to form a complete packaging line for storage, printing, die bonding, soldering and sintering, encapsulation, and testing. The institute is now ready for future work in 3D packing topics.

The research activities around testing and reliability were strengthened by a continued material characterization for the next generation of lifetime modelling for power electronics. Besides the bond line of semiconductor devices, other materials are moving into focus. The characterization is accompanied by statistical evaluation that gives a better understanding of some lifetime test results, especially at high temperatures. A new publically funded research project ("HELENE") was started in 2016 (supported by the BMBF). The aim is to develop a physics-of-failure-based lifetime model for the wear of discrete packages on printed circuit board designs.

In addition, the testing of ceramic capacitors was expanded. The devices will play a big role in the future of power electronic filters and DC links thanks to their high energy and power densities and their ability for high temperature usage. Test methods were developed to characterize the capacitors in terms of electrical parameters, especially under high voltage and temperature. A first step towards self-heating was taken with the design and setup of a tool. From now on, thermal management can be done with this type of devices, allowing them to play a more active role within power electronics.

In addition to the new publically funded projects started in 2016, there were a huge number of bilateral industrial projects in all research fields. The topics range from assistance and consulting to large feasibility studies and process developments for devices, packaging, and testing. The applied research within the department is financed by an industrial budget contribution of well above forty percent. This perfectly hits the Fraunhofer target.

One big step for the department was the merger of all research groups in one location at the Erlangen site, which is the headquarters of the institute. The complete 700 m² branch lab "Nuremberg south, ZKLM" was successfully moved. All staff and equipment had to be transferred during day-to-day business. Erlangen offers a better infrastructure inside the building, suiting the needs of the work. The main benefit is excellent communication among all staff due to very short distances.

Many thanks to all colleagues for their support during difficult days and the excellent, successful work that makes the institute ready for the future.

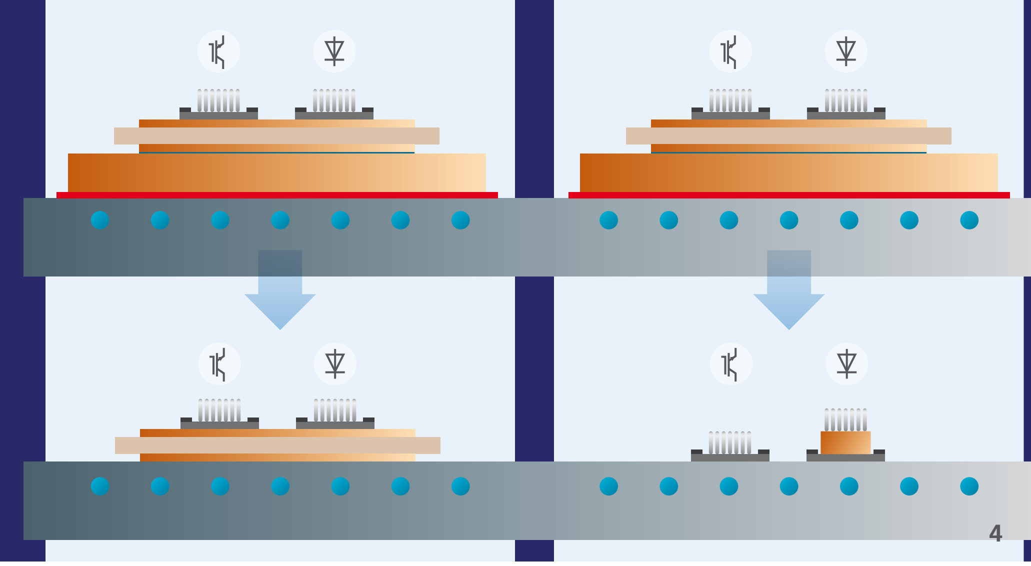
Concept for Modular Multilevel Converter Submodules

Power electronic systems are one of the core technologies that enable our energy supply to change to a self-sufficient and renewable global energy system. This includes the entire supply chain starting from the power generation, through to the power transmission, and the power distribution to the consumer. In particular, since the implementation of novel modular multilevel converters (MMC), it has been possible to control the energy flow in the grid with a very high flexibility and efficiency. One of the most important applications for such converter types are the high-voltage direct-current transmission systems (HVDC) that are used to connect offshore wind parks to the national electricity grid. In addition to HVDC, there are numerous other fields of application in the power supply system, e.g., static power factor correction (SVC) or bi-directional coupling of different grids.

Novel innovative and economic power electronic sub-components for MMCs, in particular the MMC submodules, were developed within the publicly funded project EnCN Megawatt of the "Energy Campus Nürnberg". Due to the utilization of standard high-voltage power modules for the submodules in the MMC topology, a lot of component and system costs can be saved by adopting the modules to the special boundary conditions of MMCs.

The basic configuration of a three-phase MMC consists of six legs. One leg includes one inductor and a multitude of series-connected identical submodules. Each submodule is composed of a DC capacitor and two active switches (IGBTs and freewheeling diodes) forming a half-bridge topology. Standard industrial semiconductor power modules (e. g. 3.3 kV or 6.5 kV) are utilized in high-voltage energy applications with DC voltages above 300 kV. The number of required submodules is determined by the DC system voltage and the voltage rating of the used semiconductors (e.g. up to 1500 submodules for a 400 MW HVDC system). In special fault situations, such as short circuits of the DC power lines, the diode semiconductors of one switch have to withstand high pulse currents. In many cases, an external bypass thyristor is installed in parallel to these diodes to provide a relief path. Due to the special surge, current-requirement press-pack

DEVICES AND RELIABILITY



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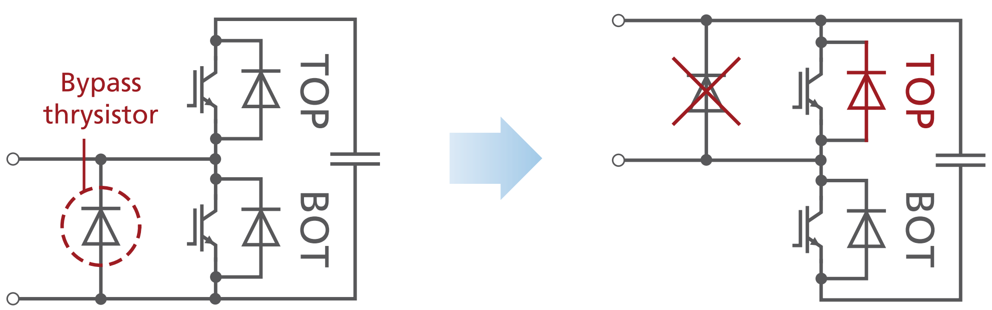
thyristors are used at this position. In addition to the cost-intensive standard industrial power modules, this auxiliary safety component causes additional costs for the thyristor, the combination of different packaging technologies (press pack thyristor and wire bonded power modules) and the control effort.

As all MMC submodules are insulated against each other, the top switch (TOP) semiconductors in the submodule topology (see figure 4) can be mounted directly onto the electrically conducting heat sink. For the BOT switch semiconductors, insulating substrates are still required, but the baseplates and thermal interface materials can be removed. These measures save a lot of intrinsic power module components such as the cost-intensive AlN-DBCs (directly bonded copper substrate) and AlSiC baseplates. Furthermore, the thermal performance can be improved significantly, which also reduces the required chip area. Thermal FEM simulations and measurements were performed to find the economic optimum for this packaging concept.



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As mentioned above, the TOP diode semiconductors of each submodule half-bridge have to withstand high surge currents in fault situations. Instead of installing external bypass thyristors in order to avoid a destruction of the power modules, the novel packaging concept considers additional thermal capacity. Therefore, a conceivable and promising solution is to join copper blocks as top side heat buffers on the concerned diodes. These heat buffers work as an intrinsic safety control.

As depicted in figure 4, insulating substrates are still required to realize the half-bridge circuit. However, the thickness and consequently the costs of these ceramic insulation layers can be reduced by homogenizing the electrical field distribution through optimized metallization edge structures and special coating technologies. A comprehensive experimentally (partial discharge testing) based study showed a possible thickness reduction of over 30%.

Moreover, the system operators of energy systems claim a lifetime of over 40 years. Therefore, the power modules also have to withstand thousands of temperature swings from the environment and billions of switching operations. By changing the standard packaging of these thick high-voltage semiconductors (6.5 kV) with this novel optimized concept, the lifetime as well as the failure mechanism had to be examined. Thus, lifetime investigations of high-voltage semiconductors on different heat sink materials and geometries using different joining technologies (e.g. soldering or silver sintering) were carried out within this project. The experiments showed a comparable lifetime of the novel concept with standard costly HV power modules.

As a final step in that project, a demonstrator of the novel submodule with 6.5 kV IGBT and diode semiconductors for an exemplary 1280 MVA HVDC system was constructed in detail (figure 1), showing all benefits of that novel submodule concept. All in all, the submodule costs can be reduced by over 30%, guaranteeing the same lifetime compared to the state-of-the-art concepts. With a suitable combination of the investigated packaging techniques, only a slight increase in chip area leads to the necessary surge resistance of the diode in order to save the external bypass thyristor of each submodule.

3 *Novel submodule topology*
© Fraunhofer IISB

4 *Novel submodule assembly concept*
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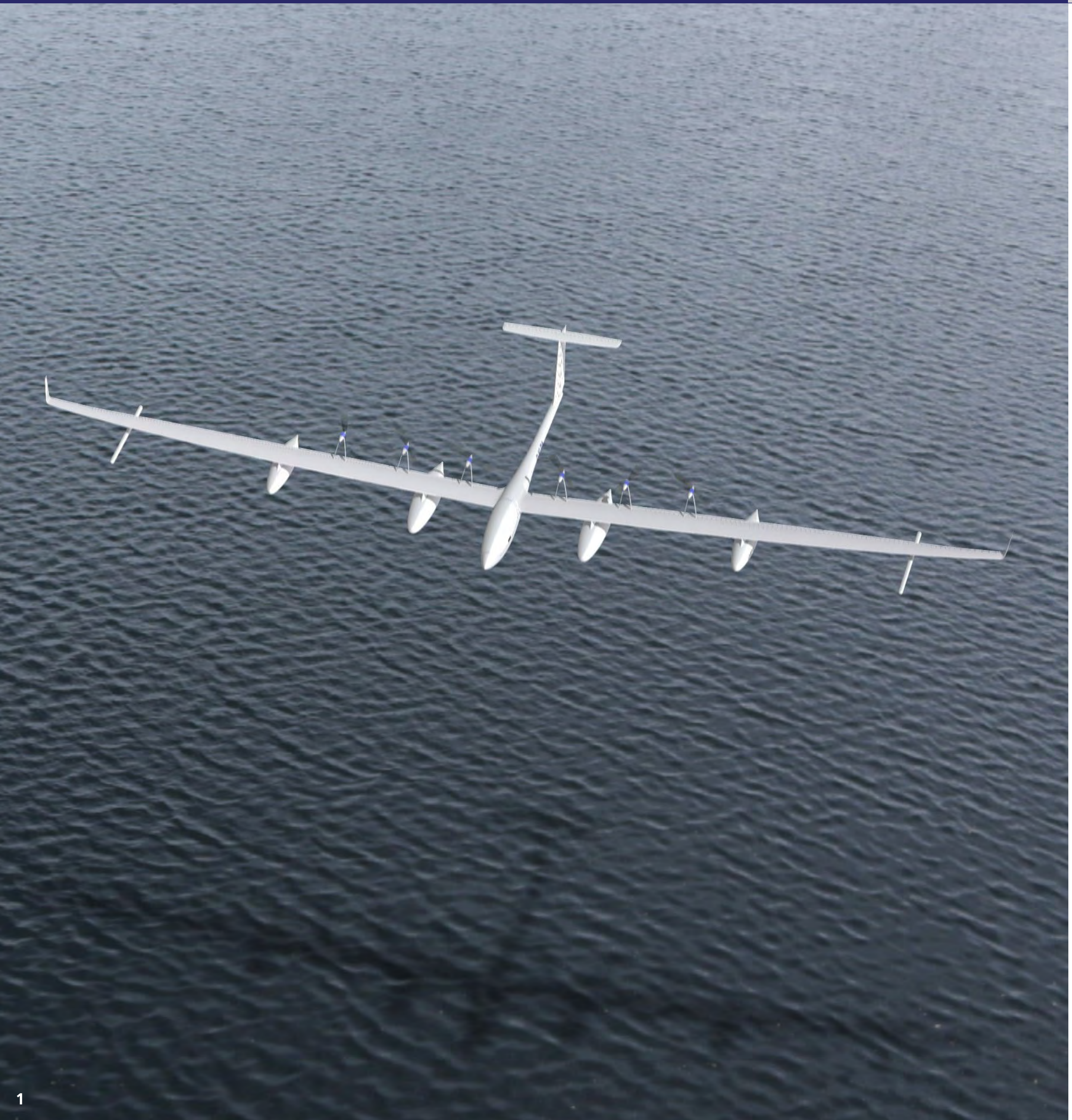

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Despite the fact that the market for electrically driven vehicles is growing very slowly in Europe, the Vehicle Electronics department faced an increasing demand for the research and development of advanced power electronic solutions for battery electric vehicles (BEV) as well as for plug-in hybrid vehicles (PHEV) in 2016. This was driven by a strong interest of OEMs in higher voltage levels of up to 850 V instead of 450 V. With the higher voltage, it is possible to make the wiring of a high-power electric drive system more lightweight and cheaper, but the biggest benefit is seen in the possibility of super-fast charging, in the future with up to 400 kW. With this huge charging power, it is possible to recharge a car for the next 300 km in just 10 minutes. The higher voltage level is necessary to achieve such high charging powers because the possible current is limited to the range of 500 A to stay with the current standardized Combined Charging System (CCS) connector and keep the handling as easy as it is.

