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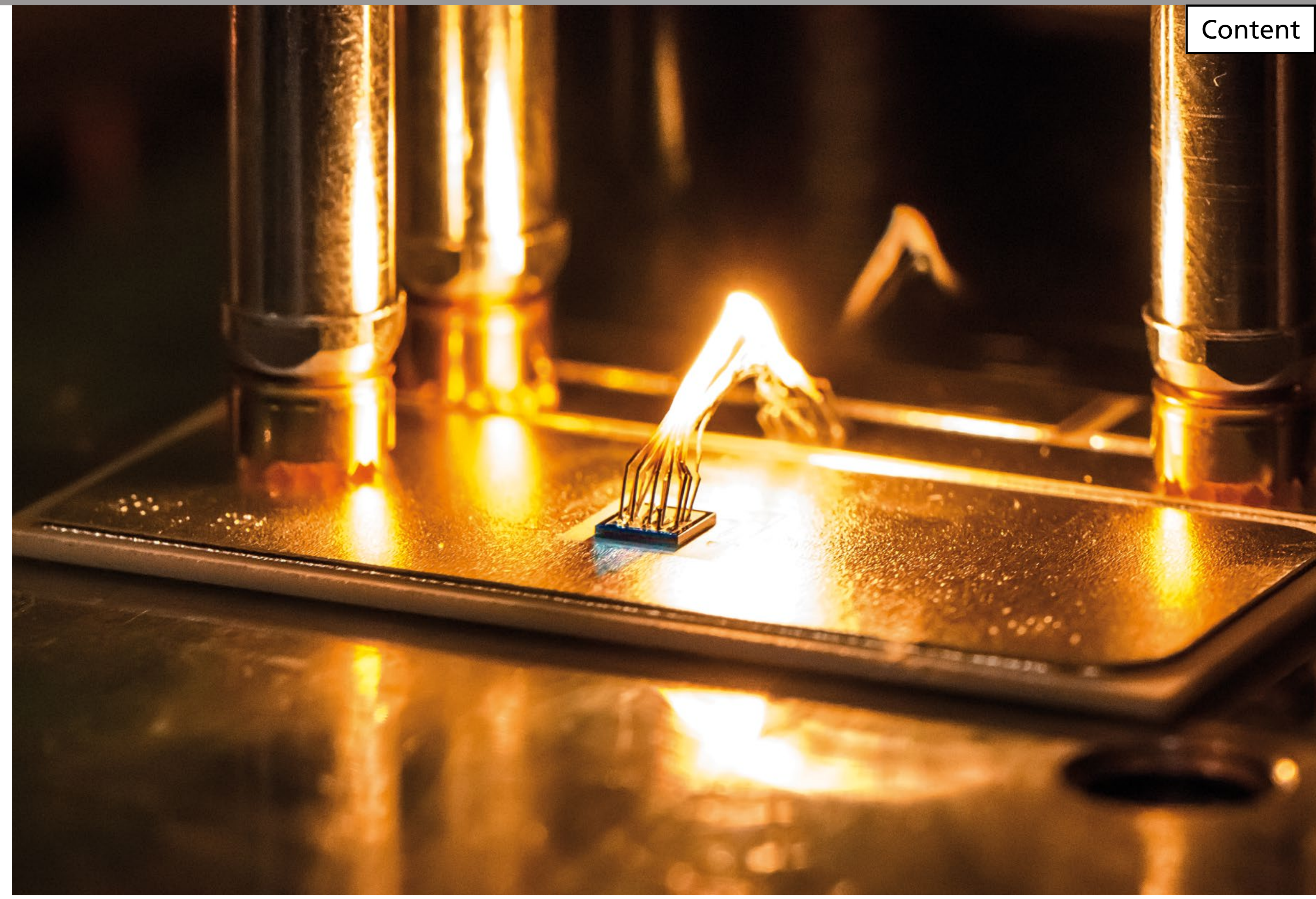
FRAUNHOFER INSTITUTE FOR INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

Content



Annual Report 2015

Fraunhofer Institute for Integrated Systems and Device Technology IISB

ANNUAL REPORT 2015

Content

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Active power cycling test of silicon carbide devices at high temperature and overcurrent.
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ACHIEVEMENTS AND RESULTS
ANNUAL REPORT 2015

Content

FRAUNHOFER INSTITUTE FOR
INTEGRATED SYSTEMS AND DEVICE TECHNOLOGY IISB

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PREFACE

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Content

1 *Prof. Dr. rer. nat. Lothar Frey, director of Fraunhofer IISB. © M. Heyde / Fraunhofer*

Looking back to a successful past and great steps towards the future: these items characterized the work of Fraunhofer IISB in 2015. The institute celebrated its 30th anniversary and started the "Leistungszentrum Elektroniksysteme", which gives us a prospect to extend our research on electronic systems.

Founded in 1985, the Fraunhofer IISB carries out R&D in the fields of semiconductors and power electronics. The institute's work covers the entire value chain for electronic systems from basic materials to power electronic application, with particular focus on electric mobility and energy supply. Besides celebrating three decades of IISB, our branch labs on power electronics in Nuremberg-South and on semiconductor materials in Freiberg could review their official inaugurations ten years ago. A look into the history of semiconductor research was the subject of our 2015 IISB Annual Conference, dealing with semiconductor manufacturing. The present and future of our semiconductor research is reflected by our successfully evolving π-Fab service for prototype fabrication of electron devices and process development in silicon and silicon carbide technologies.

In the field of power electronic systems, the progress in our Bavarian energy research project SEEDs or the official rollout of our 100%-IISB-inside electric sports car "IISB-ONE" demonstrate our steps into the future of electronic systems. Stepping into the future also means supporting young scientists. The BMBF-Fraunhofer student program on electric mobility, DRIVE-E, which in 2016 was organized at Fraunhofer IISB in Erlangen, is an excellent example.

Another highlight of the year was the foundation of the "Leistungszentrum Elektroniksysteme" (LZE) together with Fraunhofer IIS and the University of Erlangen-Nürnberg, with the goal to establish a long-term strategic cooperation between University, Fraunhofer, and industry, comprising, e.g., joint research roadmapping. The organizational activities of LZE are supplemented by four challenging scientific projects to underline the vigor of the LZE team. This leads back to our anniversary, as 30 years of IISB also means 30 years of close partnership between the Friedrich-Alexander University Erlangen-Nürnberg and the Fraunhofer institutes IIS and IISB in Erlangen. We are very grateful for this close relationship.

Fraunhofer IISB has increased its annual budget to 22 million Euros with a staff of more than 250. 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.

Lothar Frey

Prof. Dr. Lothar Frey

Erlangen, Februar 2016

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FRAUNHOFER IISB AT A GLANCE

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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 two branches in Nuremberg and one in Freiberg. As one of the 67 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.

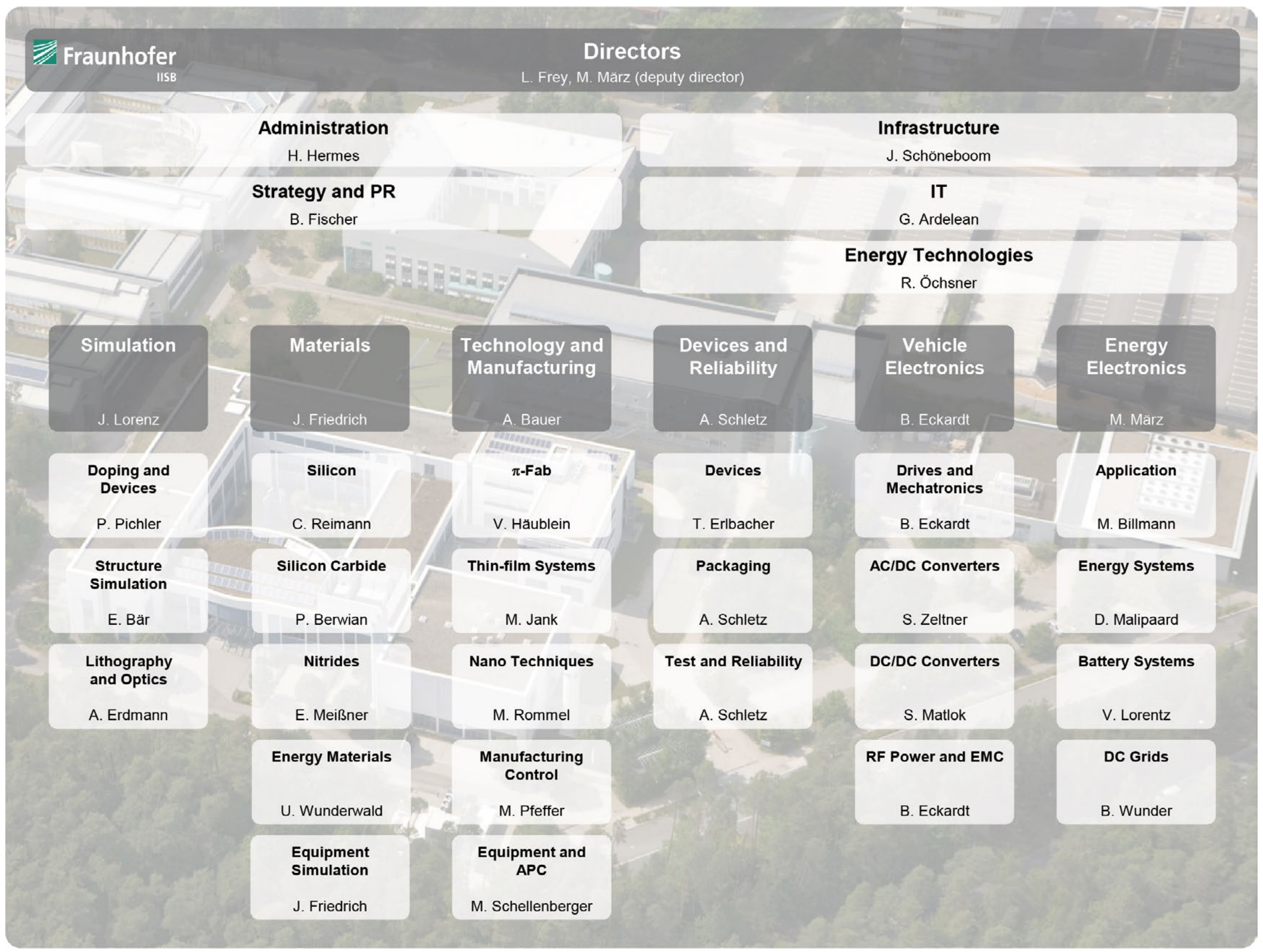
The IISB is a close partner of national and international industry. Its main objective is to provide excellent research to its customers and to set technological benchmarks as one of the leading research institutions in electronic systems. Cooperation includes research and development projects, prototyping,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

1 *Building of Fraunhofer IISB in Erlangen with test center for electric vehicles and cleanroom; behind: cleanroom laboratory and building of the Chair of Electron Devices of the University of Erlangen-Nürnberg.*
© K. Fuchs / Fraunhofer IISB

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).

FRAUNHOFER IISB AT A GLANCE



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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.

1 Organization of Fraunhofer IISB 2015: 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

FRAUNHOFER IISB AT A GLANCE

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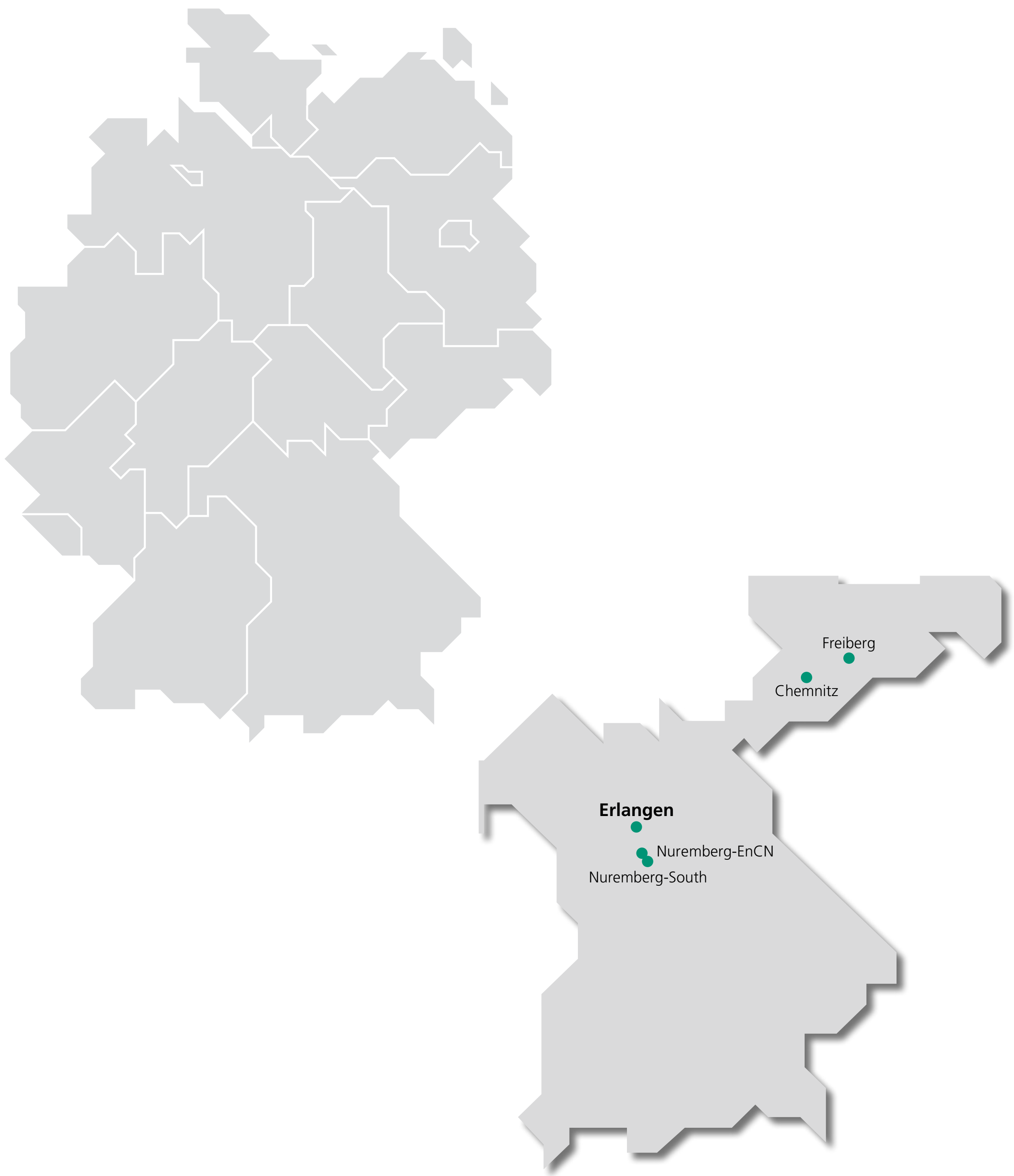

Vehicle Electronics

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-South
Landgrabenstrasse 94, 90443 Nuremberg

At Nuremberg-South, 800 m² of office and lab area are available. Research activities are focused on packaging and power electronic systems for industrial applications and energy technology.

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.*
© Fraunhofer / Fraunhofer IISB

FRAUNHOFER IISB AT A GLANCE

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Fraunhofer IISB Nuremberg-EnCN
Fürther Strasse 250, "Auf AEG", 90429 Nuremberg

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

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 m².

Chemnitz Laboratory
Reichenhainer Strasse 29a, 09126 Chemnitz

In Chemnitz, the IISB operates a laboratory of 160 m² 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 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.

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.

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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. Michael Jank
- Introduction to Printable Electronics

Dr. Jürgen Lorenz
- Process and Device Simulation

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

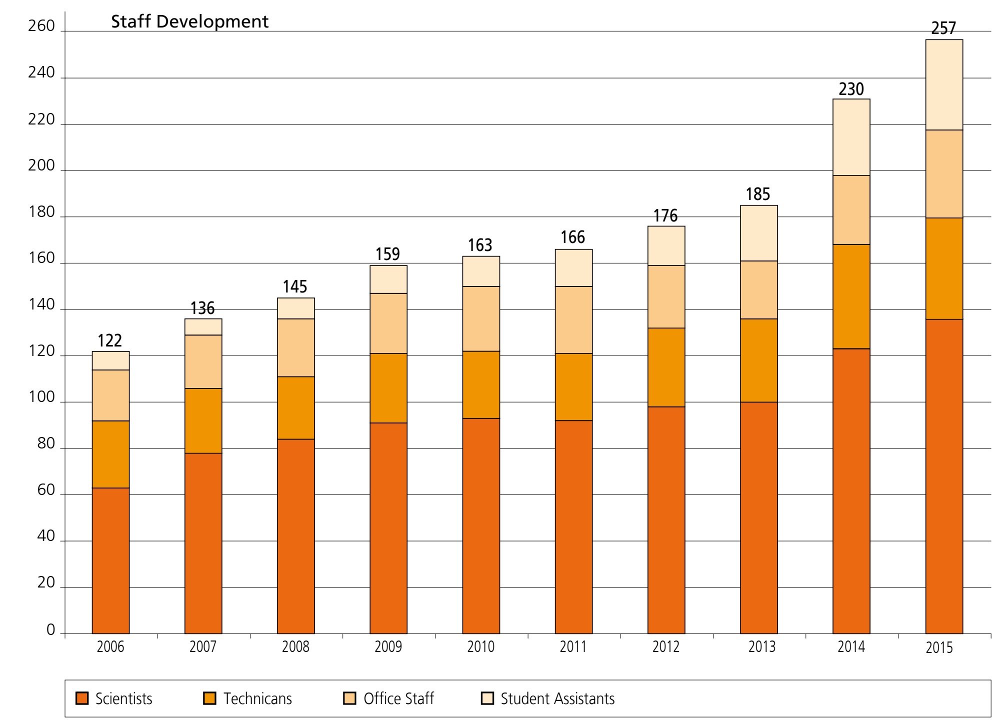
Prof. Dr. Lothar Pfitzner
- Semiconductor Equipment Technics

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

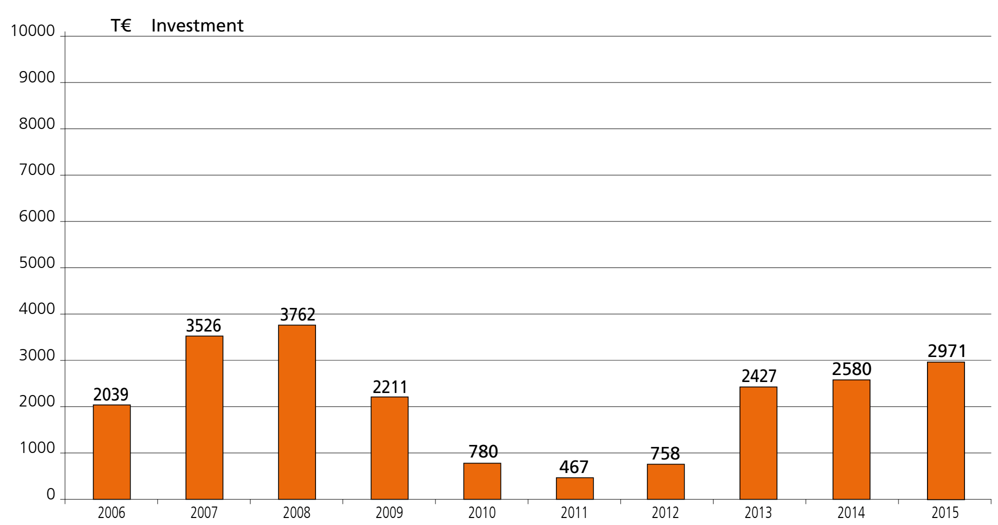
1 *Chair of Electron Devices of the University of Erlangen-Nürnberg: main building and clean room laboratory. © LEB*

Content

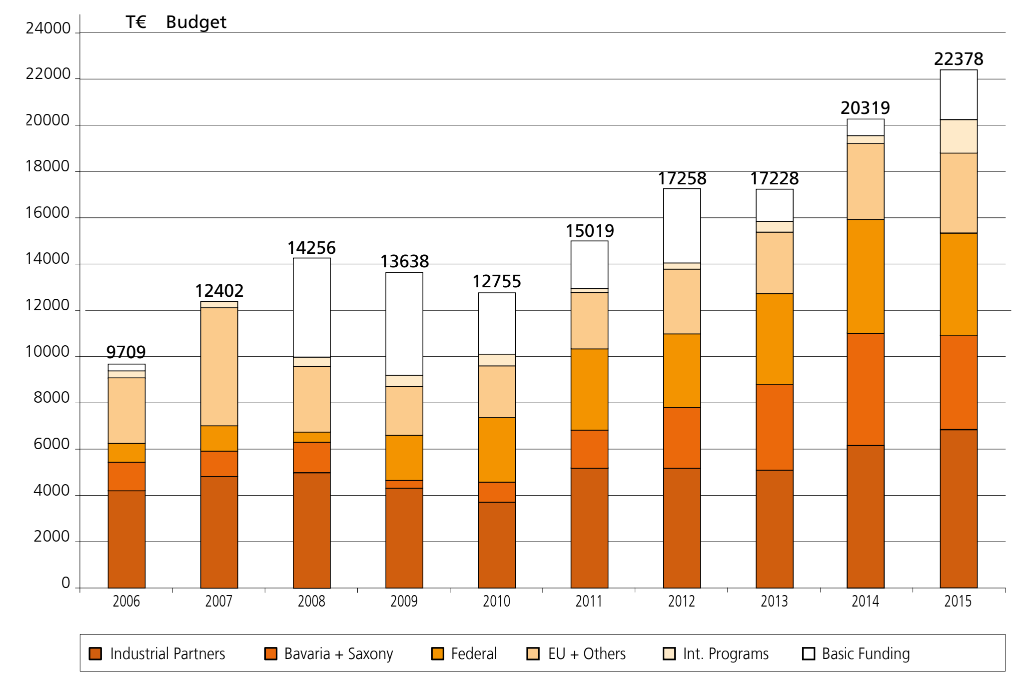
Staff Development, Investments, and Budget