1 *Full electric powered aircraft of Lange Research Aircraft GmbH.*
© Lange Research Aircraft GmbH

2 *Dr. Bernd Eckardt, head of the Vehicle Electronics department.*
© K. Fuchs / Fraunhofer IISB

Robust mechatronic system integration

In addition to these new charging concepts, the way to higher voltage levels was paved by the availability of new 1200 V SiC MOSFETs that outperformed conventional Si IGBTS in respect to conduction and switching losses. In conjunction with advanced passive components such as capacitors and mechatronic designs using 3D additive manufacturing techniques such as 3D laser sintering, these devices make new high-integration concepts possible. Such space-saving systems can be easily integrated into the powertrain of future cars. This presents new challenges for the mechanical robustness of electronic systems. They must withstand high vibration and shock loads. This challenge was tackled by focusing on the modelling, simulation, and testing of vibration robustness and creating design criteria for robust mechanic designs.

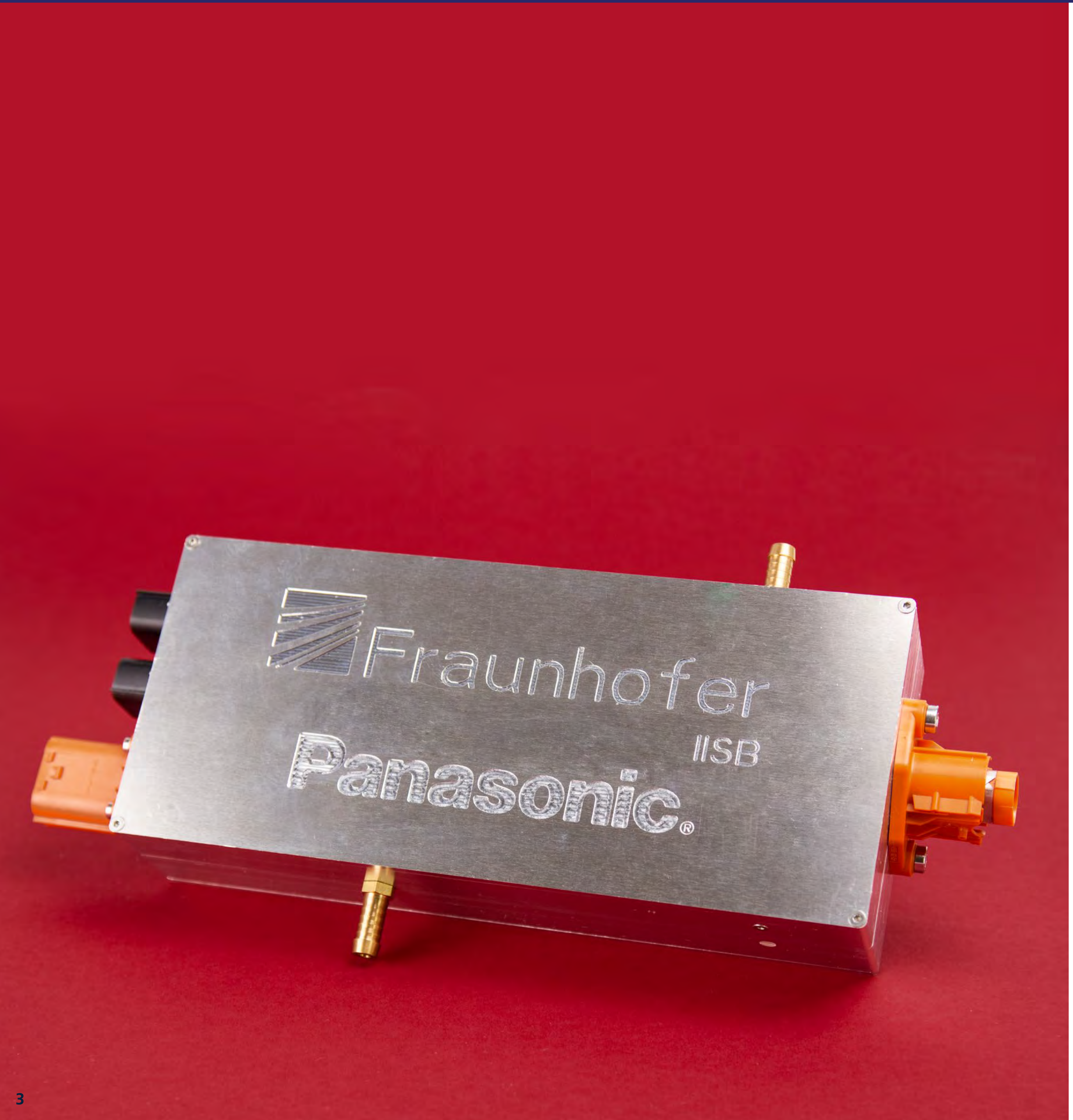
Electric aircraft propulsion

Besides robustness, weight also increasingly matters when our solutions are aimed at high-performance motor sports applications. Such lightweight solutions can even create completely new applications for power electronics.

In the last year, we had more and more requests for power electronic solutions for the electric propulsion of small-sized aircrafts, where very lightweight components are needed. This presents new challenges for our development of high-power-density drive inverters and DC/DC converters, especially demands regarding high altitude, radiation hardness, and fail-operational designs.

Many challenging industry projects were started in 2016

After finalizing many successful research projects such as the BMBF-funded Emile, HHK, and InSeL or the EnCN project funded by the state of Bavaria, we were able to start several industry



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projects. This is a great possibility for transferring the latest results from research to running prototype systems.

Sincere thanks to all colleagues for their extraordinary work, to all our partners from industry and politics for their support, and to the institute and the Fraunhofer Society for giving us these great opportunities.

Bidirectional 6kW Charger Using GaN Devices

Insulated and Bidirectional On-board Charger With Normally-Off GaN Gate Injection Transistors

New power semiconductors such as 600 V normally-off GaN gate injection transistors (GaN GITs) offer new opportunities for power topologies especially in bidirectional power-flow applications. There are very interesting implementations in bidirectional on-board chargers (OBC) for electric vehicles. Here, a bidirectional energy flow can either be used for vehicle-to-grid scenarios or for providing a high-power on-board AC socket. Because of a very low output capacitance and the ability of reverse current operation, GaN GITs offer advantages in hard switching topologies (low switching losses) as well as in soft switching topologies, where no additional leakage inductance is necessary.

Within a bilateral project with Panasonic, the Fraunhofer IISB has developed a bidirectional insulated OBC specially designed for the customer. The result was a novel 6 kW OBC with normally-off GaN gate injection transistors from Panasonic presented within only 2 dm³. The OBC is fully digitally controlled by using a special current regulator technique to reduce the higher grid harmonics. The utilized insulated power stage works like a DC transformer, determining primary-side DC operation voltage without applying any voltage regulator. The two-phase OBC consists of six equal full-bridge power modules next to the gate driver circuitry and DC link capacitors following a modularized approach.

A very high power density of approx. 3 kW/dm³ was reached with the developed prototype – which means an outstanding value for a complex bidirectional galvanically insulated OBC.

3 *Insulated and bidirectional on-board charger with normally-off GaN gate injection transistors - housing. © Fraunhofer IISB*

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4 *Insulated and bidirectional on-board charger with normally-off GaN gate injection transistors - insides.*
© Fraunhofer IISB

Challenges and solutions

To obtain the full performance of modern wide-band-gap power semiconductors such as GaN GITs, a low inductive realization of the switching power paths is necessary. Hence full-bridge power modules were developed with four 600 V (34 mΩ) Panasonic normally-off GaN GITs soldered and bonded on a FR4 together with gate drive units and DC-link capacitors.

To obtain a high efficiency OBC, a modern totem-pole circuit topology for converting the AC mains voltage to an internal DC-link voltage was chosen. For the galvanically insulated power stage, a low-loss soft-switching so-called CLLC converter was used. For extending the very efficient operation area, a switchable variable transformer ratio was implemented.

Hence, the AC/DC as well as the insulated DC/DC power stage achieve approx. 98% efficiency.

The performance of modern power electronic systems is not only dominated by power semiconductors but by control circuits as well. In this project, the 6 kW output power was divided into two identical 3 kW units each controlled by a 32 bit micro controller. Each microcontroller controls 12 power switches at a high switching frequency at approx. 130 kHz. Due to restrictions of the higher harmonic 50/60Hz grid frequency, the control of sinusoidal AC mains current is important. For this, a special version of the so-called low bandwidth current mode control technique, which is based on a non-linear feed forward control method, could be successfully implemented.

Due to the chosen double 3 kW power units, the OBC can be also used on two phases of the common three-phase 400 V AC mains system. In this case, the battery current has a pure DC portion with a superimposed AC sinusoidal content.

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ENERGY ELECTRONICS

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The Energy Electronics department focuses on power electronic systems for electrical energy supply. Target applications cover the entire power range, from a few watts up to gigawatts. The department is organized in four working groups, with a total of about 40 researchers:

The “Applications” group, headed by Mr. Markus Billmann, supports our customers in solving power electronic application problems. Whether development support or problem analysis for running facilities, the list of strengths of this group is long: longstanding application experience, fast response time, and familiarity with industrial work processes.

The focuses of the “Energy Systems” group, headed by Mr. Dirk Malipaard, are research and development on multi-level inverters in all power and voltage ranges, with a focus on medium-voltage applications (1 to 20 kilovolts). This group is based in the Energy Campus Nuremberg (EnCN).

The “Battery Systems” group, headed by Dr. Vincent Lorentz, is working on innovative solutions for Li-ion-based electrical energy storage systems for stationary and mobile applications. The activities range from the development of battery management systems, algorithms for Li-Ion SoC/SoH modeling, up to the design of full-custom high-power energy storage systems for mobile and smart grid applications.

The “DC Grids” group, under the direction of Mr. Bernd Wunder, focuses on innovative solutions for local DC grid systems. Their work ranges from basic research, e.g., on safety and stability issues of DC networks, through concept studies, up to the development of innovative grid components, such as customized DC/DC converters, DC plugs, and protection devices. The group manager, Mr. Wunder, also represents the DC topic on boards such as VDE/DKE, IEC, eMerge Alliance, and IEEE Smart Grid.

A highlight in 2016 was undoubtedly the very successful launch of the open-source project “foxBMS”. foxBMS is a free, open, and flexible development environment for the design of battery management systems. It is the first really universal development environment and platform providing a fully open-source battery management system able to manage modern and complex energy storage systems. foxBMS aims to accelerate the research, development, and test processes used in the mobile and stationary electrical energy storage domains by using seamless development processes. It is perfectly suited for research and development, including fast prototyping and testing. The beta-test period started with 15 international partners in 7 countries worldwide and ran until the end of 2016. Since 2017, foxBMS has been generally available.

Another highlight was the appointment of Prof. Maerz, the head of the department, as a full professor at the Chair of Energy Electronics (LEE) at the University of Erlangen-Nuremberg (FAU). The cooperation with the new chair will greatly strengthen the scientific basis in the field of energy

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1 *foxBMS® is a free, open and flexible development environment for the design of battery management systems for mobile and stationary applications. © Fraunhofer IISB*

2 *Prof. Martin März, head of the Energy Electronics department. © K. Fuchs / Fraunhofer IISB*

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electronics. Common research topics are new technologies for power electronic converters for the medium voltage range with special consideration of new semiconductor devices (SiC, GaN, ...), semiconductor-based safety and protection elements for DC grids in the low and medium voltage range, stability analysis in DC electric grids that are dominated by power electronics converters, and the lifetime and availability of power electronic equipment, including fault-tolerant systems. In addition to stationary decentralized electrical power systems, the addressed application fields also include the power networks in vehicles, ships, railways, and airplanes. The new is located on the premises of the Energy Campus Nuremberg (EnCN) in the direct neighborhood of the Energy Systems group of Dirk Malipaard.

At the Light + Building exhibition in Frankfurt for the first time, the DC Grid group was able to present an innovative, energy-self-sufficient work desk, a project together with the industrial partner Bachmann, a leading provider of work desk energy distribution solutions. The new work desk solution comprises a smart and handy Li-battery pack with enough energy to supply a fully equipped work desk for a complete work day, making the work desk extremely flexible and fully independent of a building infrastructure. Energy distribution on the work desk itself is based on the USB-PD standard. In 2017 the first spin-off of the department will start commercializing the battery system.

Today, the Energy Electronics department covers the entire application range in the field of electrical power supply, from the work desk level to grid and energy generation systems of the highest power. The department is therefore well prepared for the challenges and opportunities of the "energy revolution" and has already become a powerful and sought-after development partner for industry.

Apart from this, an impressive number of industrial projects were successfully completed. There were also 25 supervised bachelor's and master's theses, 14 scientific publications, and 18 lectures. In addition to our very well received monthly colloquium on power electronics, three seminars were organized for and in cooperation with the Bavarian cluster "Power Electronics". Sincere thanks to all colleagues in the department for their extraordinary dedication, to all our supporters from industry, politics, and Fraunhofer, and to the entire institute.

foxBMS

What is foxBMS?

foxBMS is a free, open, and flexible development environment for the design of battery management systems. It is the first really universal development environment and platform providing a fully open-source battery management system able to manage modern and complex energy storage systems. foxBMS aims to accelerate the research, development, and test processes used in the mobile and stationary electrical energy storage domains by using seamless development processes. It is perfectly suited for research and development, including fast prototyping and testing. The foxBMS hardware and software building blocks are used at Fraunhofer IISB in our 60 kWh stationary battery system (based on lithium-ion NMC/LTO battery cells) and in our electric vehicle (based on lithium-ion NMC/graphite battery cells), where it has obtained a road homologation.

With foxBMS, Fraunhofer IISB delivers the first generation of its open-source battery management system (BMS) research and development platform. The foxBMS platform is completely free and open, designed for a maximum of flexibility, and comprehensively documented. It includes all necessary hardware and software for potentially any kind of mobile and stationary application that uses modern rechargeable electrochemical energy storage systems (e.g., lithium-ion batteries, redox-flow batteries, supercapacitors).

foxBMS hardware: The schematics and the layout of all electronic boards are available for download, and the design is based on commonly available components and devices that do not require NDAs or confidentiality agreements.

foxBMS software: The software toolchain uses only own-developed open-source and free-of-charge components or free-of-charge third-party software, and the entire BMS source code is provided online with its own development environment and configuration files, thus enabling immediate use on Windows, Mac, and Linux operating systems.