1 *Staff development 2006 - 2015. © Fraunhofer IISB*



2 *Capital investment (without basic equipment and special funds) 2006 - 2015. © Fraunhofer IISB*



3 *Operating budget according to financing domains 2006 - 2015. © Fraunhofer IISB*

Content

Advisory Board (December 2015)

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

Dr. Stefan Kampmann (Chairman of the Advisory Board)
Robert Bosch GmbH

Dr. Helmut Gassel
Infineon Technologies AG

Thomas Harder
European Center for Power Electronics (ECPE)

Markus Lötzsch
Nuremberg Chamber of Commerce and Industry

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

Prof. Dr. Marion Merklein
University of Erlangen-Nürnberg

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Bavarian Ministry of Economic Affairs and Media, Energy and Technology

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FRAUNHOFER-GESELLSCHAFT

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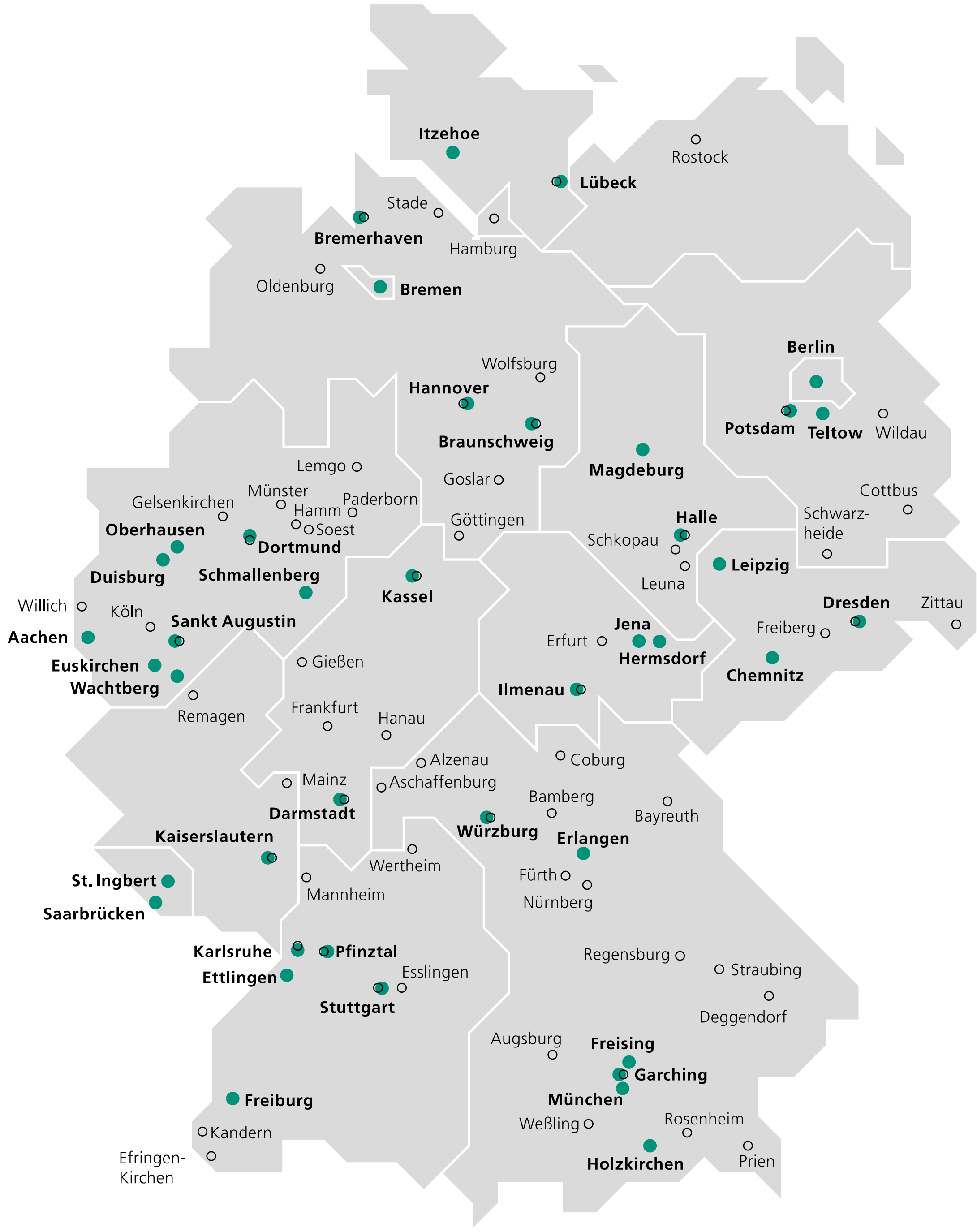

The Fraunhofer-Gesellschaft

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 67 institutes and research units. The majority of the nearly 24,000 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 1.8 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

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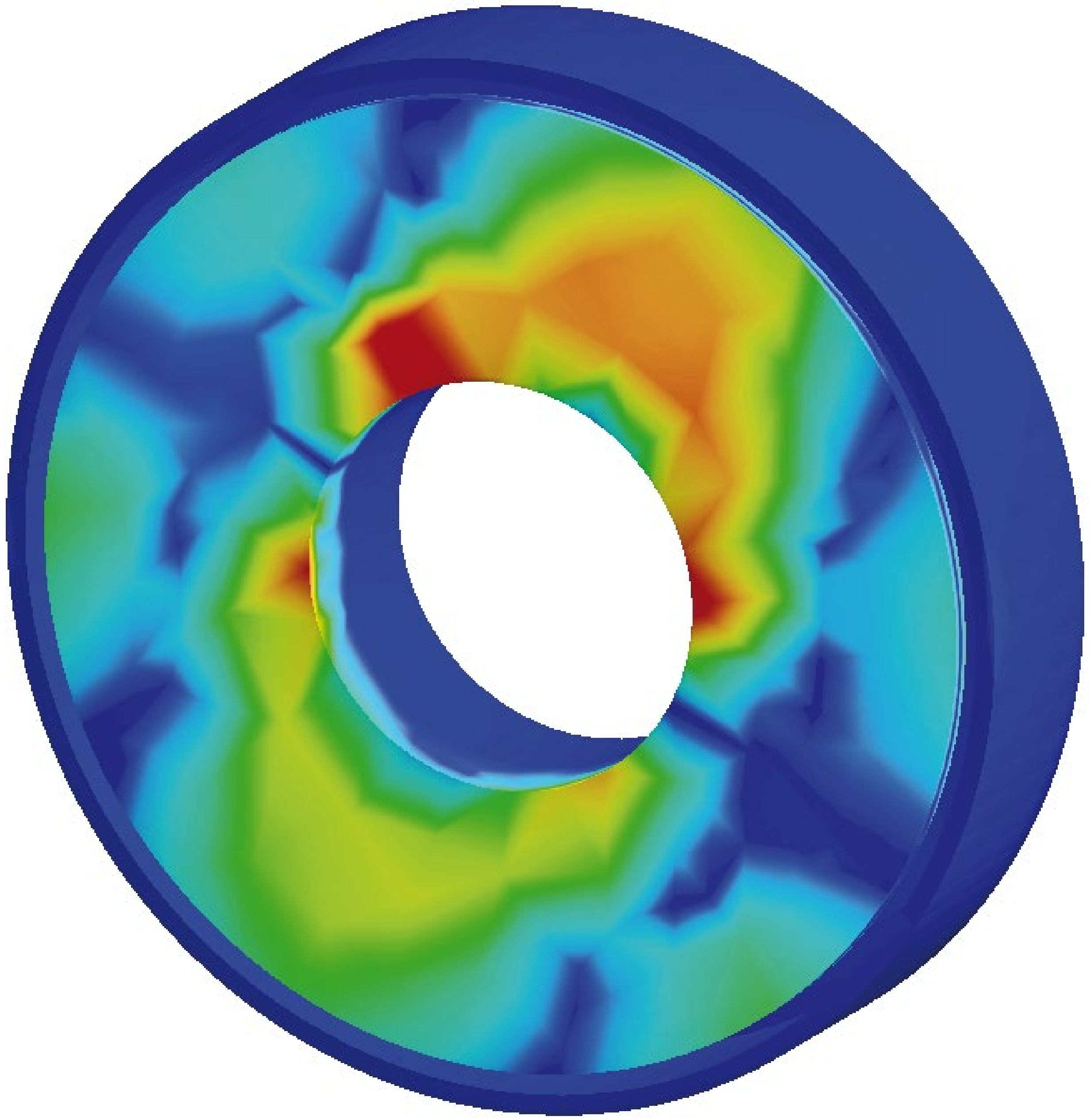

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The simulation of semiconductor fabrication processes, devices, circuits, and systems greatly contributes to the reduction of development costs in the semiconductor industry. Among others, this has been confirmed for micro- and nanoelectronics in the 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.

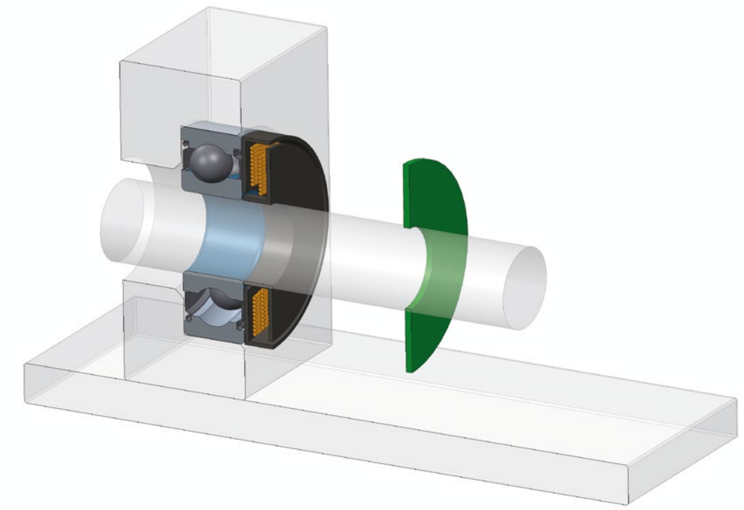
While process and device simulation has meanwhile become largely established in industry as an indispensable tool for the development and optimization of highly scaled devices ("More Moore"), the area of "More than Moore", which consists of fields such as analog / RF, low-power electronics, power electronics, 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 three cooperative projects on the European level: The EU FP7 project "Circuit Stability Under Process Variability and Electro-Thermal-Mechanical Coupling" (SUPERTHEME) coordinated by the department deals with the simulation of the impact of process variations on advanced transistors and circuits. The EU FP7 project "Computational Lithography for Directed Self-Assembly: Materials, Models and Processes" (CoLiSA.MMP) coordinated by the department deals with a very promising material-driven resolution enhancement method for the patterning of small structures. The traditionally optics-driven resolution improvements through extreme ultraviolet (EUV) lithography are addressed in the ENIAC KET pilot line "Seven Nanometer Technology" (SENATE) by a consortium of about 40 companies, research institutes, and universities, coordinated by ASML (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

1 *Modal analysis of the housing of an inductive transformer with regard to the maximum shear stress, based on a virtual prototype.*
© Fraunhofer IISB

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

SIMULATION



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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 for 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 applies its lithography simulator Dr. LiTHO for the optimization of advanced LED-based lighting systems. Lithography simulation is applied 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 2015, members of the department also organized the international conference "Gettering and Defect Engineering in Semiconductor Technology" (GADEST) held in September 2015 in Bad Staffelstein, around 70 km from Erlangen, with more than 100 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.

Virtual Prototyping for Power Electronic Systems

In January 2015, the Leistungszentrum Elektroniksysteme (LZE) – "High Performance Center for Electronic Systems" – was established in the scope of a joint initiative of Fraunhofer IIS, Fraunhofer IISB, and the University of Erlangen-Nürnberg to address future trends in the domain of electronics. The second sub-project of the LZE "Wireless Power and Data Transfer in Systems with Fast-moving Parts" focuses on inductive power and data transfer in rotating devices.

While basic foundations for wireless power transmission were already laid more than a century ago by Nikola Tesla, today's requirements are much more challenging with regard to efficiency, robustness, and costs. Commonly, sensors and actuators in wind power systems or automated autonomous production robots are connected by slip rings or flexible cables. These types of connection are widespread in all kinds of technical devices but very vulnerable to dirt, dust, and abrasion.

From a technical point of view, the goal of the project is to develop an encapsulated component for contactless power transfer between a stator and a moving part. This enclosed system is challenging with regard to the electrical design as well as because of heat balancing and vibrations. Generally, several iterations of the electrical design, prototyping, measurements, and evaluations are needed to achieve a functional prototype.

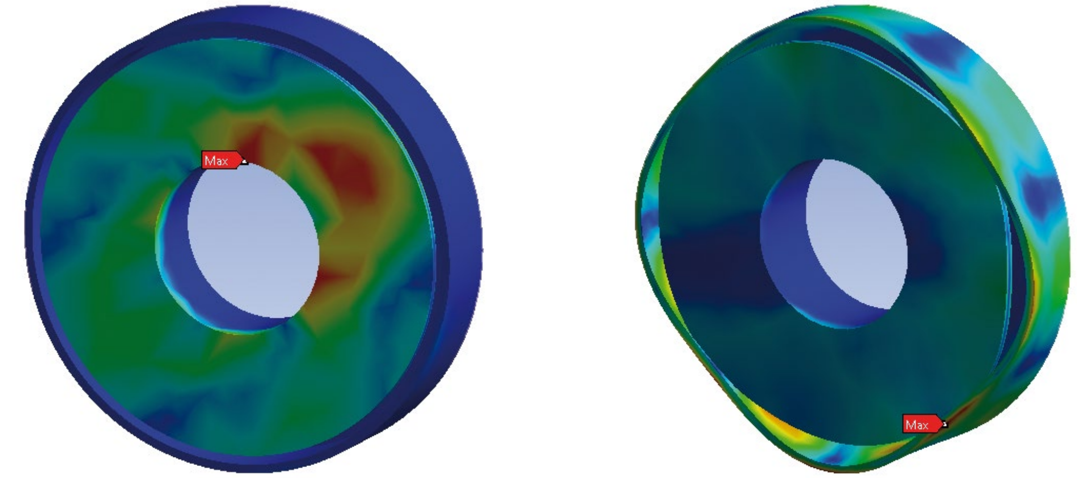
Within the project, this time-consuming and costly process was accelerated by transferring major parts of the research process from the lab to virtual prototypes. Due to long-term experience in the design of complex workflows combining different physical domains, the Simulation department designed a new, efficient concept for the virtual product design. Processes that have been established over several years in cooperation with industrial partners were enhanced and adapted to the interaction of electrical, thermal, and structural simulations.

The key factor in the initial period of the project is a fast selection of suitable designs. In close coordination among electronics experts, system engineers, and other specialists, the physical boundary conditions are defined and implemented in the simulation workflow. The resulting first virtual prototype is a fully parametric model with regard to geometry and material properties. For the inductive system, the electrical coupling can be analyzed rapidly for varying material properties (such as conductivity and magnetic permeability) used for the housing. Based on that, several hundred virtual designs are simulated to identify the range of target parameters and to detect sensitivities and variations. With the help of high-performance computers and coupled analytical-numerical approaches, highly accurate results are achieved especially for key quantities, such as inductivity, coupling, and power transfer. In coordination with system engineers, the most suitable design is used for real prototyping. Due to the virtual parametric model, the exact CAD data for all parts is provided and can be used for material purchase orders or directly manufactured by using 3D printers.

At the same time, further simulations are executed to detect weak spots with long-term usage or under extreme conditions. In highly complex simulations, vibrations in the system are analyzed

1 *Virtual prototype of an inductive system for wireless power and data transmission in rotating devices. © Fraunhofer IISB*

SIMULATION



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by using the modal analysis of harmonic waves for the entire range of possible operating points. For example, the harmonic response with regard to the maximum shear stress (over the regarded frequency range) and the equivalent stress (at 20 kHz) is visualized for the virtual prototype of an inductive system within ball-bearing systems. Additionally, the thermal impact on the electrical and structural behavior is simulated by coupling the corresponding simulations.

Within the last few years, the accuracy of the physical and mathematical models has increased continuously and so have the computational resources for resolving these effects, even on complex 3D geometries. Nevertheless, single particular experiments and prototypes are still required to verify and gauge the simulation results. However, the scope of these experiments can be restricted to problematic issues detected in the virtual model.

In future work, additional know-how of the Simulation department will be integrated in this work flow. For instance, genetic algorithms, developed and applied for more than a decade now, will be adapted and implemented to enhance not only the virtual model but also power electronic systems.

1 *Based on the virtual prototype of the inductive system, the electrical coupling is simulated depending on the conductivity and magnetic permeability of the housing of the inductive transformer. © Fraunhofer IISB*

2 *Modal analysis of the housing of the inductive transformer with regard to the maximum shear stress and the equivalent stress. © Fraunhofer IISB*

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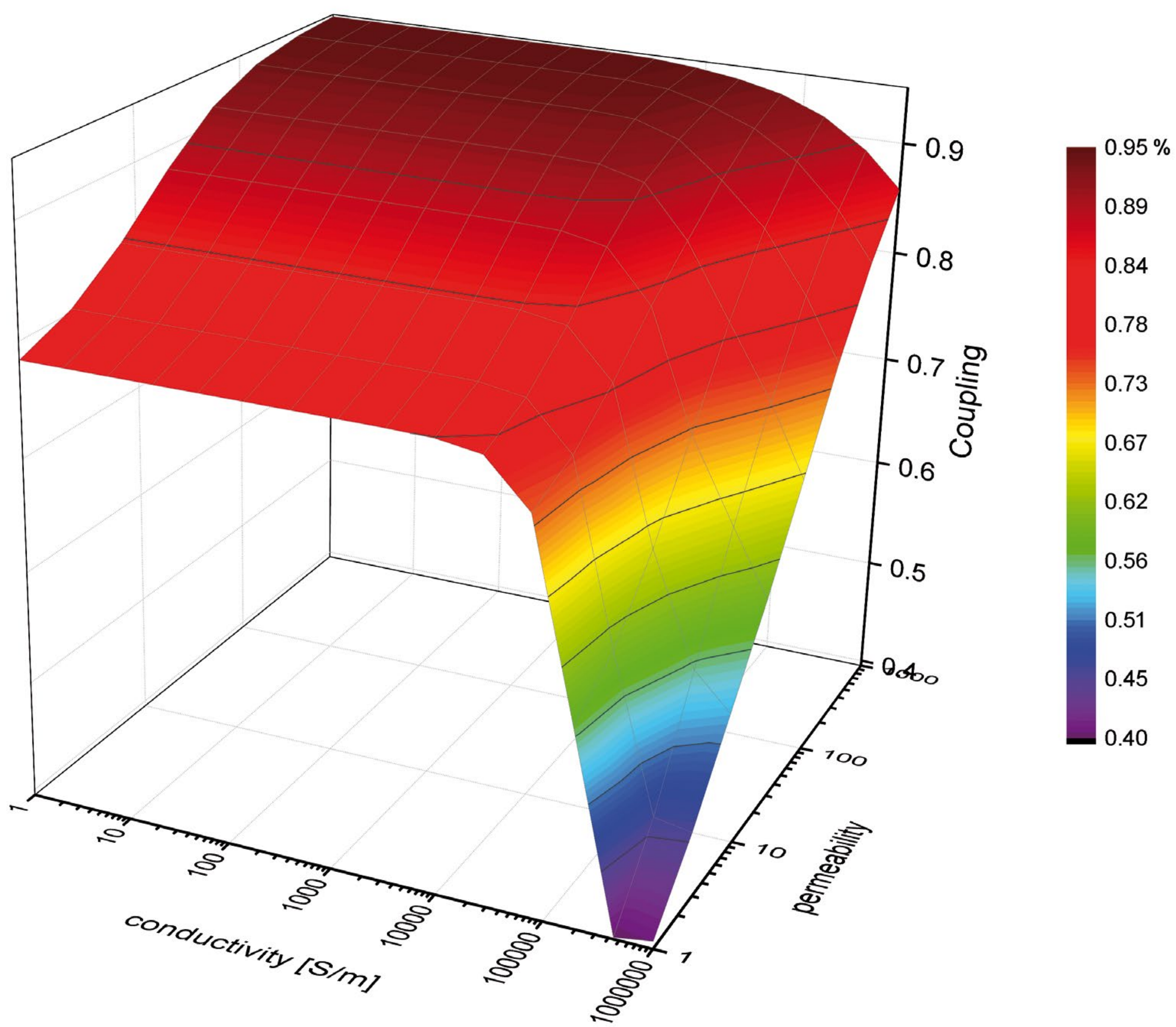

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MATERIALS

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The objective of the Materials department is to provide scientific and technological solutions for the development and characterization of crystalline materials and their production processes. A key aspect is the commercialization of these materials to enable novel applications. Special emphasis is placed on semiconductors, oxides, and halides for electronic, energy, and optical systems. The main aim is to support material, device, and equipment manufacturers and their suppliers in the areas of crystal growth, epitaxy, chip / device production, thin film deposition, and the synthesis of materials for wet chemical layer preparation and particle coating. Our materials are further processed into devices and integrated in system demonstrators in-house or at partner sites. The testing of the relationship between the material microstructures and the performance and reliability of a device in a respective application gives us the best input for the further optimization of the materials and their production processes.

The strategy of IISB, together with its branch in Freiberg/Saxony, the Fraunhofer Technology Center for Semiconductor Materials (THM), is a combinatory approach with a 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 consists of 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-Nürnberg, the Technical University Georg-Simon-Ohm Nuremberg, and the Technical University Bergakademie Freiberg, the Materials department supervises students carrying out research projects, bachelor's, master's, and PhD theses.

During 2015 the research topics of the Materials department were in the areas of silicon, silicon carbide, gallium nitride, and energy materials.