Experience gained from international research and development projects over the last 15 years in the field of electrochemical energy storage systems at Fraunhofer IISB has been implemented in the hardware and software of the foxBMS platform. It is designed to manage high-performance prototypes of advanced and innovative lithium-ion battery systems of any size (i.e., from a few cells up to several hundreds of kWh and kW), especially for systems requiring the highest availability and safety levels. The free and open-source version of foxBMS is not intended for immediate use in commercial products, as they have to meet specific standards and require application-dependent certifications. foxBMS is a safe research, development, and test platform providing all functions for managing the complexity and size of state-of-the-art electrochemical energy storage systems.

Specific adaptions of foxBMS can be ordered directly from Fraunhofer IISB or can be jointly developed, for example for automotive, aviation, space, submarine, industrial, and renewable energy storage applications.

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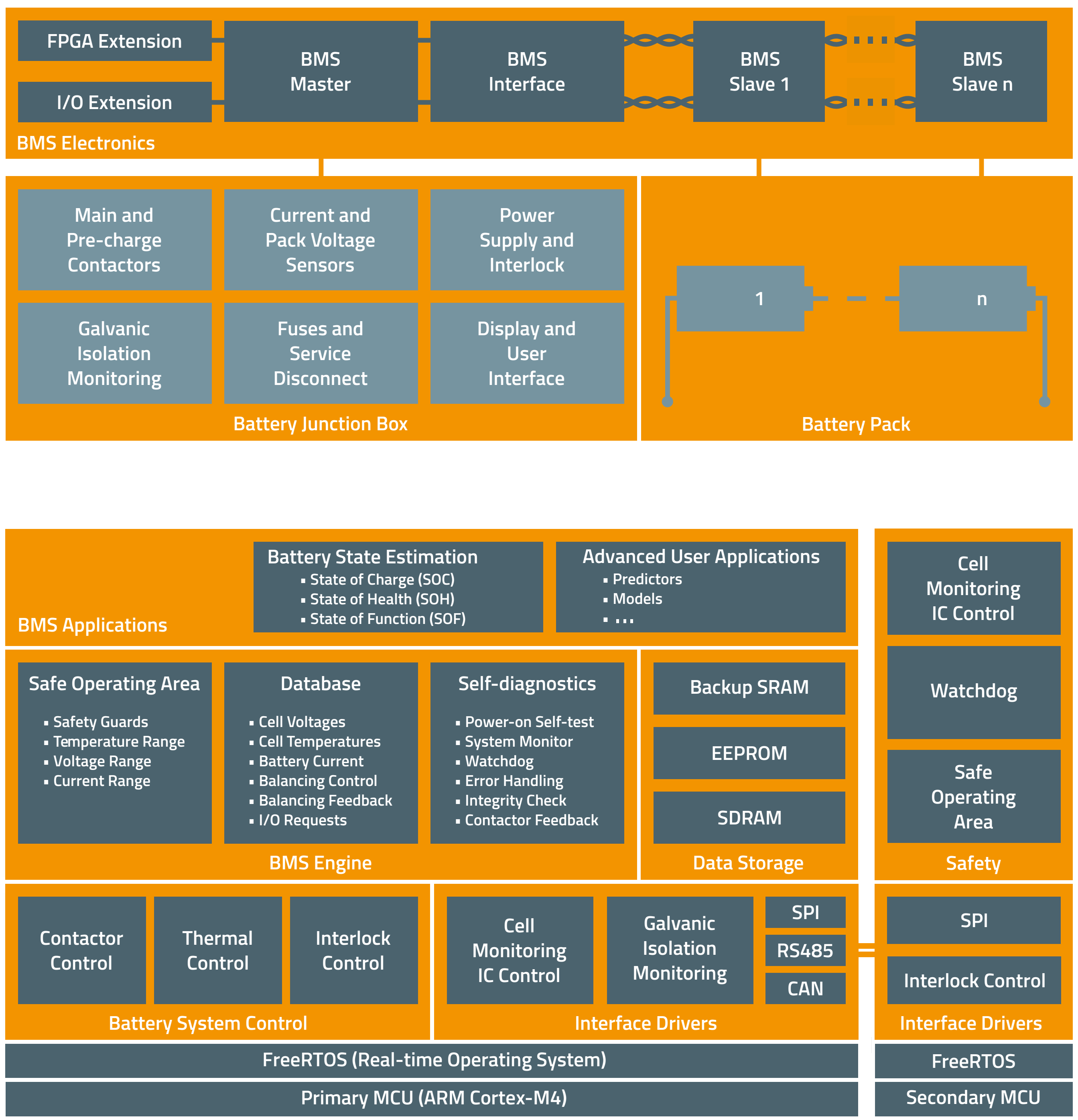

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3 *Schematic overview of the foxBMS hardware and the foxBMS software.*
© Fraunhofer IISB

Who is the intended audience?

foxBMS is a free and open BMS platform that can be used for developing and testing products. The foxBMS hardware and documentation are licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license. The foxBMS software is licensed under the BSD 3-Clause license. This means that foxBMS parts can be utilized unrestrictedly, including commercial use.

The foxBMS platform addresses especially:

- R&D and test engineers requiring a smart and powerful, well documented BMS platform
- Engineering companies requiring a maintained and supported BMS for their developments
- Small enterprises requiring a flexible and future-proof BMS for developing their products
- Large enterprises requiring a reliable and safe BMS for testing their prototypes
- Research organizations requiring a simple and universal BMS development platform
- Students looking for a free and open BMS software development toolchain

Technologies

foxBMS is suitable and adaptable to current and future rechargeable energy storage systems based on lithium-ion batteries (LIB) or comparable electrochemical rechargeable accumulator cells (e.g., other chemistries such as lithium-sulfur, sodium-ion, or even all-solid-state batteries), lithium-ion capacitors (LIC), electric double-layer capacitors (EDLC or supercapacitors), or even vanadium redox-flow batteries (RFB).

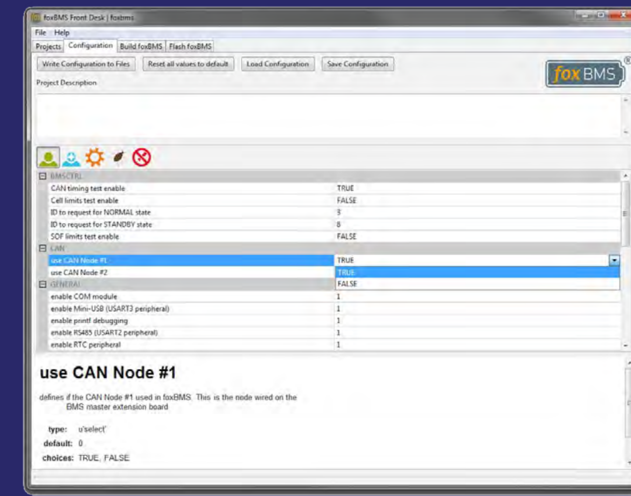
Applications

foxBMS can be implemented in potentially any area of activity, such as in the automotive, aviation, space, (sub)marine, railway, industrial, consumer, and renewable energy domains. The hardware and software building blocks are under perpetual and intensive development, thus evolving constantly and being updated regularly. Commercial hardware and software adaptations to specific application requirements can be inquired anytime by contacting us.

Environment

The architecture of foxBMS is the result of more than 15 years of development in innovative hardware and software solutions for lithium-ion battery systems at IISB in Erlangen. The foxBMS hardware and software building blocks are used as a battery management system at Fraunhofer IISB in nearly all of our research and development projects. Our self-developed 60 kWh stationary lithium-ion battery system and our road-homologated electric vehicle are two examples.

ENERGY ELECTRONICS



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Hardware

The hardware of foxBMS is designed in a redundant way to allow a safe software development process. It enables the management of high-performance prototypes of complex lithium-ion battery systems of any size (i.e., from one cell up to several hundreds of cells). The redundant hardware architecture of foxBMS is well suited to develop battery systems requiring a high level of safety and availability. The hardware is licensed under the Creative Commons Attribution 4.0 International (CC BY 4.0) license and contains only commonly available components and devices that do not require any confidential agreements.

Software

The software implemented in foxBMS uses only specifically developed open-source and free-of-charge software components or free-of-charge third-party software. The entire source code of foxBMS is provided online on GitHub, and it includes its own development environment and configuration files, thus enabling immediate use on Windows, Mac, and Linux operating systems. The software is licensed under the BSD 3-Clause license. All foxBMS parts can therefore be utilized unrestrictedly, including free and open-source use, as well as closed-source commercial use.

Type of services we offer in relation with foxBMS

- Distribution of electronic battery management system board prototypes
- Design of electronic BMS hardware and optimization for your specific requirements
- Development of embedded BMS software and configuration for your specific environment
- Modelling of battery cells (electric and thermal) for accurate state estimation algorithms (e.g., SOC, SOH)
- Prototyping of complex battery systems
- Consulting in the field of battery systems and failure analysis

4 *foxBMS master control unit and slave (monitoring unit). © Fraunhofer IISB*

5 *Screenshot of the foxBMS graphical user interface (GUI) for software configuration. © Fraunhofer IISB*

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Electricity from Industrial Exhaust Gas – Fuel Cell System for Hydrogen Gas Mixtures

At the Fraunhofer IISB, a system that converts hydrogen-rich exhaust gas from a semiconductor manufacturing unit into electricity has been developed as part of the Bavarian energy research project SEEDs. For many years, the institute has been researching the optimization of epitaxy processes for producing modern semiconductors – especially in the area of silicon carbide components (SiC), which are required for modern power electronic systems. The epitaxy process, in which thin films of semiconductor material are created, requires large amounts of hydrogen as a carrier gas. Together with other process gases, this creates a hydrogen-rich exhaust stream in the epitaxy facility. Previously, this exhaust stream was cleaned and then released into the atmosphere. The energy content of the hydrogen remained unused in the process.

Greater efficiency from converting non-pure hydrogen exhaust gas into electrical energy

Researchers at Fraunhofer IISB have made it their mission to convert the previously unused energy of the hydrogen-rich exhaust gas into electrical energy. In this way, the hydrogen, which is only used as a carrier gas in the epitaxy process, serves a second purpose as well. This increases the resource and energy efficiency of semiconductor processes. In view of the large worldwide production volume of semiconductor componentsdevices, this method has a high application potential.

Intelligent solution with state-of-the-art fuel cell technology

The heart of the electricity conversion system is a polymer electrolyte membrane (PEM) fuel cell that efficiently converts hydrogen from the exhaust gas with oxygen from the ambient air into electrical energy. Modifications to the fuel cell system that were developed by IISB researchers allow the fuel cell system to work with hydrogen concentrations between 40 and 100% by volume. The fuel cell system is thus also able to convert non-pure hydrogen or a hydrogen mixture into electricity. Conventional fuel cell systems, on the other hand, require a hydrogen purity of at least 99.97% by volume. This is the world's first conversion of epitaxial exhaust gas to electricity in a fuel cell.

A special diaphragm compressor is used between the exhaust line and the fuel cell system. This compresses the exhaust gas that is present at atmospheric pressure before the fuel cell and thereby decouples the electricity conversion and epitaxy process. The electricity conversion system thus does not affect the sensitive epitaxial process, its process quality, or the gas cleaning system of

1 *Researchers at Fraunhofer IISB in Erlangen have developed an electricity conversion system for hydrogen-rich exhaust gases. This is the first time that epitaxial exhaust gas has been converted into electricity in a fuel cell. © K. Fuchs / Fraunhofer*

2 *Epitaxial reactor VP508 GFR at Fraunhofer IISB and operator during loading. © K. Fuchs / Fraunhofer IISB*

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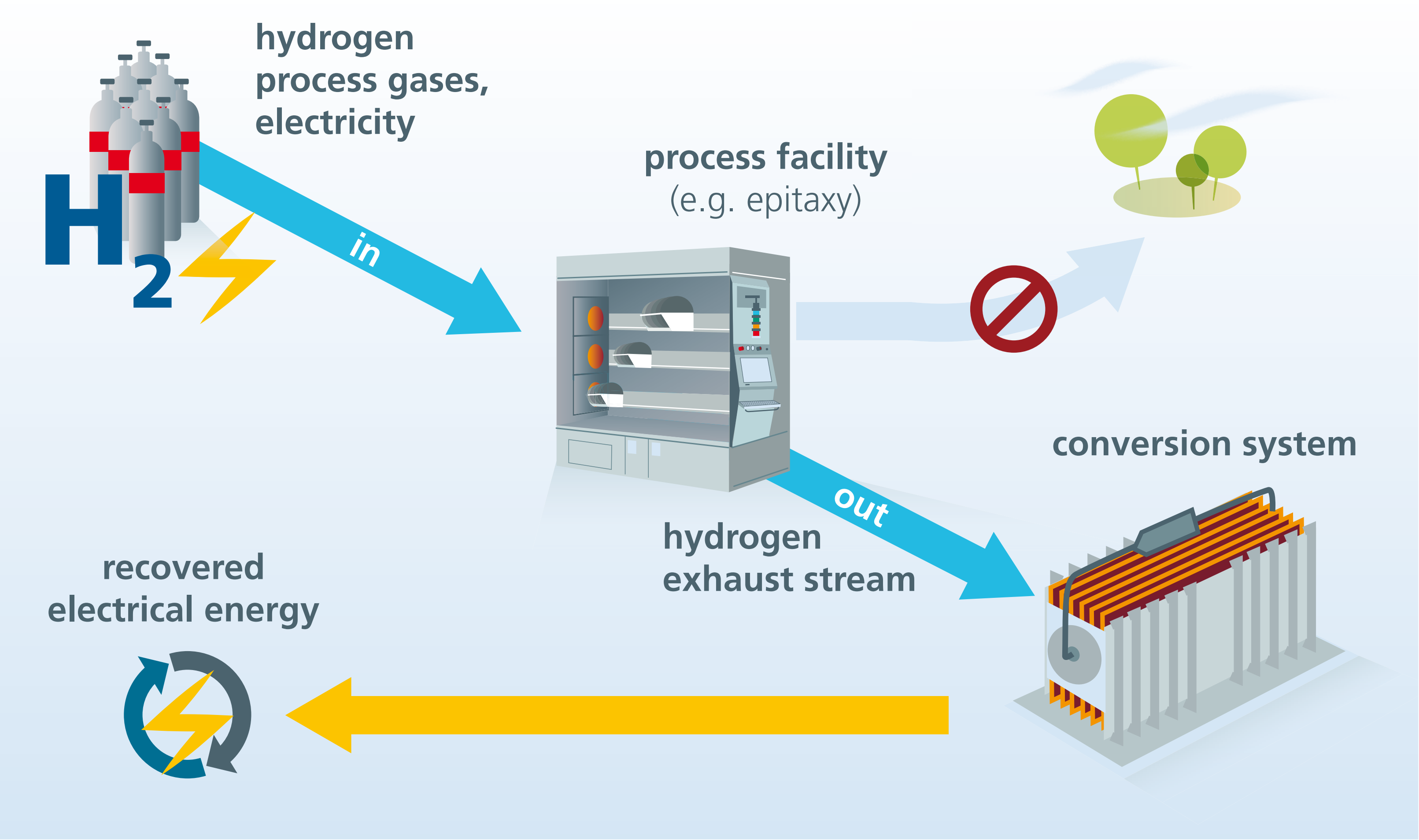