In the field of directional solidification of silicon, the scientific highlight was our Parsiwal experiment, which we carried out onboard the TEXUS 51 rocket mission under microgravity conditions. In our Parsiwal experiment, we were able to clarify that the lift force that is caused by buoyant convection on earth can have a significant influence on the incorporation of SiC particles. Of

1 *Launch of TEXUS 51 research rocket from the Esrange Space Center near Kiruna in northern Sweden on 23 April 2015 at 09:35 CEST. © DLR*

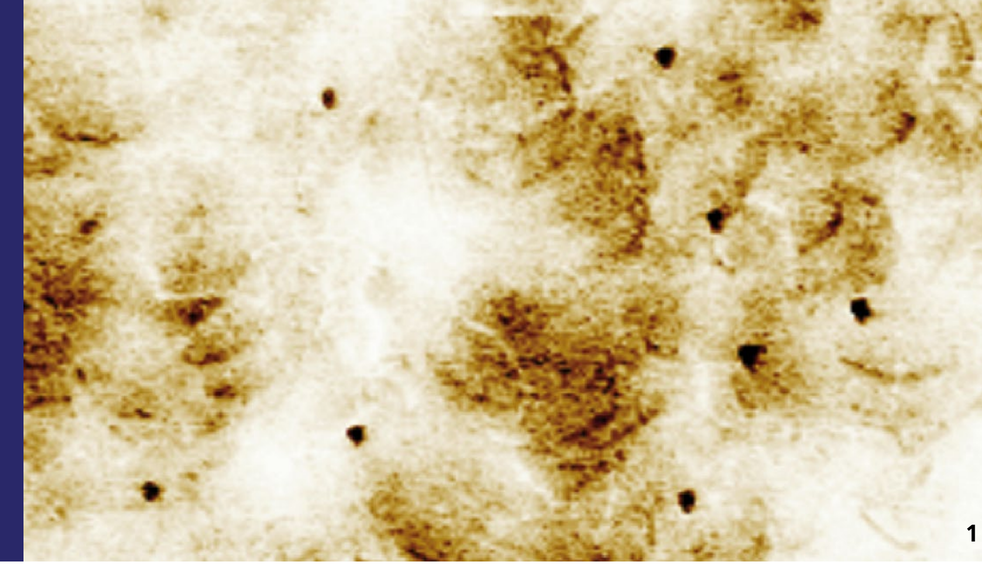
2 *Dr. Jochen Friedrich, head of the Materials department. © K. Fuchs / Fraunhofer IISB*

more practical relevance was our research on so-called high-performance multicrystalline silicon. For industrial partners we developed several technological solutions to achieve material that is characterized by a fine-grained structure along with a high amount of random grain boundaries and thus a low density of dislocation clusters. We have shown that such material properties can be obtained by heterogeneous nucleation of the silicon melt either on silicon feedstock with micrometer-sized grains or on an optimized Si_3N_4 coating, or on particles or coatings with a particular chemical composition.

In the field of Czochralski-grown silicon, we have started to established a characterization line that allows us to measure relevant material properties such as intrinsic and extrinsic point defects, oxygen precipitates, dislocations, or the solid-liquid interface shape from samples that we either prepare from complete crystals or crystal pieces. Furthermore, numerical simulations based on a special 2D-3D coupling approach were used to propose which measures are needed to optimize an industrial Czochralski process for photovoltaic applications with respect to lower oxygen content and higher throughput. For heavily doped silicon, we extended our investigations on the causes of the higher probability of structure loss during crystal pulling towards heavily phosphorous-doped silicon with a 300mm diameter. From our results, we can conclude that the origin of the structure loss is most likely linked to growth instabilities close to the triple point.

In the field of gallium nitride, the Materials department focusses on two research areas: i) the development of the HVPE process for growing GaN boules and ii) reliability investigations of GaN power devices. Regarding i), we have upscaled our HVPE process for growing crack-free GaN boules with thicknesses of a few millimeters from 2" to 3" in diameter. Our novel in-situ monitoring system for in-situ curvature and thickness monitoring of the growing GaN crystal has proven to be successful and an important prerequisite for optimizing the growth conditions with respect to stress management in crystals. The experimental work was supported by numerical simulations of the temperature fields and gas flows in order to further improve the reactor geometry with respect to more uniform growth conditions over the growing surface. Regarding ii), the electrical performance and reliability of GaN power devices was correlated with the structural properties of GaN epitaxial layers grown on silicon substrates. We found with CL and SIMS measurements that a non-uniform distribution of carbon in the material is responsible for a shift in the breakdown voltage. Furthermore, we confirmed with C-AFM measurements that a certain number of dislocations are especially highly conductive and that a vertical leakage current occurs in combination with the lateral conduction through the 2DEG of the HEMT structure.

In the field of silicon carbide, we transferred our knowledge of growing thin and thick SiC epitaxial layers with low defect densities from our R&D epitaxial growth reactor to state-of-the-art production equipment. We are now able to offer our internal and external customers high-quality epitaxial layers on 75 mm, 100 mm and 150 mm SiC substrates. Our epitaxial layers are regularly characterized with respect to residual structural defects by our newly developed UV photoluminescence scanner. We were able to clearly show that these measurements allow us to predict, directly after the epitaxy process, on which areas of the wafer, e.g., bipolar devices will degrade due to the presence of certain dislocations. Another topic that we are addressing is the improvement of the minority carrier lifetime in SiC all along the value chain of the device manufacturing process. For that purpose, we are working on the reduction of carbon vacancies, which currently limit the lifetime. In the field of numerical simulation, related to SiC, a numerical model was developed that calculates the temperature and stress fields during the so-called thermal laser separation process for separating SiC devices. This model helps to figure out how technical parameters such as laser power or cooling conditions influence the crack propagation during the separation process.



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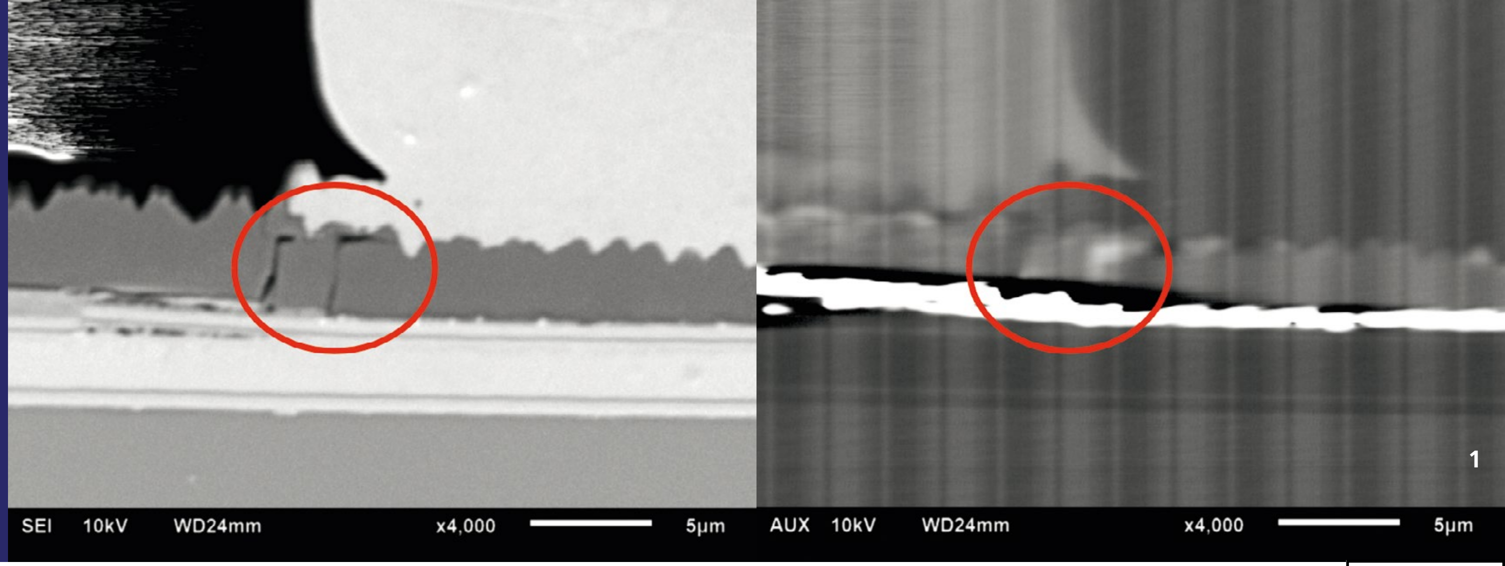
1 *C-AFM image: Localized conductive spots in GaN on silicon. Relative color scale: the darker the color the higher the conductivity. The width of the image is 5 µm.*
© Fraunhofer IISB

In the field of energy materials, we have developed a route for the synthesis of nanometer-sized, almost phase-pure, tetragonal barium titanate (BTO) powder. Its pyroelectricity makes it attractive for future energy recovery systems. It was demonstrated in a small system demonstrator that such pyroelectric materials can be used to produce hydrogen through a cyclic temperature change. We were also able to vary the physical properties of dense BTO layers that were deposited by spin coating over a wide range by using special conditioning steps. This opens up new applications in the field of passive electrical components such as the usage of BTO as capacitors. In this field of capacitors and especially metal foil - electrolytic – capacitors, we have supported our partners with our characterization tools. We were able to prove that the usage of special surface conditioned foils improves the electrical characteristics of the capacitors. We have achieved initial promising results in the field of secondary aluminum ion batteries. By using our own synthesized cathode materials or commercial graphite electrodes, we were able to show the electrochemical reversibility and the active potential range of such battery systems. Numerous methods for the electrochemical characterization of full and half cells are available.

Reliability-related Aspects of GaN-based Devices from a Materials Perspective

Due to the physical properties of GaN, recent GaN-based devices have a disruptive performance. For this reason, the attention paid to this material has increased rapidly in the last years. Fast switching, power HEMTs enable, e.g., more efficient power conversion and thus a reduction of the total power consumption and the size of the related systems. However, since it is a new technology, the question as to the reliability of the devices and systems is a key issue for developing this technology so that it enters the market with all its strict boundary conditions.
In principle, GaN devices can be manufactured on GaN native substrates, sapphire, SiC, or silicon.

MATERIALS



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The silicon substrate is naturally the cheapest one, readily available in large diameters. GaN on silicon is thus at first glance the most attractive choice for GaN devices for power electronic applications, whereas the choice for optoelectronic devices such as light emitting or laser diodes is different. However, the lifetime of a system is very important, and investigating the reliability and failure mechanisms of GaN devices for a physical understanding of failure and a clear vision of how long these devices will last in the field is a key issue. Compared to silicon technology, it is not clear what device lifetime or failure rates for the GaN devices will apply, and comparable qualification routes have not yet been defined. Moreover, there are many issues related to the materials inside a particular device that are not yet fully understood and rarely investigated. Establishing a link between the electrical performance of a device and the microstructure of the materials inside is very complex. Compared to silicon, GaN-based devices contain an extremely high amount of structural disturbances in the epitaxial layers, like dislocations. Therefore, distinguishing between technological reasons and materials issues is quite difficult. In order to generate a standard qualification at a later stage, one needs to understand the fundamentals of failure in these devices, which is where we contribute. An important problem which needs to be solved is, e.g., the vertical leakage of GaN on silicon HEMTs, which means an unwanted current flow through the GaN layer stack from the front side to the silicon substrate at the back. A typical HEMT structure contains many buffer layers that manage the strain and defect contents between the silicon substrate and the GaN functional layers where the two-dimensional electron gas (2DEG) exists. Before the 2DEG is created between the last unintentionally doped GaN layer and an AlGaN barrier, a thick semi-insulating layer is deposited in order to insulate the device vertically. The vertical insulation is very important for the functionality and the performance of such lateral HEMTs. It is strongly suggested that the vertical leakage through the insulating GaN layer is the limiting factor for the breakdown voltage of the device.

However, in an electrically tested device, the microstructure of the materials on an atomic scale is not easily accessible, and the electrical properties of structural issues, e.g., such as a single dislocation, are not easy determined experimentally. We investigate nitride semiconductor materials and heterostructures from a materials perspective, applying different analytical techniques. The EU project E2CoGaN, a large European joint undertaking where Fraunhofer IISB is one of the partners, addresses the reliability of GaN HEMTs rated for 600 and 800 V. In this framework, we study the relation between the dislocation microstructure in the insulating buffer layer and the vertical leakage and breakdown of the devices. Conductive AFM (C-AFM) measurements clearly show that the vertical current flow through the structure is extremely inhomogeneous. It varies locally by orders of magnitude. A portion of the vertical dislocations (purely screw or mixed-type dislocations with a large screw part) are found to be extremely conductive. The C-AFM images reveal them to be discrete spots of high conductivity, and as such, they form a conductive path to the silicon substrate, which is correlated with a vertical current flow through the whole structure. Cathodoluminescence (CL) imaging is one of the possibilities for localizing and visualizing dislocations as places for non-radiative recombination and, moreover, any physical reason which changes the luminescence spectra in terms of wavelength or total intensity of emission bands. In highly carbon-doped, insulating GaN buffer layers for HEMT structures, it is shown that the carbon dopant concentration may be depleted locally around a dislocation or more extensively in the vicinity of a dislocation bundle. The depletion of the dopant, which creates the insulating properties of the buffer, may result in a locally altered electrical conductivity, more towards n-type conduction rather than semi-insulating, as the buffer is supposed to be. In turn, the effective "electrical radius" of a dislocation might be much larger (µm) than expected (nm) just by the dislocation itself and its strain field. The image depicts an example of the localization of highly conductive spots revealed by C-AFM.

However, in the case of optical devices as well, laser diodes (LDs) and light emitting diodes (LEDs), electron microscopic techniques combined with the methods described above, proved to securely reveal material-related failure causes of, e.g., LEDs mounted in field systems. In the example case shown in the following figure, microscopic imaging first visualized the breakage of the semiconductor layer under the bond foot. The first result is not necessarily the reason for the malfunction of the device, since the rest of the layer works as expected, though the LED would be less bright but, e.g., not short circuited. In order to identify if these cracks could form a shortcut, the location was imaged under electron beam induced current flow (EBIC) with the scanning electron microscope (SEM). From that investigation, it was concluded that the crack is conductive and indeed shortcuts the backside contact and the front bond. The reason for this conductive behavior could be subsequently identified with a high spatial resolution energy dispersive x-ray analysis (EDS), which shows the presence of Al-metal decoration along the crack, which may have happened over the operation time of the device. It can be speculated that eventually a non-optimized bonding process can mechanically strain or crack the semiconductor layer, leading to a failure of the device at a later stage during use.

The examples described above illustrate the strong potential of microscopic techniques in combination with highly locally resolved electrical (C-AFM, EBIC) and optical or chemical measurements (CL, EDS) for the study of device failure related to materials issues in various senses. The correlative approach of these methods applied at the same location of a sample and on different length scales is even more powerful.

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1 *Left side: SEM image showing cracks in the semiconductor layer underneath the bond foot. Right side: EBIC image at the same place, under vertical current flow, from the front bond to the back contact. The bright, white contrast at the same location of the crack revealed in the SEM image proves the conductive property of the crack.*
© Fraunhofer IISB

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. Furthermore, from nanotechnology to printable macro-electronics, the Technology department is your contact for the realization and characterization of single process steps up to prototype devices. Based on comprehensive cleanroom 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. 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 1000 m² (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 power semiconductors 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. The devices currently under development include diodes and merged pin diodes in the voltage range well above 1 kV, as well as MOSFET devices such as vertical or lateral DMOS.

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 *View of the cleanroom laboratory.*
© Fraunhofer IISB

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

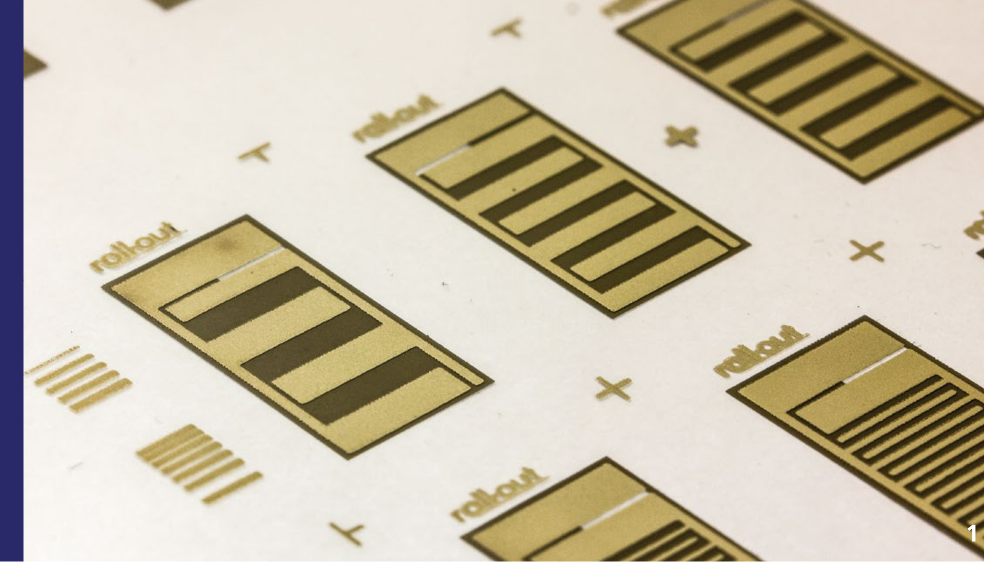
TECHNOLOGY AND MANUFACTURING

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).

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 photo resist 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 at the Technology department.

The focus of the department's activities in the field of thin film electronics is on the investigation and development of manufacturing methods for the solution processing of inorganic thin films for electronics, especially printable electronics. A special emphasis is placed on the interaction of processing with the resulting electrical properties for specific applications. Based on inks with semiconducting, conducting, and insulating nanoparticles or their respective molecular precursors, thin-film transistors (TFTs) are created that comprise printed features. The properties of functional thin films made by means of liquid processing are also analyzed in detail.

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.



Content

1 *Screen-printed unidirectional fill-level sensors for liquid containers.*
© Fraunhofer IISB

Thin-Film Systems

Fraunhofer IISB targets thin-film systems from a materials perspective as well as fully-integrated electronic systems, following current trends, such as the Internet of Things (IoT), Industrie 4.0, and Smart Wearable Electronics. The focus is to replace spatially distributed discrete devices such as sensors by large-area thin-film devices and to integrate the respective control and readout electronics using the same technology. The resulting systems reduce the need for mounting space, assembly effort, and cost. To achieve the latter, a variety of techniques, such as printing, coating, and traditional physical and chemical vapor deposition techniques, are combined. Bendable systems serve dedicated wearable applications or enable mounting on curved surfaces. The use of thin, transparent metal-oxide materials allows for novel integration solutions in optical technologies.

Thin-film sensors paving the way for large-area electronics

In 2015 the group extended its competences in the field of thin-film sensors. A highlight has been the development of biochemical sensors for the detection of ammonia levels in human sweat. The work performed within the Leistungszentrum Elektroniksysteme (LZE) aims to detect muscular overstress during sports exercises and will be integrated in a system for monitoring and correlating a variety of vital parameters within a functional textile. The transducer uses screen-printed metal electrodes together with a structured encapsulant and a dispensed ion-selective membrane. The sampled devices show a response of ~60 mV per decade of ammonia ion concentration change, meeting the theoretical prediction.

Temperature sensors are available in different printed as well as transparent instances, the latter being ideally suited for integration in optical devices and systems. Printed interdigitated capacitors in different geometries are employed as orientation-dependent fill-level detectors, proximity sensors, or for the equipment of surfaces with touch functionalities.

Towards future integrated thin-film systems

One step further, the ROLL OUT project funded by the European Commission under its Horizon 2020 program purses the integration of large-area sensors with thin-film electronics for sensor readout, data processing, and interaction with the user or the technical environment. Within the project, IISB is heading the work package on component development and integration and is responsible for translating the application requirements of the partners from the automotive, packaging, and textile industries into functional electronic systems.

TECHNOLOGY AND MANUFACTURING

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Wireless communication is becoming more and more indispensable in light of facile system integration and connectivity. As a consequence, thin-film transistors (TFTs) have to be developed to new performance levels with respect to the working frequencies. The branch of the thin-film systems group at the Chair of Electron Devices of the University of Erlangen-Nürnberg (LEB) was recently awarded a grant by the Priority Program High Frequency Flexible Bendable Electronics for Wireless Communication Systems (SPP 1796) funded by the Deutsche Forschungsgemeinschaft (DFG). The joint project with the electronics engineering institute of the FAU allows the group to further investigate a novel, patented TFT architecture that allows for an ultimate reduction of gate lengths.

Materials

The long-term experience in the solution processing of metal-oxide materials has recently led to new application fields beyond classic thin-film electronics. Based on a unique chemistry, a broad range of material classes, such as (transparent) conductors, semiconductors, insulators, sensitive layers, or even battery electrodes, can be deposited from dissolved metal salts. To serve the needs of our customers, a new deposition system enabling spray pyrolysis and spray coating of materials has been successfully installed at Fraunhofer IISB. Ultrasonic spray heads enable the ultrafine nebulization of the precursor for the achievement of homogeneous and low-roughness functional layers.