the installations. This is a significant prerequisite for using the process in semiconductor manufacturing. The electricity conversion system has already been successfully tested with the industrial epitaxy facility operated in the clean-room laboratory at the IISB, where it has achieved an overall electrical efficiency of up to 25%. As a result, one quarter of the heating value of the hydrogen exhaust gas can be converted into electrical energy. The lower performance compared to fuel cell systems for pure hydrogen, with an efficiency of around 50 - 60%, is due to additional losses in the diaphragm compressor as well as in the fuel cell system. These losses result from the need to convert the hydrogen-rich gas into electricity without damaging the fuel cell. However, there are further development stages in construction with an overall efficiency that is over 30% better and, above all, lower losses in the fuel cell system. Fraunhofer IISB has thus developed an attractive process for sustainable production and opened up a new application area for modern, clean fuel cell technology.

About the SEEDs project

The electricity conversion system for hydrogen-rich exhaust gas was developed in the scope of the SEEDs project. The focus of this project is to examine all the energy flows in an industrial energy system and consistently use all resources as efficiently as possible. A holistic consideration of all energy flows and the connection of different energy forms, such as chemical energy and electrical energy in this case, make it possible to discover as many efficiency potentials as possible for industrial equipment and operations.

In SEEDs, the entire chain of energy technology is considered and used. The researchers place special emphasis on efficiently linking individual components and demonstrators through electronic interfaces into an optimized and stable overall system. The institute building of the IISB serves as a research and demonstration platform. The performance class of the building is comparable to an average-sized industrial plant with strongly varying loads, peak loads, and considerable secondary energy requirements due to the extensive laboratory and equipment technology, as well as a continuous clean-room operation in particular. The IISB reflects the office aspect as well as the industrial/laboratory aspect and thus many facets of our energy industry.

In addition to the Fraunhofer IISB, the Fraunhofer institutes IIS and ISC are also involved in SEEDS, in cooperation with numerous Bavarian industry partners. The project is supported by the Bavarian State Ministry for Economic Affairs and Media, Energy, and Technology.

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3 *Hydrogen in process gas from a semiconductor manufacturing facility, previously released un-used into the atmosphere, can be converted into electrical energy with the electricity conversion system of the IISB and thus reused.*
© Fraunhofer IISB

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Groundbreaking for an Extension of IISB

On June 30, 2016, the construction start for the next extension of the institute was celebrated with a groundbreaking ceremony. The new laboratory facilities will be available for research and development of highly efficient power electronic systems in summer 2018. These systems are essential components of modern power grids, energy stores, industrial drive technology, and electric vehicles. The building will also be used as a demonstration and test platform for sustainable energy supply infrastructure on an industrial scale.

Guests of honor at the groundbreaking were Ilse Aigner, Bavaria's Minister of Economic Affairs, Stefan Müller, parliamentary State Secretary of the Federal Ministry for Education and Research, Dr. Florian Janik, Mayor of Erlangen, Prof. Günter Leugering, Vice President of the University of Erlangen-Nürnberg, as well as Prof. Alexander Kurz, a member of the board of the Fraunhofer-Gesellschaft. Together, they were able to see the competences of the IISB in the area of energy-efficient electronic systems for themselves at the event.

Among other things, the road-legal electric sports car "IISB-ONE", which was completely developed at the institute itself, could be seen in action. In addition, a new energy store system for industrial applications was presented that is integrated in a container and directly connected to the local direct current system of the IISB. The long-term storage system, which was developed in the framework of the Leistungszentrum Elektroniksysteme (Center of Excellence for Electronic Systems, LZE), is based on the production of hydrogen, which is stored in an organic carrier fluid, and its conversion into electricity.

"The Bavarian State Government supports the IISB extension with 7.5 million euros. This will strengthen Erlangen as a top location for energy research. Fraunhofer IISB is a leading research institution in the areas of power electronics and semiconductors. The institute has been an important service provider for industry, especially in Bavaria, for over 30 years. The IISB significantly contributes to the success of the energy revolution with their research on electromobility and energy infrastructures. They are also an important partner in the Energie Campus Nürnberg as well as in the Leistungszentrum Elektroniksysteme," stated Bavaria's Minister of Economic Affairs, Ilse Aigner, on the occasion of the groundbreaking.

"To be successful in global competition, Germany needs strong research on energy efficiency – for electromobility as well as for power supply to households and industry. With their expertise in power electronics, Fraunhofer IISB in Erlangen leads in this field. I am very happy that the German Federal Government and the Bavarian State Government are now contributing together to the further expansion of precisely this research focus at Fraunhofer IISB," added State Secretary Stefan Müller.

1 *From left to right: Prof. Alexander Kurz, member of the Fraunhofer board, Prof. Lothar Frey, IISB institute director, Ilse Aigner, Bavarian Minister of Economic Affairs, Stefan Müller, parliamentary State Secretary in the BMBF, Dr. Florian Janik, Mayor of Erlangen, Prof. Günter Leugering, Vice President of the University of Erlangen-Nuremberg.*
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The extension building is supported with a total of 15 million euros for construction and basic equipment – half from federal funds and half from the State of Bavaria. Fraunhofer IISB thanks the funding authorities – the Bavarian State Ministry for Economic Affairs and Media, Energy, and Technology as well as the German Federal Ministry for Education and Research (BMBF).

An initial extension building was opened in 2012, and the new extension takes into account the continuous and successful development at the main location in Erlangen. The institute currently has around 250 employees as well as numerous college students. The urgently needed space for laboratory facilities and offices is emerging on the 4,000-square-meter area of the extension building. The building will be primarily used for the areas of power electronics and energy supply. It contains, among other things, a medium-voltage hall with an innovative mains simulator in a multilevel converter topology as well as several laboratory systems for the Bavarian energy research project SEEDs. The building of the IISB serves as a demonstration and test platform for this project. The extension building furthermore accommodates the crystal pulling laboratories in which the researchers will work on the development of electronic materials.

Nuremberg Receives a Chair for Energy Electronics (LEE)

On September 1, Prof. Martin März took over the new Chair of Energy Electronics (LEE) at the Friedrich Alexander University of Erlangen-Nuremberg (FAU). The chair is part of the Energie Campus Nürnberg (EnCN) on the former AEG company grounds on Fürther Straße – and the first chair that has resulted from the EnCN.

The focus of research at the new chair will be on power electronics for supplying electrical energy in stationary and mobile applications. In addition to decentralized electrical power grids – for example, in office buildings and industrial plants – these also include the on-board networks of electric vehicles, railroads, and airplanes. One focus of research at the LEE is on circuit and system technology for power electronics in the high voltage and power range, i.e., up to several tens of kilovolts and several tens of megawatts. Especially great potentials – as well as challenges – are found in the use of power semiconductor components based on silicon carbide and gallium nitride that have only recently become available. Issues concerning availability, sturdiness, and reliability on the system level also play a great role, as well as aspects of volume, weight, and cost reduction.

2 *Bavaria's Minister of Economic Affairs, Ilse Aigner, took advantage of the opportunity to test the road-legal electrical sports car "IISB-ONE" developed at the IISB in a short test drive. Behind her, with thumbs up (from left to right): Dr. Florian Janik, Mayor of Erlangen, Prof. Lothar Frey, IISB institute director, Prof. Günter Leugering, Vice President of the University of Erlangen-Nuremberg, Stefan Müller, parliamentary State Secretary in the BMBF, and Prof. Alexander Kurz, member of the Fraunhofer board.*
© K. Fuchs / Fraunhofer IISB

3 *Prof. Martin März was appointed to be full-professor of the newly established Chair of Energy Electronics at the University of Erlangen-Nürnberg. His research areas are new technologies for high power density and efficiency in power electronics, low and medium voltage DC-grids, and thermal management.*
© LEE / Fraunhofer IISB

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After obtaining a degree in electrical engineering and receiving his doctorate from the University of Erlangen-Nuremberg, Martin März worked for five years in the semiconductor division at Siemens, later Infineon Technologies. In 2000, he switched to Fraunhofer IISB, where he built up the power electronic systems department, which has become the main pillar of the institute and has strongly contributed to its growth. Meanwhile, the activities in the field of power electronics at the IISB have branched into several departments. Martin März will continue to lead the department of energy electronics at the IISB in the future and manage the overall power electronic systems division of the IISB.

Prof. Lothar Frey, the institute director of the IISB and holder of the Chair for Electron Devices (LEB) at FAU, congratulated his colleague of many years: "With Martin März, the Chair for Energy Electronics gets a director who is committed to research and education in electronics with enormous passion and great competence. His and his team's work will contribute to the development of important technological solutions for energy supply and mobility in the future. The close cooperation of FAU and Fraunhofer IISB in Erlangen and in the Metropolitan Region of Nuremberg, which has existed since the foundation of the institute, will continue to intensify. I am already looking forward to our further joint work."

DRIVE-E Academy 2016

54 college students on the electromobility fast track

"The week was unbelievably positive: Interested, technically well-informed college students and young professionals directly meet with experts and executives from industry. They take on responsibility and want to shape the future of mobility together" is how Academy participant Stephan Weber from TU Berlin summarizes the week of events. The seventh edition of the student recruitment program for electromobility, which was initiated by the German Federal Ministry for Education and the Fraunhofer-Gesellschaft, was held from June 12 to 17, 2016. The university partner was the Technische Universität Braunschweig, and the host was the Automotive Research Centre Niedersachsen (NFF) located there.

Experiencing innovative mobility live

At the opening on Monday morning, Prof. Martin März from the Fraunhofer IISB took a look at the electromobility of tomorrow. According to März, in the future, cars could be „refueled" in a completely contactless way via induction strips in the license plate, for example. The tiresome connection of a charging cable would be a thing of the past with a system developed at the IISB. After that, Dr. Stefan Riederer from BWM presented the Visio.M project, in which a consortium

4 *The participants of the DRIVE-E Academy 2016 in Braunschweig were able to test contemporary electric cars at the Braunschweig driver training area.*
© I. Massel / DRIVE-E

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has put a full-carbon electric light vehicle on wheels. The crash test videos that the automobile manufacturer showed were especially impressive. Two former participants in the DRIVE-E Academy were also there and gave a first-hand account of their personal experience in completing their PhD and starting a business in the field of electromobility. With oral presentations and a tour, the 54 participants selected by a jury also got to know the hosting NFF better.

Under the motto „Mobility of the Future – Exchange of Ideas", the young researchers were invited on the second day of the Academy to discuss electromobility concepts in German model regions, other European countries, and the USA with German and international speakers. For example, Ian Faye from Robert Bosch showed what successful cooperation between different companies in the area of power electronics could look like, using examples from his own company.

Practical insights during excursions to companies

On Wednesday and Thursday, the students got a taste of practical work during several excursions to industrial companies in the region. They spent the late morning at the university's Battery LabFactory Braunschweig (BLB). In the afternoon, they visited the Volkswagen plant in Isenbüttel with the technology center there. VW employees gave specialist presentations on the areas in which they are currently working on automobile electrification – for example, in the development of hybrid components. On Thursday, they visited Robert Bosch Electronik in Salzgitter, where the DRIVE-E participants attended an exciting workshop in which they learned about challenging strategic management decisions that now have to be made in the supply industry. A plant tour through the production department and training centers informed them about the different projects of the company for alternative drive forms. Afterwards, it was "meet the management": The complete management team of the Bosch plant in Salzgitter came to lunch with the young electromobility experts. The second excursion destination was Alstom Transport Deutschland. Dr. Carsten Söffker, a technical expert for energy management at the railway supplier, explained electromobility on rail. During the subsequent factory tour, the students learned about the production of railway vehicles and enjoyed the genuine railroad atmosphere at the Alstom museum.

Study award recipients present their papers

At the end of the Academy, the winners of the DRIVE-E study awards, which they had been presented at the beginning of the week for their student papers, were called upon again. They gave insights into their research work, presented results, and were available for questions from the DRIVE-E Academy participants. In addition to further specialist lectures from professors of TU Braunschweig, the students drew up their personal summary of this year's DRIVE-E Academy in a humorous review of the week. Last but not least, Ludwig Merz, a member of

5 *Participants of DRIVE-E Academy 2016 in front of the Automotive Research Centre Niedersachsen (NFF).*
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The Pilgreens, informed the students about the not-so-limited possibilities of electromobility by describing his 20,000-kilometer-long trip from Bangkok to Toulouse in an electric "tuk-tuk".

6 *Prof. Heiner Ryssel, former director of Fraunhofer IISB, during his speech about 40 years of ion implantation © K. Fuchs / Fraunhofer IISB*

Erlangen Ion Implantation Symposium

On the occasion of the 75th birthday of Prof. Heiner Ryssel, the former director of the IISB, the institute held a scientific symposium on the topic of ion implantation, the standard process for doping semiconductors, on December 9 in Erlangen.

After a welcome by the institute director, Prof. Lothar Frey, former President Prof. Karl-Dieter Grüske offered congratulations in the name of the University of Erlangen-Nürnberg administration, and Fraunhofer CFO Prof. Alfred Gossner expressed the best wishes of the Fraunhofer-Gesellschaft board of directors.

In the scientific program of the symposium, renowned experts from industry and science presented current research topics, scientific highlights, as well as retrospectives from the extensive field of ion implementation. These were combined with personal recollections of the many years of cooperation with Prof. Heiner Ryssel. In his closing remarks, Prof. Ryssel looked back at 40 years of ion implantation and described the scientific and technical development of this process as well as his personal background in this field.

At the symposium, it was announced that the International Conference on Ion Implantation Technology (IIT) in 2018 would be organized by the IISB and Infineon. It will be held from September 16 to 21 in Würzburg, Germany. The scientific directors will be Prof. Lothar Frey (IISB, chair), Dr. Reinhard Ploss (Infineon, co-chair), and Dr. Volker Häublein (IISB, program chair). Prof. Heiner Ryssel will head the local organizational committee. The biannual conference is a renowned and important international forum for specialist exchange among experts in the field of ion implementation.

20 Years of the International Conference on Semiconductor Processes and Devices

20 years after the initial conference, the IISB organized the "2016 International Conference on Simulation of Semiconductor Processes and Devices" (SISPAD 2016) from September 6 to 8 in Nuremberg. SISPAD provides an international forum for presentation and discussion of the latest research results in the field of semiconductor process and component simulation. The first SISPAD

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was held in Tokyo in 1996. In the year before, IISB had already organized SISDEP, one of three predecessor conferences of SISPAD (together with NUPAD and VPAD). The scientific direction of this year's SISPAD was in the hands of Dr. Jürgen Lorenz (conference chair) and Dr. Peter Pichler (conference co-chair) from the IISB.

The organizers were pleased to welcome nearly 150 participants from Europe, America, and Asia at the Le Meridien Grand Hotel in Nuremberg, where the conference was held. The scientific program consisted of 7 invited speakers as well as 64 oral presentations and 20 posters, which were selected from 138 submitted abstracts. At the conference dinner, Siegfried Selberherr (TU Vienna) from the SISPAD honorary committee held a speech in which he looked back on the development of the conference and illuminated perspectives for the future. On the day before the conference, three workshops were held on selected topics in the field of simulation, with a total of over 60 participants.

Highlights of the supporting program of SISPAD 2016 were the conference reception at the Germanisches Nationalmuseum with short guided tours on history topics and exhibits at the museum as well as the conference dinner at the historic town hall of Nuremberg.

Semiconductor Experts Meet in Dresden

Around 170 experts from business and science met from March 16 to 18, 2016 in the Görges-Bau building of the TU Dresden for the DKT2016 / GCCCG-1 to exchange ideas and discuss the latest research results from the production of crystals and thin crystalline films with special physical properties. The development of new crystals or crystalline films opens up numerous new application possibilities in information and communication technology. These include, e.g., more energy-efficient electrical drive solutions, lower-loss power lines, energy-saving lighting concepts, a more economical production and integration of regenerative energies, and innovative methods in manufacturing, testing, and medical technology. In these markets, semiconductor materials such as silicon, gallium arsenide, silicon carbide, and gallium nitride, as well as oxidic crystal materials play a large role. The production of such crystals is called "crystal pulling", and their artificially caused increase in size is called "crystal growth".

Under the auspices of the German Society for Crystal Growth and Crystal Pulling (DGKK), the DKT2016 / GCCCG-1 was held together with the Czechoslovak Association of Crystal Growth (CSACG).

One focus of the DKT2016 / GCCCG-1 was to examine the significance of crystal pulling for Saxony as a technology location. 100 years ago, Prof. Jan Czochralski invented the crystal pulling

7 *Dr. Jürgen Lorenz of the IISB (left, at the speaker's podium) at the opening of the conference in the Richard Wagner Saal room of the Le Meridien Grand Hotel in Nuremberg.*
© A. Kradisch / Fraunhofer IISB

8 *Dr. Jochen Friedrich (in the middle), head of the IISB department of materials and one of the four chairmen of the DKT2016 / GCCCG-1, during a speech at the conference dinner.*
© Th. Jauss / Fraunhofer THM

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process named after him, in which a monocrystal is pulled out of the melt. Today, the Czochralski process is by far the most important crystal pulling method. It is used above all to produce semiconductor crystals for microelectronics and photovoltaics as well as oxide crystals for laser and sensor applications. The Czochralski process is a technologically important basis for the State of Saxony as a globally important microelectronics location. Without Czochralski's invention, there would be no semiconductor crystals produced in Freiberg that are processed further into electronic components in Dresden, and there would be fewer possibilities for researching how crystal and component production can be improved.

9 *Despite a full program at the DKT2016 / GCCCG-1, there was enough time during the breaks to explore further discussion as well as to make and cultivate contacts.*
© Th. Jauss / Fraunhofer THM

In addition to over 70 oral presentations and posters on current research results, the DKT2016 provided the specialist audience with an industry exhibition where companies presented their innovations in the area of crystal and coating production. The research awards of the DGKK were also presented as part of the supporting program of the conference. For example, Dr. O. Supplie from TU Ilmenau received the DGKK award for young scientists. Dr. Supplie's work has made a significant contribution to a better understanding of the metal organic chemical vapor deposition of III-V semiconductors on silicon, especially in relation to the nucleation of III-V compounds on the silicon interface. Mr. J. Erlekampf from Fraunhofer IISB in Erlangen was honored with the DGKK Best Paper Award for his oral presentation on the increase in charge carrier lifetime in the semiconductor material silicon carbide. The poster on volume crystal pulling of silicon germanium mixed crystals by Ms. S. Weit from the University of Freiburg was honored with the DGKK Best Poser Award.

Prof. Johannes Heitmann from the TU Bergakademie Assumes a Leadership Role at Fraunhofer THM

For over 10 years, the Fraunhofer Technology Center for Semiconductor Materials THM in Freiberg has done research together with the TU Bergakademie Freiberg in the field of electronic material manufacturing and material processing. Saxon companies in particular profit from the successful research cooperation. To strengthen the collaboration between the university and Fraunhofer further, Prof. Johannes Heitmann, director of the Institute for Applied Physics at the TU Bergakademie, has also become the head of the material production work group at THM.

This will bundle the already complementary competences in the field of production and characterization of semiconductor materials and components at the TU Bergakademie and Fraunhofer THM. In practice, the scientific work on optimized and new semiconductors is of great impor-

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tance, for example, for energy-efficient electric drive solutions and energy-saving lighting concepts or for the economical production and integration of regenerative energies as well.

The Fraunhofer Technology Center for Semiconductor Materials THM Freiberg was founded in 2005 with the objective of supporting the research activities of the semiconductor industry concentrated in Freiberg. This is done in close cooperation with the two parent institutes, Fraunhofer IISB in Erlangen and Fraunhofer ISE in Freiburg. Fraunhofer THM operates a modern crystallization and wafer technical center in the immediate vicinity of the Freiberg semiconductor companies. The technical center was officially opened in 2012 and financed by the German Federal Ministry for Education and Research and the State of Saxony, using funds from the European EFRE program. Today, Fraunhofer THM employs around 35 people, including college students. Research focuses on a more economical manufacturing of crystal materials with simultaneously improved material properties as well as the wafers made of them. Examples of this include, e.g., silicon for microelectronic and photovoltaic applications or gallium nitride (GaN) for energy electronics.

The TU Bergakademie and Fraunhofer THM work together as strategic partners who supplement each other's competences and use resources together. This strengthens their capacity to achieve progress in science and for industry to their mutual benefit. Since its foundation, Fraunhofer THM has cooperated with numerous institutes of the TU Bergakademie Freiberg in the framework of research projects. Joint research projects financed by the German Federal Government and Saxony have supported local industry in developing processes for semiconductor manufacturing and improved their ability to compete in the global market. This has resulted in numerous patents, presentations at national and international conferences, as well as joint publications by scientists at the TU Bergakademie and Fraunhofer THM. Employees of the THM are also active in teaching at the TU Bergakademie and hold lectures there. Conversely, students at the TU also have the option of doing their theses at the THM in close cooperation with the university. In the past five years, around 40 student theses have been successfully completed at the THM. In the past, jointly organized specialist conferences have also helped to make the university and THM more attractive.

The close academic and personal connection in the form of a common leadership role is especially important to the TU Bergakademie and Fraunhofer THM. This is ensured by the integration of Prof. Johannes Heitmann in the THM as head of the material production work group. Prof. Heitmann has been director of the Institute for Applied Physics (IAP) at the TU Bergakademie Freiberg since 2010 and previously worked as a senior scientist in the semiconductor industry. With his team at the IAP, he conducts research on the development and evaluation of dielectric layers for more powerful semiconductor components, on the synthesis and characterization of semiconductor nanocrystals, as well as on the reliability of solar cells and solar modules. This excellently

10 *From left: Prof. Dr. Johannes Heitmann (TU Bergakademie Freiberg / Fraunhofer THM), Simone Raatz (Member of Parliament), Prof. Dr. Klaus-Dieter Barbknecht (President of the TU Bergakademie Freiberg), Dr. Jochen Friedrich (spokesman of the THM), and Prof. Hans-Joachim Möller (deputy spokesman of the THM). © D. Müller / TU Bergakademie Freiberg*

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complements the expertise of Fraunhofer THM in the area of material production and processing for component technology and thin film deposition. The clean room laboratory headed by Prof. Heitmann at the TU Bergakademie also plays an important role here.

Prof. Johannes Heitmann has taken over as head of the material production work group at THM from Dr. Jochen Friedrich. With the handover of the baton, Prof. Klaus-Dieter Barbknecht, President of the TU Bergakademie Freiberg, and Dr. Simone Raatz, a Member of the German Parliament and Deputy Chairperson of the Committee for Education, Research and Technology Assessment there, learned about previous and future developments at Fraunhofer THM. "The active inclusion of Prof. Heitmann in the THM will further intensify the cooperation between the TU Bergakademie and Fraunhofer," says Prof. Barbknecht. "I am pleased that the new constellation will create a secure basis for further consolidating the continuing successful cooperation between the TU Bergakademie and THM for the benefit of the local semiconductor industry, especially with regard to semiconductor materials," states Dr. Simone Raatz, who has followed and accompanied the development of the Fraunhofer THM for over a decade.

Andreas Erdmann Named SPIE Fellow

SPIE, the international society for optics and photonics, has made Dr. Andreas Erdmann, head of the lithography and optics group in the simulation department of the IISB, an honorary member. Andreas Erdmann received the award on February 2 at the world's largest and most important conference for optical lithography, SPIE Advanced Lithography, in San José, USA. SPIE named 32 new honorary members, the so-called SPIE fellows. This title honors outstanding scientific and technical work in the field of optics, photonics, and imaging performance. The SPIE fellows are furthermore distinguished by their above-average commitment to the scientific community. Since the foundation of the society in 1955, around 1,200 scientists have been honored as SPIE fellows.

Andreas Erdmann received the award for his accomplishments in the field of modeling optical as well as extreme ultraviolet (EUV) lithography. He has been working in the field of applied optics for over 25 years. His research topics have included, among others, holography, non-linear optics, modeling of optical systems, and, for more than 20 years, modeling of lithography in particular. Andreas Erdmann has made important contributions to lithography simulation and to the development of lithography simulation programs. His research focuses include the application of rigorous electromagnetic simulation to advanced lithography methods and the investigation of the effects of mask topography. The characterization of the influence of defects in optical or EUV lithography as well as investigations of the influence of effects in wafer topography are also among his research topics.

11 *Conference chair Mircea Dusa (ASML) and Bruce Smith (Rochester Institute of Technology) appoint Dr. Andreas Erdmann to a SPIE Fellow at SPIE Symposium Advanced Lithography in February 2016 in San Jose (USA). © SPIE*

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In addition to his scientific achievements, Andreas Erdmann's commitment as a university teacher at the Friedrich Alexander University of Erlangen-Nuremberg is also noteworthy. Many of his former students now work at important semiconductor firms or at companies in the optical industry. Erdmann has presented his results in more than 200 oral presentations at international scientific conferences, many of those as an invited speaker, as well as in more than 200 scientific publications in journals and conference proceedings, including various SPIE publications. Andreas Erdmann has been scientific director of the internationally renowned Fraunhofer IISB Lithography Simulation Workshop for 13 years. He is involved in the conferences organized by SPIE in many ways. His contributions have been honored with the SPIE Best Paper Award and the SPIE Best Poster Award. During the past five years, Andreas Erdmann has been a member of the program committee of the SPIE Advanced Lithography Symposium, and for the past two years, he has served as the co-chair.

Prof. Frey Takes Over as Chairman of the Scientific Advisory Council of the Bavarian Research Foundation

Since February, IISB director Prof. Lothar Frey has been chairman of the scientific advisory board of the Bavarian Research Foundation (BFS). The scientific advisory board advises the foundation on research and technology questions and gives recommendations for individual projects and research cooperation, based on the opinions of external experts. The BFS was established in 1990 and provides funds for 35 to 45 projects per year. The BFS has supported nearly 800 projects and awarded more than 450 scholarships to date.