1 *Screen-printed biosensor for the detection of ammonia levels in sweat. The integration of the sensor with a fitness-shirt application is executed within the Leistungszentrum Elektroniksysteme (LZE)*
© Fraunhofer IISB

2 *An ultrasonic nebulizer produces fine droplets of metal-salt precursors for the solution-based pyrolysis of metal-oxide materials.*
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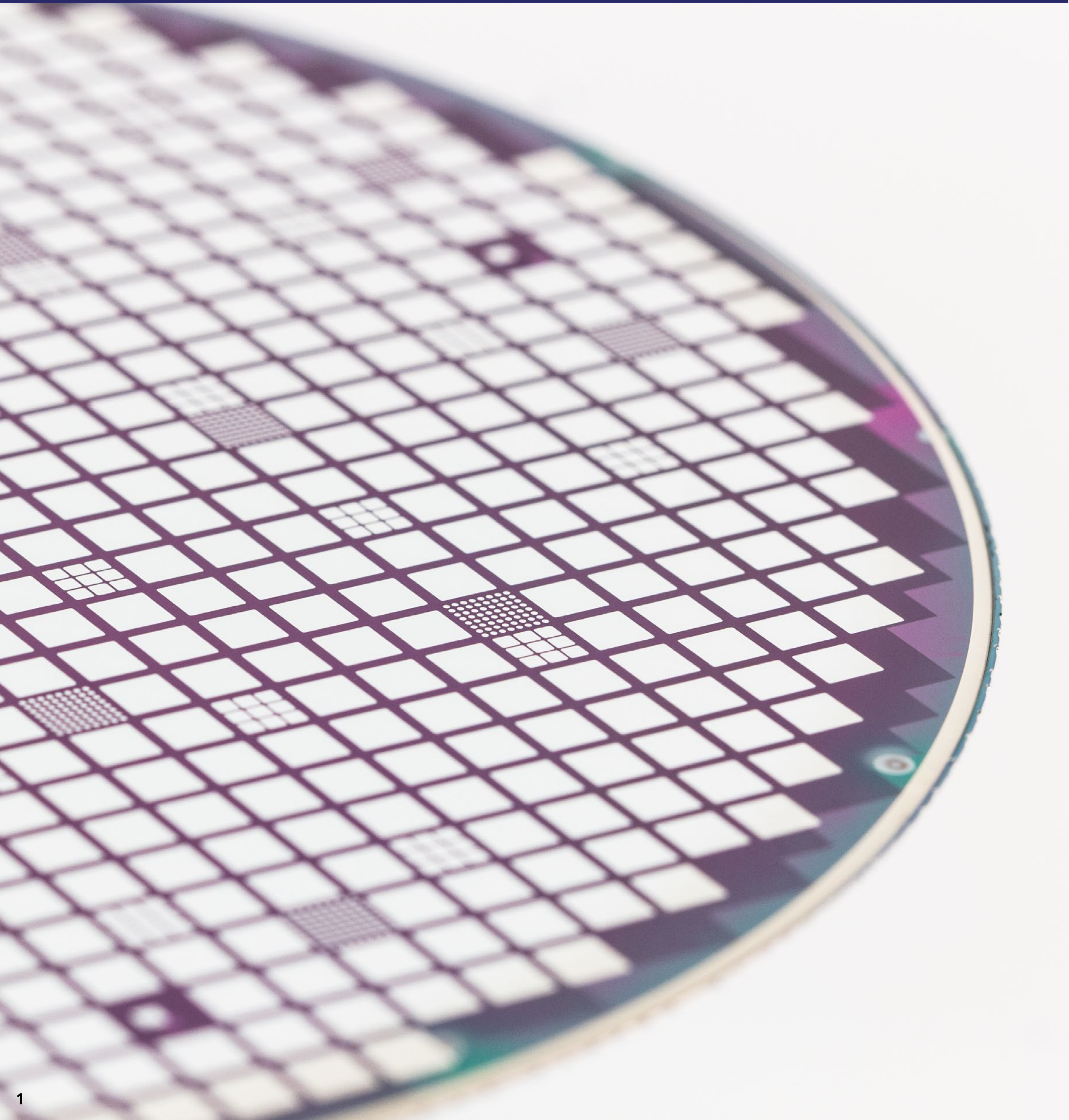
DEVICES AND RELIABILITY



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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 consolidation and advancements in silicon carbide process technology were the focus of last year's SiC activities. The incorporation of these process steps into the quality management system of ourπFab allows for a high reproducibility and yield of our SiC devices.

The design and fabrication of 1.2kV MOSFETs and 3.3kV diodes were successfully implemented, which showed our capabilities. In this regard, back-thinning of SiC wafers and subsequent processing of 90 µm thin SiC substrates were successfully demonstrated for a high voltage bipolar device.

Similar activities in thin wafer handling were launched for silicon devices fabricated on 200 µm thin substrates, following the global trend for power semiconductor devices. Among others, unipolar 600 V silicon diodes with a low forward voltage drop based on 3D patterning were realized. Additionally, the process technology for 600 V silicon capacitors was developed, and the first devices with a continuous operating voltage of 900 V were implemented.

The design, assembly, and verification of a dynamic characterization setup for (ceramic) capacitors extend the capabilities of device measurement and reliability analysis at our institute.

In the field of packaging, several new publically funded research projects were started in 2015. One of these is called Luftstrom and is supported by the German Federal Ministry of Education and Research (BMBF). The aim is an excellent thermal management in combination with electrical insulation for wide band gap semiconductors using printed circuit boards. Another project, DiaLE, which is funded by the Fraunhofer-Zukunftsstiftung, started with a focus on new packaging concepts for diamond semiconductor devices for the next generation of wide band gap devices and their requirements. The project GaN-PV, which is sponsored by the German Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU), was successfully finalized with the application of a new type of ceramic insulation substrate combining power and signal electronics. This brings together the two worlds of GaN semiconductor and gate drive electronics on one carrier. In addition to that, IISB's first monolithic integrated silicon DC link capacitor was integrated into the new power module.

Moreover, effort was invested in a reproducible double-sided silver sintering process. Now the die attach for power modules with an exceptional lifetime can be provided for in-house power electronics prototypes and customers.

1 *600V silicon capacitor devices for very fast switching applications on a wafer © Fraunhofer IISB*

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

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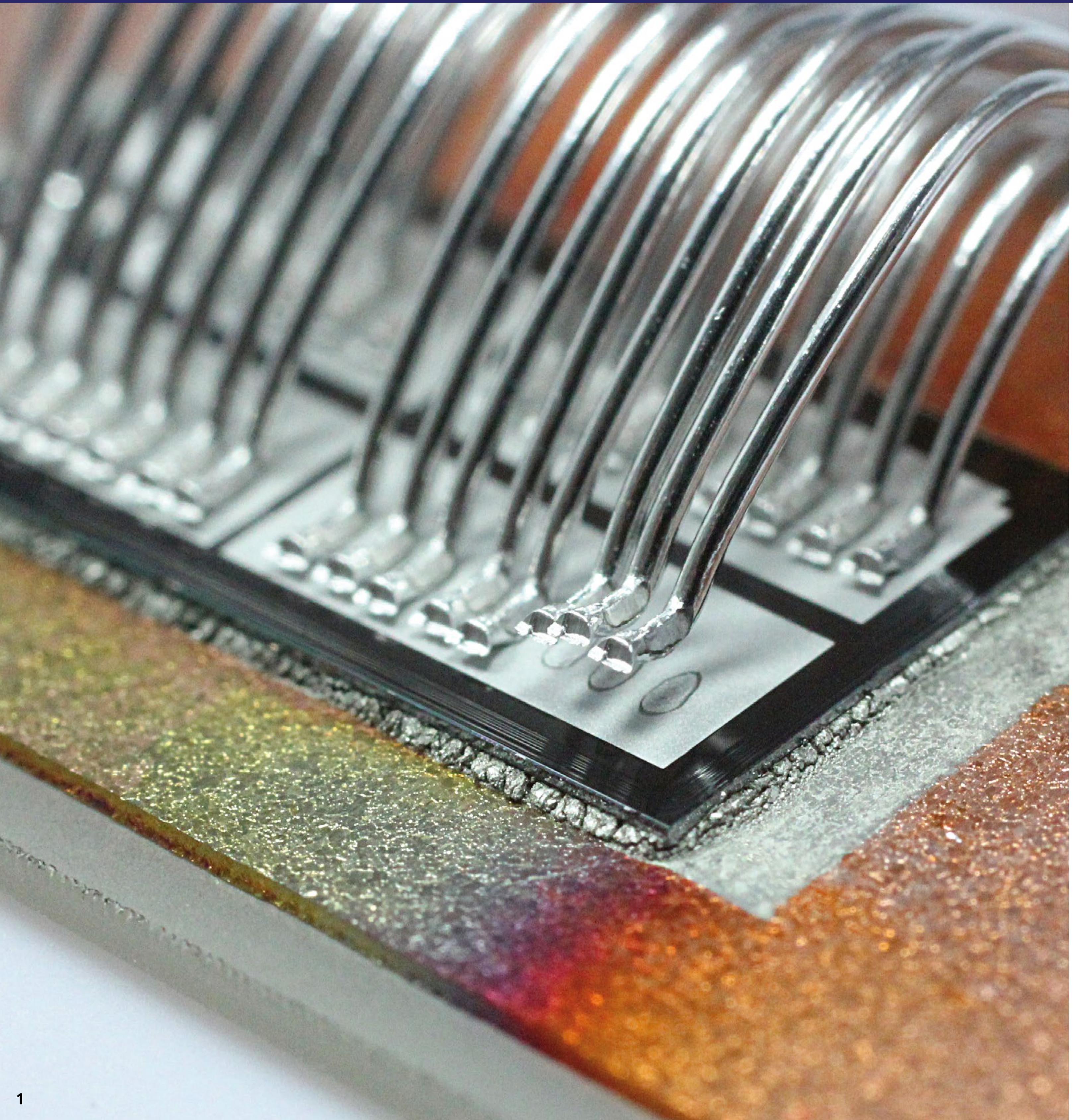

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The planning was started for a new clean room to meet the demands of different packaging technologies. This makes our institute ready for future work in 3D packing topics.

The research activities around testing and reliability were strengthened by intensive material characterization for the next generation of lifetime modelling for power electronics. Especially the silver sintering bond line for the die attach was in the focus of the investigations. In combination with that, a variety of accelerated active power cycling tests were performed at elevated temperatures up to 250 °C. Besides that, the work in high voltage power electronics continued, leading to new degrees of freedom in the design of such electronics. The measured partial discharge phenomenon is now in good conjunction with electric field simulation. Additionally, the lifetime testing of passive components was expanded to include ceramic capacitors, which will play a big role in the future.

In addition to the new publically funded projects started in 2015, there were a huge number of bilateral industrial projects. 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 around forty percent. This perfectly hits the Fraunhofer target. Many thanks to all colleagues for their support during difficult days and the excellent work that makes the institute ready for the future.

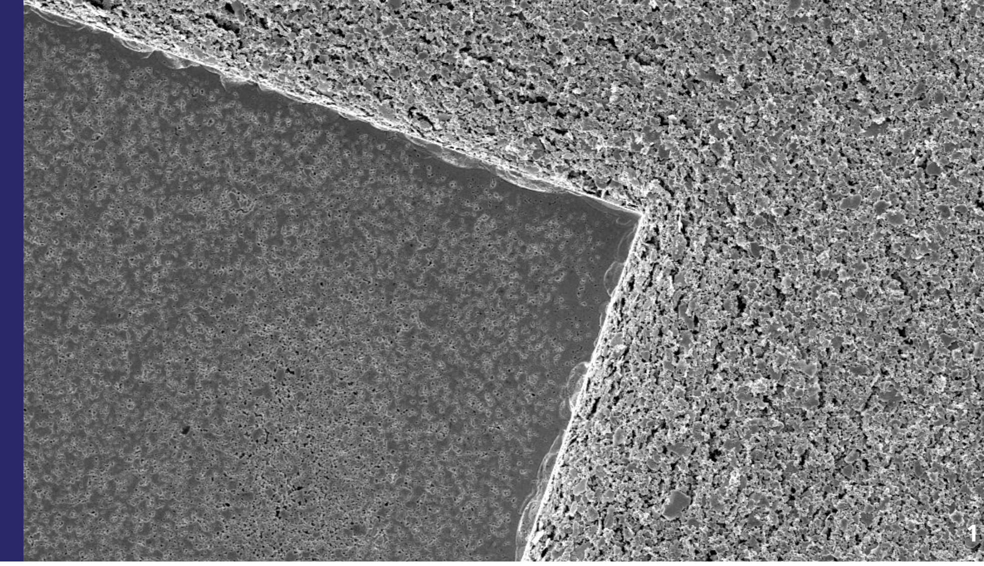
1 *Bond wire lift off as a result of an active power cycling test until the end of life.* *© Fraunhofer IISB*

Material Characterization for the Next Generation of Lifetime Simulation

The development of automotive power electronic technologies is rapidly improving thanks to the extreme cost targets. In the past, great improvements in semiconductor devices were made by using new materials such as SiC or GaN. These materials can operate at higher temperatures due to their wider bandgap. This will consequently increase the operating temperatures of power modules and systems in the future. However, not only the devices have to withstand these high temperatures; all materials used in packaging are thermo-mechanically stressed by operation due to their unequal and absolute thermal expansion coefficients. This commonly results in fatigue for the weakest materials and limits the lifetime of the power electronic systems.