SEMIKRON Innovation Award for a New Type of Power Electronics Test

They are indispensable when electrical energy is distributed, converted, or stored: power electronic components. These components have to be especially reliable when they are used at central or difficult-to-access points in the power grid, such as in transformer stations or offshore wind turbines. Particularly for higher voltage classes, components made of silicon carbide could replace conventional silicon components in the future, since considerably more energy-efficient solutions can be realized this way. However, silicon carbide contains significantly more material defects than silicon, and these defects sometimes only become apparent over time when a com-

12 *SEMIKRON Innovation Award: (From left to right) Bettina Martin (SEMIKRON Foundation), Prof. Leo Lorenz (ECPE e.V.), Dr. Patrick Berwian (Fraunhofer IISB), Larissa Wehrhahn-Killian (Infineon Technologies), Dr. Michael Krieger (LAP, Friedrich Alexander University of Erlangen-Nürnberg), and Dr. Steffen Oppel (Intego) representing Michael Schütz (Intego).*
© SEMIKRON

13 *Logo of the Bavarian Research Foundation (Bayerische Forschungsstiftung, BFS).*
© BFS

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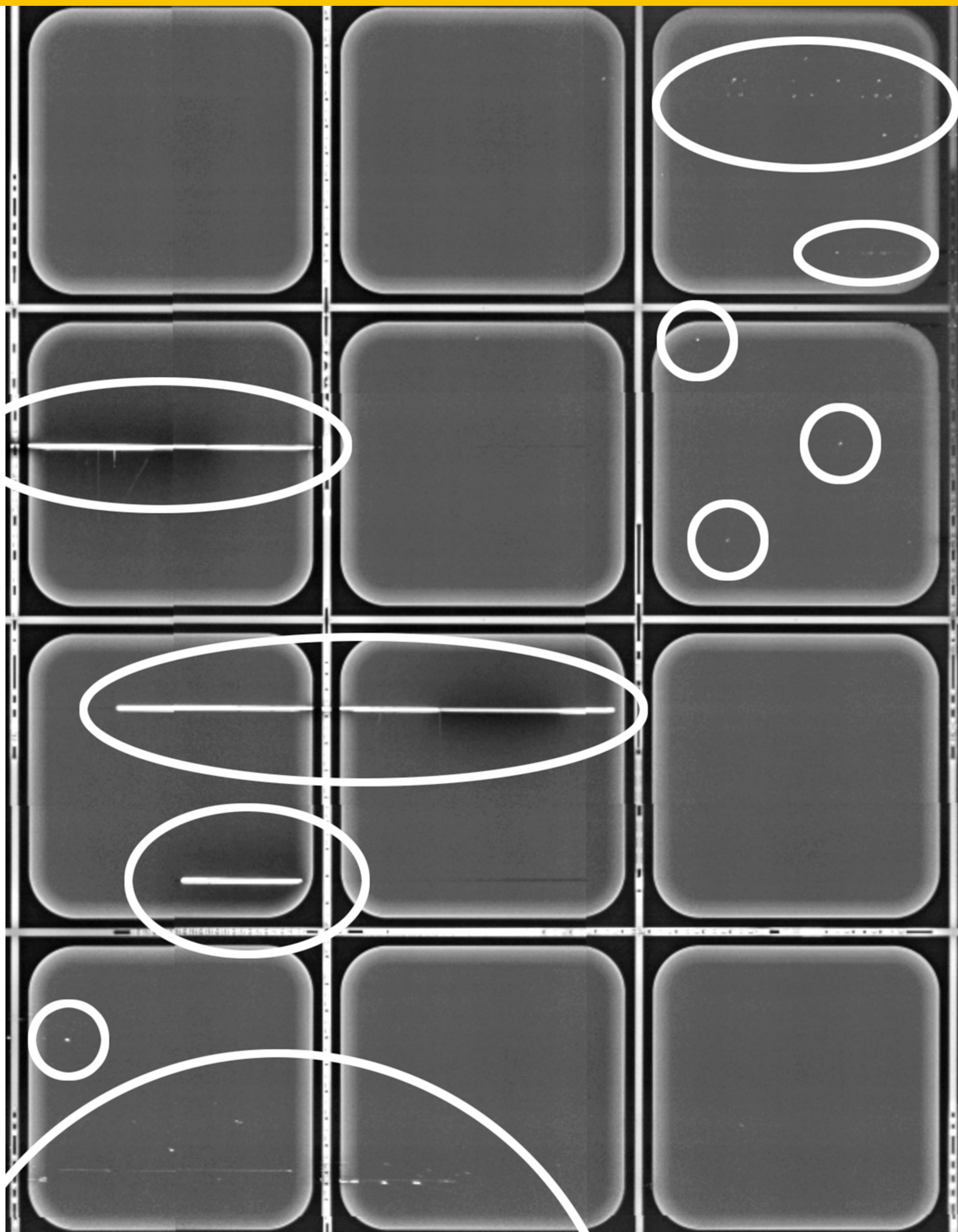

ponent fails. A consortium from industry and science has succeeded in developing a low-cost test that can already detect even very small defects on silicon carbide wafers – the raw material for new, especially energy-efficient components. On behalf of their teams, the four project managers Dr. Patrick Berwian (Fraunhofer IISB), Dr. Michael Krieger (Friedrich Alexander University of Erlangen-Nürnberg), Larissa Wehrhahn-Kilian (Infineon Technologies), as well as Dr. Michael Schütz (Intego) were honored with the SEMIKRON Innovation Award 2016

Semiconductor components made of silicon carbide (SiC) can play a central role in future power electronic systems. Compared to conventional silicon-based power electronics, SiC-based power electronics have the potential to considerably increase the energy efficiency of all applications and simultaneously reduce costs on the system level. The production of low-cost, energy-efficient, and extremely reliable SiC power components for energy applications is therefore an important goal of the semiconductor industry.

In respect to manufacturing and processing, however, SiC is a demanding material. Up to now, so-called unipolar SiC components, which are already commercially available, have demonstrated a very high reliability. On the other hand, bipolar SiC components, which are needed for applications in energy systems with higher voltage classes, are still significantly more susceptible to certain material defects. One difficulty is that these defects do not always lead to the immediate failure of the bipolar component but cause a slow degradation that is currently unacceptably expensive to detect during manufacturing or in the final component testing at the manufacturer's.

Against this backdrop, Infineon Technologies and Intego joined forces with the Fraunhofer IISB as well as the Chair for Applied Physics (LAP) of the Friedrich Alexander University of Erlangen-Nürnberg in the project „SiC-WinS“ supported by the Bavarian Research Foundation. The objective of this cooperation was to improve a process step that is critical to quality in component manufacturing, the so-called epitaxy of the drift region, and to develop and evaluate a new method for quality control. The vision was to achieve a zero-defect tolerance in quality control and thus guarantee 100% reliability in components for especially demanding applications in energy technology.

The idea of the project partners was to detect the cause of the component degradation – specific crystal defects in the SiC wafers – through direct imaging. For such a method to be used in industrial production lines as well, it would have to be designed for the inspection of entire SiC wafers as well as be non-destructive and contamination-free and above all fast. The researchers therefore decided on the method of imaging photoluminescence (PL) at room temperature to detect the critical defects.

14 *Photoluminescence image of a silicon carbide semiconductor wafer with partially processed components. Unusual structures that lead to inoperative or operationally unreliable components are marked.*

© Fraunhofer IISB

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The results obtained with this imaging photoluminescence measuring technology are impressive and have surpassed the original expectations. After only the first process step in component manufacturing – the epitaxial deposition of the drift region – the PL scanner identifies material defects in still unfinished components. In extensive studies, it could be shown that precisely these components fail in later operation, even when they were absolutely normal in the usual electrical standard tests. This makes the newly developed inspection procedure a very valuable addition to the quality control methods in the industrial production of bipolar SiC high-voltage components. By predicting malfunctions, the PL measuring technology directly contributes to the introduction of reliable and efficient bipolar SiC power components in the energy and high-voltage market.

15 *Dr. Andreas Bräuer (left), director of administration at the Erlangen Graduate School in Advanced Optical Technologies (SAOT) and SAOT Innovation Award winner Maximilian Rumler (right) at the award presentation on July 8, 2016 at the University of Erlangen-Nürnberg.*
© Georg Pöhlein / FAU

SAOT Innovation Award 2016 for the Production of Complex Surface Structures

The SAOT Innovation Award of the Erlangen Graduate School in Advanced Optical Technologies went to Maximilian Rumler in 2016. The graduate mechatronics engineer received the award for an innovative approach to the production of so-called hierarchical structures. Rumler developed the method as part of his research work at Fraunhofer IISB in Erlangen. Hierarchical structures make it possible to realize functional surfaces that are interesting for many technical applications, such as in photonics or biotechnology.

The SAOT Innovation Award, worth 20,000 euros, was presented on July 8, 2016 together with other research awards from the Erlangen Graduate School in Advanced Optical Technologies (SAOT) of the Friedrich Alexander University of Erlangen-Nuremberg (FAU) at a festive ceremony in Erlangen.

In his doctoral thesis at the IISB, Maximilian Rumler dealt with possibilities for the large-area production of nanostructures for photonic applications. He received the SAOT award for developing an innovative approach that can considerably simplify the production of so-called hierarchical structures, among other things.

Hierarchical structures combine topographies of different size scales – here, one in the micrometer range and one in the nanometer range. As a result of this combination, special physical features of surfaces can be created. Examples of this can be found in nature, for example, with the well-known lotus effect. The petals of the lotus plant have a double structure on their surface that provides a low wettability and thereby repels water. Such structures are also very interesting for a wide variety of technical applications, such as in photonics or biotechnology, for example.

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One area of application could be the manufacturing of optical waveguides with integrated lattice structures for gas sensors.

Up to now, hierarchically structured surfaces usually have had to be produced with great expense in several steps, since the micro- and nanostructures could not be produced simultaneously due to their greatly different scales. This is precisely where Maximilian Rumler's idea comes in: he combines the advantages of two existing structuring technologies, direct laser writing (DLW) and substrate conformal imprint lithography (SCIL), in one step.

With the DLW method, a light-sensitive polymer coating is locally cured using a laser. The desired structures can be directly written on a micrometer scale through focused guidance of the laser beam. In addition, the desired smaller nanostructures are stamped into the polymer coating of the surface with a transparent forming die, which is permeable for the laser beam, via the SCIL process. This allows the microstructures defined by the laser as well as the nanostructures of the functional surface that are specified by the forming die to cure in a single process step. Where the laser beam is not applied, the coating remains fluid and can then be easily washed away; the underlying carrier substrate of the structures, e.g., glass or silicon, then remains there.

Maximilian Rumler is currently working as a research associate at the Chair of Electron Devices (LEB) at the FAU. He will use the award money to study the possibilities and limits of the approach that he has developed.

Best Paper Award of the DKT 2016 for Jürgen Erlekampf

Jürgen Erlekampf, an associate in the materials department at the IISB, was presented with the Best Paper Award at the German Crystal Pulling Conference DKT 2016 from March 16 to 18 in Dresden.

He received the award for his oral presentation on his work on increasing the charge carrier lifetime in the semiconductor material silicon carbide. In silicon carbide deposited using epitaxy, the charge carrier lifetime is limited by intrinsic point defects in the material (carbon spaces) that inevitably result due to the high temperatures in the epitaxy process. In addition to possibilities for improving the point defect budget in epitaxy, Jürgen Erlekampf also presented ways to prevent a deterioration in the charge carrier lifetime or even considerably improve it in subsequent technology steps.

16 *Jürgen Erlekampf from Fraunhofer IISB was honored with the DGKK Best Paper Award for his oral presentation on the increase in charge carrier lifetime in the semiconductor material silicon carbide.*
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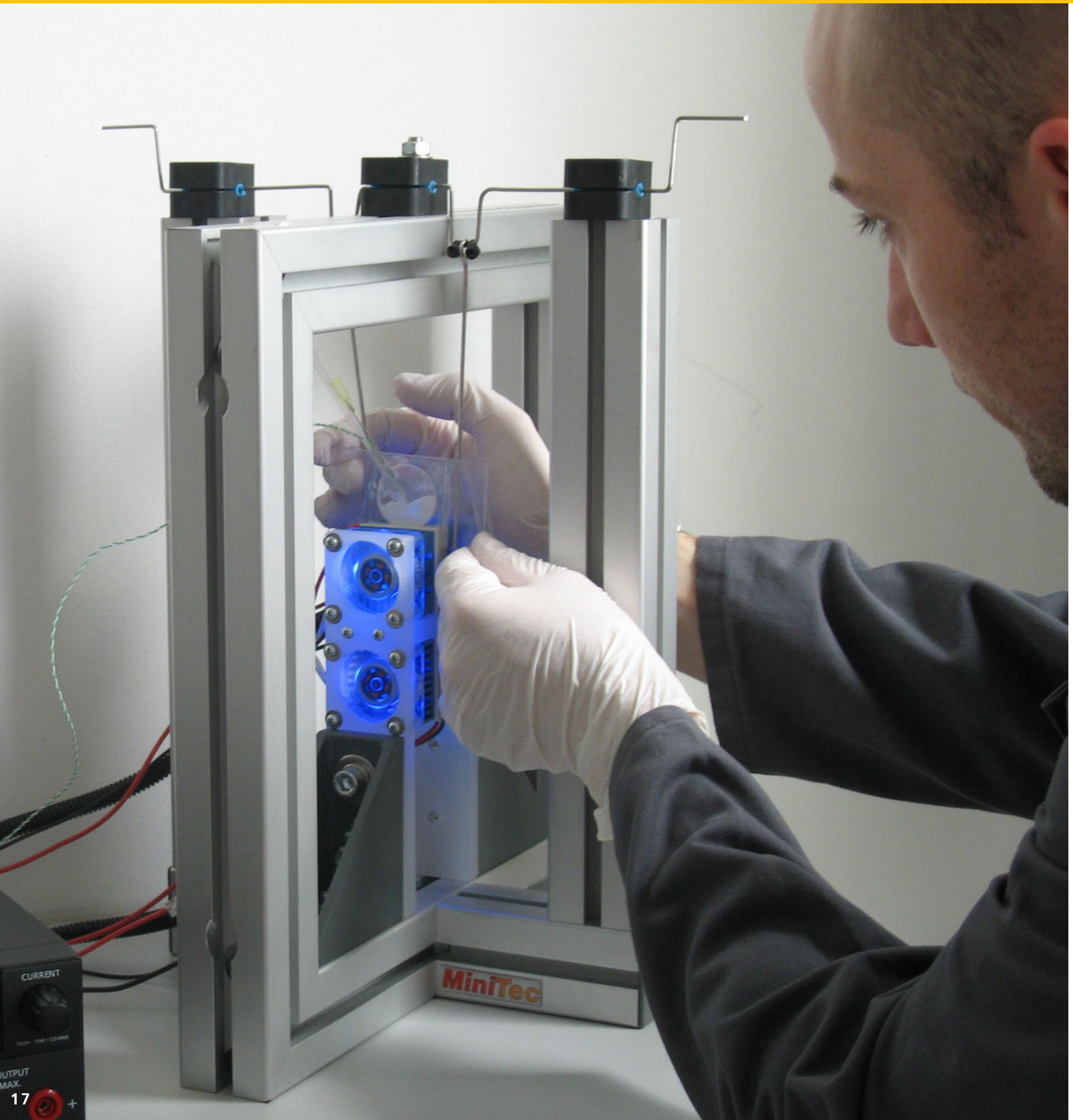

E-MRS Best Poster Award for Rico Belitz

At the E-MRS spring conference held from May 2 to 6 in Lille, France, Rico Belitz from Fraunhofer THM in Freiberg was honored with the Best Poster Award in Symposium W (“Materials and Systems for Microenegry Harvesting and Storage”).

In his work, Rico Belitz was able to demonstrate that hydrogen can be obtained using special crystals. With these so-called pyroelectric crystals, temperature changes induced from the outside cause the crystal surfaces to become electrically charged. The acquisition of charge carriers from the environment (to compensate for these surface charges) can be used to extract hydrogen from water. According to this principle, previously unused low-temperature waste heat can be converted into valuable chemical energy, for example.

17 *Honoree Rico Belitz equips the test setup with a microreactor. This setup can verify pyroelectric hydrogen extraction with crystals.*

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NAMES AND DATA

Content

Guest Scientists

Chaoqun, Z.; Jincai, Y.
February 24, 2016 - March 22, 2016
China
BYD Company Ltd.

Dantec, M. le
January 18, 2016 - June 22, 2016
Suisse
EMPA Zürich
Kontaktwinkelmessungen von Silizium-Tropfen auf Al_2O_3-Substraten

Dongsheng, L.
May 28, 2016 - June 26, 2016
China
Hebei Semiconductor Research Institute
Herstellung von SiC Leistungsbauelementen

Liang, T. Y.
April 29, 2016 - June 25, 2016
China
Hebei Semiconductor Research Institute
Herstellung von SiC Leistungsbauelementen

Lingyan, S.
January 1, 2016 - September 30, 2016
China
Shanghai Institute of Microsystem and Information Technology (SIMIT), Chinese Academy of Sciences (CAS)
Modeling of AlGaN power devices

Petr, P.; Miklos, F.; Juhasz, G.; Csaba, M.
October 24, 2016 - October 28, 2016
Hungary
MFA-MTA Hungarian Academy of Sciences
Line-based ellipsometry im Projekt SEA4KET

Ryotaro, H.
January 12, 2015 - February 28, 2017
Japan
High-temperature, highly integratd monolitic capacitors for high-voltage applications

Schangdong, H.
January 7, 2016 - January 6, 2017
China
Chongqing University
TCAD Modellierung von Ladungskompensationsstrukturen in 4H-SiC

Wu, X.
February 3, 2016 - June 27, 2016
China
University of Hongkong
Simulation und Optimierung optischer Abbildungsverfahren mit Dr. LiTHO

Yongwei, W.
May 2, 2016 - May 26, 2016
China
Hebei Semiconductor Research Institute
Herstellung von SiC Leistungsbauelementen

Yunbin, G.; Zhao, Y.; Chen, X.
July 18, 2016 - July 31, 2017
China
Zhuzhou CRRC Times Electric Co. Ltd.
CRRC 3,5 kV SiC-MOSFET

Zhao, Y.
July 18, 2016 - July 31, 2017
China
Zhuzhou CRRC Times Electric Co. Ltd.
CRRC 3,5 kV SiC-MOSFET

Patents

Bauer, A.; Erlbacher, T.:
Integrierter Kondensator und Verfahren zum Herstellen desselben
JP 2015-111671 A / 5981519

Bauer, A.; Erlbacher, T.:
Integrated capcaitor and method for producing the same
US 9,455,151 B2

Dorp vom, J.; Erlbacher, T.:
Elektrisches Überbrückungselement, insbesondere für Speicherzellen eines Energiespeichers
EP 2 642 582 A2 / EP 2 642 582 B1

Dorp vom, J.; Erlbacher, T.:
Elektrisches Überbrückungselement, insbesondere für Speicherzellen eines Energiespeichers
EP 2 642 582 A2 / 50 2013 001 971.3

Dorp vom, J.; Erlbacher, T.:
Electrical bypass element, in particular for storage cells of an energy storage device
US 2013/0252039 A1 / US 9,337,467 B2

Erlbacher, T.:
Verfahren und Detektoranordnung zur Detektion von Sonnenlicht
DE 10 2014 018 722 B3

Friedrich, J.; Reimann, C.:
Verfahren und Vorrichtung zur Bestimmung der Schmelzhöhe und zur Regulation der Erstarrung und Schmelzung einer Schmelze in einem Tiegel
DE 10 2013 002 471 A1 / DE 10 2013 002 471 B4

Jank, M.; Teuber, E.:
Dünnfilmtransistor
DE 10 2011 085 114 A1 / DE 10 2011 085 114 B4

März, M.; Tchobanov, D.:
Kühlkörper und Verfahren zur Herstellung eines Kühlkörpers und Leiterplatte mit Kühlkörper
DE 10 2007 057 533 A1 / DE 10 2007 057 533 B4

Content

Continuation: Patents

Reimann, C.; Trempa, M.:
Device and method for producting silicon blocks
US 9,371,597 B2

Schneider, V.; Reimann, C.:
Wiederverwendbarer Tiegel aus einer Siliziumnitrid-Keramik sowie dessen Verwendung bei der Herstellung eines mono- oder multikristallinen Halbmetallkörpers aus einer Schmelze
DE 10 2012 101 214 A1 / DE 10 2012 101 214 B4

Schöpka, U.; Öchsner, R.:
Vorrichtung und Verfahren zum Beschichten eines Substrates
EP 2 501 836 A1 / EP 2 501 836 B1

Schöpka, U.; Öchsner, R.:
Vorrichtung und Verfahren zum Beschichten eines Substrates
EP 2 501 836 A1 / 50 2010 012 574.4

Trempa, M.; Reimann, C.:
Verfahren und Vorrichtung zur Herstellung von Silizium-Blöcken
DE 10 2011 006 076 A1 / DE 10 2011 006 076 B4

Trempa, M.; Reimann, C.:
Verfahren zur Herstellung von Silizium-Blöcken sowie Soilizium-Block
DE 10 2011 086 669 B4

Participation in Committees

Bauer, A.
- Koordination der VDE/VDI-Fachgruppe 1.2.4 "Heißprozesse und RTP"

Erdmann, A.
- Conference chair of SPIE Advanced Lithography, San Jose, US, February, 2016
- Program committee member of 2nd International DSA Symposium, Grenoble, FRA, October, 2016
- Program committee of European Mask and Lithography Conference (EMLC), Dresden, GER, June, 2016

Erlbacher, T.
- Leiter der VDE-GMM-Fachgruppe 1.3.2 "Leistungselektronik und energieautarke Systeme"
- Reviewer for the German Research Foundation
- Reviewer for IET Power Electronics Journal
- Reviewer for IEEE Transactions on Power Electronics
- Reviewer of the European Conference of Silicon Carbide and Related Materials

Friedrich, J.:
- Co-Chair of DGKK-Arbeitrskreis "Herstellung und Charakterisierung massiver Halbleiter"
- Counciler in the Executive Committee of the International Organization of Crystal Growth (IOCG)
- Advisory Committee of International Workshop on Crystalline Silicon for Solar Cells
- Reviewer for Journal of Crystal Growth, Applied Physical Letters

Häublein, V.
- Vorsitz in der GMM-Fachgruppe 1.2.2 und der ITG-Fachgruppe 8.1.1 "Ionenimplantation"

Jank, M.
- Associate Editor des Open Access Journals Frontiers in Materials – Translational Materials Science, Frontiers Media S.A.
- VDE/VDI-GMM-Fachgruppe 1.3.3 "Materialien für Nichtflüchtige Speicher"
- Mitglied des Exzellenzclusters EXC315/2 "Engineering of Advanced Materials" der FAU Erlangen-Nürnberg
- Arbeitskreis "Printed Electronics Franken"

Kallinger, B.:
- Reviewer for physica status solidi – A Journal of Crystal Growth, Materials Science in Semiconductor Processing

Lorenz, J.
- Conference chairman of SISPAD 2016, Nuremberg, GER, September 6 - 8, 2016
- Member of the Steering Committee of the SISPAD series of conferences
- Member of the Technical Program Comittee, ESSDERC 2016, Lausanne, AUT, September 12 -15, 2016
- Member of the PENTA Technical Expert Group

Meissner, E.:
- Reviewer for Journal of Crystal Growth and Materials Chemistry and Physics, Physica Status Solidi Rapid Research Letters, The Journal of Supercritical Fluids
- Expert Panel Member for the Research Council of Norway

Content

Continuation: Participation in Committees

Pfeffer, M.

- Member of the "Factory Integration International Focus Team" (FI IFTs) of the "IEEE International Roadmap for Devices and Systems (IRDS)"
- Member of the "Yield Enhancement International Focus Team" (YE IFTs) of the "IEEE International Roadmap for Devices and Systems (IRDS)"
- Member of Semicon Europe Semiconductor Technology Programs Committee (STC)

Pichler, P.

- Conference co-chairman SISPAD 2016, Nuremberg, GER, September 6 - 8, 2016

Reimann, C.:

- Reviewer for Journal of Crystal Growth, Crystal Research and Technology, Progress in Photovoltaics: Research and Applications, and Journal of Photovoltaics

Roeder, G.

- Koordinator der VDI/VDI-GMM-Fachgruppe 1.2.3 "Abschneide- und Ätzverfahren"

Rommel, M.

- Koordinator der VDE/VDI-GMM-Fachgruppe 1.2.6 "Prozesskontrolle, Inspektion & Analytik"
- International Program Committee der Konferenz MNE 2016 (42nd International Conference on Micro&Nano Engineering 2016)

Schellenberger, M.

- Mitglied im Programmkommitee der europäischen APCM-Konferenz
- Leiter der europäischen SEMI PCS-Taskforce

Schletz, A.

- Session Chair of International Conference and Exhibition on Ceramic Interconnect and Ceramic Microsystems Technologies (CICMT), 2015, Dresden
- Reviewer of the 26th European Symposium on Reliability of Electron Devices, Failure Physics and Analysis (ESREF2015)
- Reviewer of the 9th International Conference on Integrated Power Electronics Systems 2016
- Reviewer for Microelectronics Reliability Journal Volume 54
- Member of the ZVEI Core Team "Computergestützte Lebensdauervorhersage"
- Member of the ZVEI APG-AK HTE+LE Core Group "Qualifikation von Film-Kondensatoren"

Trempa, M.:

- Reviewer for Journal of Crystal Growth

Conferences, Workshops, Fairs, and Exhibitions

6th jDGKK Meeting
Dresden, GER, March 5, 2016

9th International Workshop on Crystalline Silicon for Solar Cells | 3rd Silicon Materials Workshop
Phoenix, Arizona, USA, October 10 - 12, 2016

14th Fraunhofer IISB Lithography Simulation Workshop
Hersbruck, GER, September 22 - 24, 2016

14th Workshop „Beams and More" 2016, IMS CHIPS
Stuttgart, GER, November 10, 2016

15. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.6 "Prozesskontrolle, Inspektion und Analytik"
Regensburg, GER, March 17, 2016

16th European advanced process control and manufacturing (apc|m) Conference
Reutlingen, GER, April 11 - 13, 2016

19. Workshop der GMM-VDE/VDI-Fachgruppe 1.2.3 "Abschneide- und Ätzverfahren"
Erlangen, GER, December 7, 2016

22nd ESA Symposium on European rocket and balloon programmes and related research
Tromsø, NOR, June 7 - 12, 2016

27th European Symposium Reliability of Electron Devices, Failure Physics and Analysis
Halle, GER, September 19 - 22, 2016

34. CADFEM ANSYS Simulation Conference
Nuremberg, GER, October 5 - 7, 2016

39. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.4 "Heißprozesse und RTP"
Erlangen, GER, April 6, 2016

40. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.4 "Heißprozesse und RTP"
Erlangen, GER, December 8, 2016

55. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.2 "Ionenimplantation"
Erlangen, GER, April 7, 2016

56. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.2 "Ionenimplantation"
Erlangen, GER, December 8, 2016

56. Treffen des Arbeitskreises „Systemzuverlässigkeit von Aufbau- und Verbindungstechnologien"
Berlin, GER, February 2, 2016

APEC 2016, IEEE Applied Power Electronics Conference and Exposition
Long Beach, USA, March 20 - 24, 2016

Batterieforum Deutschland
Berlin, GER, April 6 - 8, 2016

Biodevices 2016, 9th International Conference on Biomedical Electronics and Devices
Rom, ITA, February 21 - 23, 2016

BIOSTEC 2016, 9th International Joint Conference on Biomedical Engineering Systems and Technologies
Rome, ITA, February 21 - 23 February, 2016

Content

Cont.: Conferences, Workshops, Fairs, and Exhibitions

CEFC 2016, 17th Biennial IEEE Conference on Electromagnetic Field Computation
Miami, USA, November 13 - 16, 2016

CIPS 2016, 9th International Conference on Integrated Power Electronics Systems
Nuremberg, GER, March 8 – 10, 2016

CONTACT 2016, 23. Nordbayerische Kontaktmesse für Industrie und Studierende technischer Fachrichtungen
Erlangen, GER, November 23 - 24, 2016

contactING, 17. Firmenkontaktmesse
Nuremberg, GER, November 17, 2016

CoFAT 2016, 5th Conference on Future Automotive Technology
Fürstenfeld, GER, May 3 -4, 2016

Deutscher Luft- und Raumfahrtkongress
Braunschweig, GER, September 13 - 15, 2016

DGKK-Arbeitskreis Massive Halbleiterkristalle
Erlangen, GER, October 12 - 13, 2016

DLR Postflight Review TEXUS-51, -52, -53 and MASER-13
Bonn, GER, June 22, 2016

DKT2016 / GCCCG-1, Deutsche Kristallzüchtungstagung 2016
Dresden, GER, March 6 - 8, 2016

DGKK Arbeitskreis "Industrielle Kristallzüchtung"
Freiberg, GER, November 7 - 8, 2016

DGKK Arbeitskreis "Massivhalbleiter"
Erlangen, GER, October 11 - 12, 2016

DRC 2016, 74th Device Research Conference
Newark, USA, June 19 - 22, 2016

DVM-Arbeitskreis „Zuverlässigkeit mechatronischer und adaptronischer Systeme"
Regensburg, GER, February 24, 2016

eCarTec 2016
Munich, GER, October 18 - 20, 2016

ECPE Cluster-Schulung – Isolationskoordination in leistungselektronischen Baugruppen und Geräten
Nuremberg, GER, March 3, 2016

ECPE Cluster-Schulung – Simulation in der Leistungselektronik
Nuremberg, GER, October 13, 2016

ECPE Tutorial – Thermal Engineering of Power Electronic Systems Part I: Thermal Design and Verification
Erlangen, GER, July 19 - 20, 2016

ECPE Workshop – Power Electronics for e-Mobility
Stuttgart, GER, June 22 - 23, 2016

ECPE Workshop – Thermal and Reliability Modeling and Simulation of Power Electronics Components and Systems
Fürth, GER, December 1, 2016

ECSCRM 2016, 11th European Conference on Silicon Carbide & Related Materials,
Halkidiki, GRC, September 25 - 29, 2016

ECTC 2016, 66th IEEE Electronic Components and Technology Conference
Las Vegas, USA, May 31 - June 03, 2016

Electronica 2016
Munich, GER, November 8 - 11, 2016

Electronica Embedded Platforms Conference
Munich, GER, November 10, 2016

EMAG 2016, Electron Microscopy and Analysis Group Conference
Durham, UK, April 6 - 8, 2016

E-MRS Spring Meeting
Lille, FRA, May 2 - 6, 2016

EMLC 2016, 32nd European Mask and Lithography Conference
Dresden, GER, June 21 - 22, 2016

EMC 2016, 16th European Microscopy Congress
Lyon, FRA, August 28 - September 02, 2016

Energy Storage Europe 2016
Düsseldorf, GER, March 15 - 17, 2016

Erlanger Symposium Ionenimplantation
Erlangen, GER, December 9, 2016

ESARS 2016, IEEE International Conference on Electrical Systems for Aircraft, Railway, Ship Propulsion and Road Vehicles
Toulouse, FRA, November 2 - 4, 2016

EUPOC 2016, Block Copolymers for Nanotechnology Applications
22 - 26 May 2016, Gargnano , Italy

EU PVSEC 2016, 32nd European Photovoltaic Solar Energy Conference and Exhibition
Munich, GER, June 20 - 24, 2016

EuroSimE 2016, IEEE International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in Microelectronics and Microsystems
Montpellier, FRA, April 17 - 20, 2016

EUVL 2016, International Symposium on Extreme Ultraviolet Lithography
Hiroshima, JPN, October 24 - Oct 26, 2016

Forum Be-Flexible
Munich, GER, November 21 - 22, 2016

GCCCG-1 / DKT2016, 1st German Czechoslovak Conference on Crystal Growth
Dresden, GER, March 16 - 18, 2016

Girls' Day 2016, "Wie entsteht ein Chip?"
Erlangen, GER, April 28, 2016

ICCGE-18, 18th International Conference on Crystal Growth and Epitaxy
Nagoya, JPN, August 7 - 12, 2016

ICEP 2016, International Conference on Electronics Packaging
Sapporo, JPN, April 20 - 22, 2016

ICMIM 2016, IEEE MTT-S International Conference on Microwaves for Intelligent Mobility
San Diego, USA, May 19 - 20, 2016

ICPSCG10, 10th International Conference of Polish Society for Crystal Growth
Zakopane, POL, October 16 - 21, 2016

IECON 2016 - 42nd Annual Conference of the IEEE Industrial Electronics Society
Florence, ITGA, October 23 - 26 2016

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Cont.: Conferences, Workshops, Fairs, and Exhibitions

IEEE SENSORS 2016
Orlando, USA, October 30 - November 02, 2016

IIT 2016, 21st International Conference on Ion Implantation Technology
Tainan, TWN, September 26 - 30, 2016

IMAPS Advanced Technology Workshop & Tabletop Exhibition on Wire Bonding
Los Gatos, USA, February 9 - 10, 2016

INTELEC 2016, IEEE International Telecommunications Energy Conference
Austin, USA, October 23 - 27, 2016

International Workshop on EUV-Lithography
Berkeley, USA, June 13 - 16, 2016

ISCAS 2016, IEEE International Symposium on Circuits and Systems
Montreal, CAN, May 22 - 25, 2016

iSEnEC 2016, Integration of Sustainable Energy Conference
Nuremberg, GER, July 11 - 12, 2016

ISIE 2016, IEEE International Symposium on Industrial Electronics
Santa Clara, USA, 2016

ISPSD 2016, 28th IEEE International Symposium on Power Semiconductor Devices and IC´s
Prague, CZE, June 12-16

ITEC 2016, IEEE International Transportation Electrification Conference
Toulouse, FRA, November 2 - 4, 2016

IWN 2016, International Workshop on Nitride Semiconductors
Orlando, Florida, USA, October 2 - 7, 2016

Karrieremesse Orte
Freiberg, GER, January 14, 2016

Kolloquium zur Halbleitertechnologie und Leistungselektronik
Erlangen, GER, 2016

Leistungselektronik – Gemeinsame Vortragsreihe des Bayerischen Clusters Leistungselektronik und des Fraunhofer IISB
Erlangen, GER, 2016

LOPEC 2016, Large-area, Organic & Printed Electronics Convention
Munich, GER, April 5 - 7, 2016

Medizin Innovativ - MedTech Summit 2016
Nuremberg, GER, June 15 - 16, 2016

MNE 2016, 42nd International Conference on Micro&Nano Engineering
Vienna, AUT, September 19 - 23, 2016

MRS Spring Meeting
Phoenix, Arizona, USA, March 30 - April 1, 2016

Nanoelectronics Forum 2016
Rom, ITA, November 23 - 24, 2016

Nanoimprint Lithography (NIL), Seminar des Graduiertenkollegs 1986 (Complex Scenarios of Light-Control)
Erlangen, GER, July 14, 2016

NEIS Conference 2016, Nachhaltige Energieversorgung und Integration von Speichern
Hamburg, GER, Septemberg 15 - 16, 2016

Netzwerksitzung LOHCmobil (ZIM-Kooperationsnetzwerk)
Erlangen, GER, November 9, 2016

NIL Industrial Day 2016
Wien, AUT, March, 2016

NNT 2016, 15th International Conference on Nanoimprint & Nanoprint Technology
Braga, POR, September 26 - 28, 2016

Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.3 "Abschneide und Ätzverfahren"
Erlangen, GER, December 6, 2016

OSA Topical Meeting, Imaging Systems and Applications
Heidelberg, GER, July 25 - 28, 2016

OTTI, 5. Fachforum Thermische Energiespeicher
Neumarkt, GER, Juni 30 - July 1, 2016

OTTI, Anwenderforum Effiziente Kältetechnik in der Anwendung
Regensburg, GER, February 2 - 3, 2016

PATMOS 2016, International Workshop on Power an Timing ModelingOptimization and Simulation
Bremen, Germany, September 21 - 23, 2016

PCIM Europe 2016, International Exhibition and Conference for Power Electronics, Intelligent Motion, Renewable Energy and Energy Management
Nuremberg, May 10 - 12, 2016

P-Seminar "Kristallzüchtung" der Berthold-Brecht Schule Nürnberg
Nuremberg, GER, October 21, 2016

realize your visions! – Ingenieure gestalten Zukunft, Berufs- und Informationsmesse
Nuremberg, GER, February 18, 2016

Schülerexkursion des Emil-von-Behring-Gymnasiums Erlangen-Spardorf
Nuremberg, GER, July 25, 2016

SEMICON Europa 2016
Grenoble, FRA, October 25 - 27, 2016

Seminar of Paul Scherrer Institut
Villigen, SUI, December 2016

Seminar "Elektromobilität" des Instituts für Geographie der Universität Erlangen-Nürnberg
Erlangen, GER, June 1, 2016

SIMS Europe 2016
Münster, GER, September 18 - 20, 2016

SISPAD 2016, 21st International Conference on Simulation of Semiconductor Processes and Devices
Nuremberg, GER, September 6 - 8, 2016

SISPAD 2016, Workshop "Simulation of Advanced Interconnects"
Nuremberg, GER, September 5, 2016

SISPAD2016, Workshop "Variability-Aware Design Technology Co-Optimization"
Nuremberg, GER, September 5, 2016

SPIE Advanced Lithography
San Jose, California, USA, February 21 - 25, 2016

STEEP Final Workshop
Brno, CZE, February 17, 2016

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Cont.: Conferences, Workshops, Fairs, and Exhibitions

Symposium Material Innovativ 2016
Würzburg, GER, February 23, 2016

TechConnect World Innovation, National Innovation Summit and National SBIR/STTR Conference
Washington / National Harbor, USA, May 23 - 25, 2016

VARI 2016, 7th International Workshop on CMOS Variability
Bremen, GER, September 21 - 23

WHEC 2016, World Hydrogen Energy Conference
Zaragoza, SPA, June 13 - 16, 2016

WIPDA 2016, 4th IEEE Workshop on Wide Bandgap Power Devices and Applications
Fayetteville, USA, November 7 - 9, 2016

Wireless Congress: Systems & Applications
Munich, GER, November 10, 2016

WiSNet 2016, IEEE Topical Conference on Wireless Sensors and Sensor Networks
Austin, USA, January 24 - 27, 2016

Yokogawa Power-Meter-Seminar 2016
Erlangen, GER, October 19, 2016

ZS-Handling Technology Forum
Regensburg, GER, June 7, 2016

Publications

Akdere, M.; Giegerich, M.; Wenger, M.; Schwarz, R.; Koffel, S.; Führer, T.; Waldhör, S.; Wachtler, J.; Lorentz, V. R. H.; März, M.:
Hardware and software framework for an open battery management system in safety-critical applications
Proceedings 42nd Annual Conference of the IEEE Industrial Electronics Society, IECON 2016, IEEE, 2016, pp. 5507-5512
DOI: 10.1109/IECON.2016.7793001

Albrecht, M.; Hürner, A.; Erlbacher, T.; Bauer, A. J.; Frey, L.:
Experimental Verification of a Self-Triggered Solid-State Circuit Breaker Based on a SiC BIFET
Materials Science Forum 897 (2017) 665
DOI: 10.4028/www.scientific.net/MSF.897.665

Albrecht, M.; Erlbacher, T.; Bauer, A. J.; Frey, L.:
Potential of 4H-SiC CMOS for high temperature applications using advanced lateral p-MOSFETs
Materials Science Forum 858 (2016) 821
DOI: 10.4028/www.scientific.net/MSF.858.821

Aufgebauer, H.; Kundin, J.; Emmerich, H.; Azizi, M.; Reimann, C.; Friedrich, J.; Jauß, T.; Sorgenfrei, T.; Cröll, A.:
Phase-field simulations of particle capture during the directional solidification of silicon
Journal of Crystal Growth 446 (2016), pp.12-26
DOI: 10.1016/j.jcrysgro.2016.04.032

Badr, E.; Pichler, P.; Schmidt, G.:
Modeling the post-implantation annealing of platinum
Proceedings Gettering and defect engineering in semiconductor technology XVI, Trans Tech Publications, 2016, pp. 258-263
DOI: 10.4028/www.scientific.net/SSP.242.258

Baer, E.; Niess, J.:
Equipment simulation for studying the growth rate and its uniformity of oxide layers deposited by plasma-enhanced oxidation
Proceedings International Conference on Simulation of Semiconductor Processes and Devices, SISPAD 2016, IEEE, 2016, pp. 137-140
DOI: 10.1109/SISPAD.2016.7605166

Baer, E.; Burenkov, A.; Evanschitzky, P.; Lorenz, J.:
Simulation of process variations in FinFET transistor patterning
Proceedings International Conference on Simulation of Semiconductor Processes and Devices, SISPAD 2016, IEEE, 2016, pp. 299-302
DOI: 10.1109/SISPAD.2016.7605206

Content

Continuation: Publications

Banzhaf, S.; Schwaiger, S.; Erlbacher, T.; Bauer, A. J.; Frey, L.:
Post-Trench Processing of Silicon Deep Trench Capacitors for Power Electronic Applications
Proceedings of the 28th International Symposium on Power Semiconductor Devices & IC´s (ISPSD), June 12-16, Prague, Czech Republic 7520862 (2016) 399
ISBN: 978-1-4673-8769-9

Bayer, C. F.; Waltrich, U.; Schneider, R.; Souedan, A.; Bär, E.; Schletz A.:
Enhancement of the partial discharge inception voltage of DBCs by adjusting the permittivity of the encapsulation
ETG-Fb. 148: CIPS 2016 - 9th International Conference on Integrated Power Electronics Systems, Proceedings March, 8 - 10, 2016, Nuremberg/Germany

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