Therefore, methods for determining the lifetime and reliability of power electronic systems are implemented in the product development process. Common methods for modelling the load duty cycle in practice are accelerated aging tests such as passive temperature cycling or active power cycling. However, these methods are very time-consuming and expensive. Only a couple of parameter sets can be tested at the same time. A possible and usual way to decrease develop-

DEVICES AND RELIABILITY



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ment costs and overcome these difficulties is to use numerical simulations. To perform quantitative reliable simulations, it is essential to make proper assumptions about the physical boundary conditions. This requires a good comprehension of the behavior of the involved materials and their distinct properties.

Common reliability investigations typically provide results about failure rates. To interpret these, it is important to separate the failure modes and identify the failure causes. At this point, the material properties can provide useful information since they usually depend on the individual manufacturing and processing parameters.

For the next generation of power electronic modules, new joining technologies such as silver sintering have been developed in the past. Since these layers are typically in the range of a few micrometers in thickness, special testing equipment with high measurement accuracy is needed. A common way to obtain information about the behavior of metallic materials is the tensile test. A tensile testing machine was therefore modified in regard to its measurement accuracy by an improved special sample mounting system in order to avoid transverse or torsional forces on the thin samples. Furthermore, an optical position measurement system and a special oven were used to allow precise measurements up to 300 °C in different atmospheres.

Dog bone specimens made of sintered silver were manufactured and tested in the modified tensile testing machine. The results revealed strong temperature- and sintering-pressure-dependent mechanical properties. To prove the reliability of the results, scanning electron microscopy was performed on the samples. The areas near the lateral edges showed a gradient in porosity from the center position to the edges. This may be related to the drying process, where the shrinkage may be higher at edge locations due to the higher surface area, leading to vertical flattened edges and non-uniform compression in the sintering process.

Since the mechanical properties strongly depend on the sintering pressure, the results of the tensile tests only provide global average values of the mechanical properties. That may not properly represent the behavior in any case. If the focus of the optical investigation had moved close to the edges, another influence on the tensile results might have appeared. The edges were quite rough, exhibiting notches with partially sharp radii. At these locations, the stress is concentrated and reaches high values. The values are limited by the elastic limit of the metal, where plastic deformation occurs. Plastic deformation enlarges the radius, and crack propagation is decelerated. In a sintered structure, the tip radius remains at the radius of the pores and the stress concentration may not be compensated, leading to a brittle failure in tensile tests at room temperature.

Possible ways to circumvent these difficulties are nanoindentation experiments where localized measurements are possible. The values measured were higher than those of the tensile tests. This could be traced back to the rough edges of the dog bones, leading to lower values for fracture or yield stress in the tensile tests. A higher modulus in nanoindentation experiments could be explained by the inhomogeneous porosity along the cross section of the samples. The resulting modulus in tensile tests is averaged and decreased by the partial lower porosity. Furthermore, the indentation measurements showed a higher modulus in more dense regions and a lower modulus for the more porous regions. The results for the hardness conformed to this trend. This means that global material parameters obtained by tensile tests may not represent the bond line properties very well in numerical simulations.

In conclusion, both methods can be combined to obtain a reliable database of bond lines for use in power electronic systems. Tensile tests can be used to obtain the averaged global material models, whereas the indentation will show the local properties for an improvement in the manufacturing process or for material design at highly stressed locations. This work is not limited to bond lines or power modules. All stressed materials in power electronic systems need extensive investigations for the next generation of thermo-mechanical simulations and lifetime models.

1 *Top view of a silver sinter layer with inhomogeneous material properties in the area of the (dark color) edges of the semiconductor device.*
© Fraunhofer IISB

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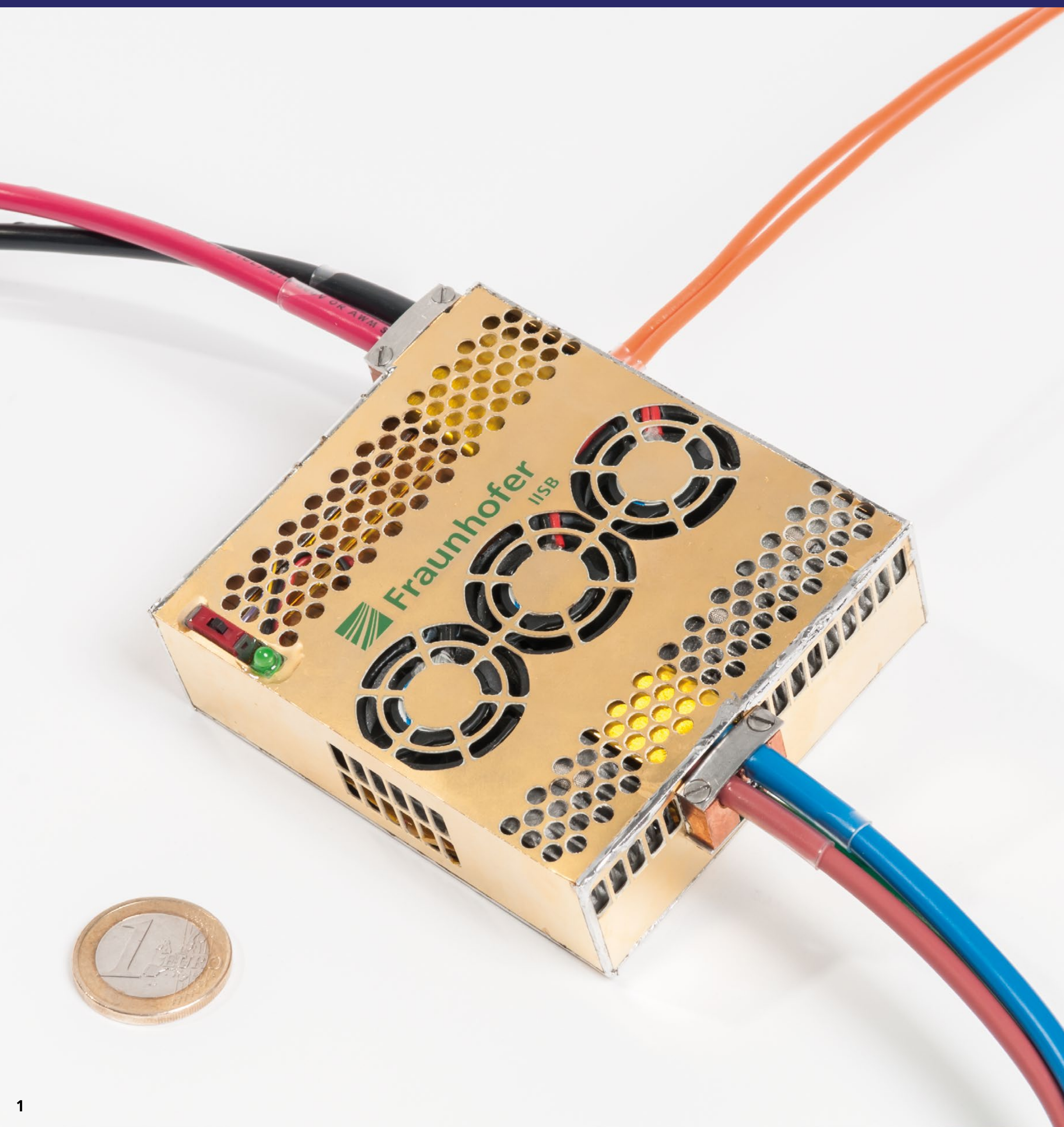
VEHICLE ELECTRONICS



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In addition to the public discussion of the slow progress of purely electric and hybrid vehicles entering the market, demand is still growing for new automotive power electronic solutions. Especially the emerging SiC and GaN power semiconductors make much smaller and more efficient solutions possible and are pushing a discussion of new automotive voltage levels up to 850 V and new temperature levels of 200 °C and above.

SiC automotive power electronics

With its superior behavior, SiC brings a lot of new challenges to the development process for automotive power electronic devices. To use the possibilities of a high switching speed to reduce the losses, completely new solutions for power modules with extremely low stray inductances must be developed. This challenge is tackled by the publically funded (BMBF) research project "HHK" with the goal of realizing a commutation cell consisting of a DC-link capacitor and power module with less than 5 nH. However, the switching speed is currently limited, e.g., by the isolation of the motor windings, which are not suitable for the extremely high du/dt possible with SiC switches. At the PCIM Europe 2015, we were able to show several solutions for systems equipped with SiC MOSFETS, such as a bidirectional 200 kW DC/DC converter and a 60 kW full SiC drive inverter with a power density of up to 160 kW / dm³.

Taking part in the Little Box Challenge

Power electronics with outstanding power densities is a key competence of the Vehicle Electronics department. We therefore decided to take part in the worldwide challenge for the smallest 2 kW solar inverter fulfilling the EMC requirements and enduring 100 hours of intense testing. With our solution of a single PCB inverter with 900 V SiC MOSFETs, we reached a power density of 200 W / in³. That is more than the 50 w / in³ demanded in the competition by a factor of four. With our concept, we were among the 18 finalists, and we took our inverter to the National Renewable Energy Lab in the United States for testing. The finalist will be announced at the beginning of 2016.

2015, a year of ongoing growth

Due to the many projects, the staff of the department was increased to 39 engineers and technicians working in the field of applied research on new mechatronic solutions, power electronic circuits, and embedded software for the next generation of automotive power electronics. The demand of our industry partners for new solutions enabled us to achieve a very good distribution between publicly and industry-funded projects, with an industry rate of well above 35 %.

I am sincerely grateful to all of my colleagues for the excellent work in 2015.

1 *Single PCB inverter with 900 V SiC MOSFETs and a power density of 200 W / in³. © Fraunhofer IISB*

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

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Electric Sports Car "IISB-ONE" – A Flexible and Modular R&D Platform

1 *Electric sports car "IISB-ONE" during a test drive in the city of Nuremberg. © K. Fuchs / Fraunhofer IISB*

In July, the Vehicle Electronics department presented its "IISB-ONE" electric sports car, a test vehicle for power-electronic vehicle components that is open to adaptations. The modular vehicle concept allows the flexible integration of future developments. The vehicle is based on a chassis by the former Artega company, and it is equipped exclusively with Fraunhofer IISB components. These were developed in various research projects and in cooperative projects with the automobile industry.

Integrated electrical 2 x 80 kW drive system

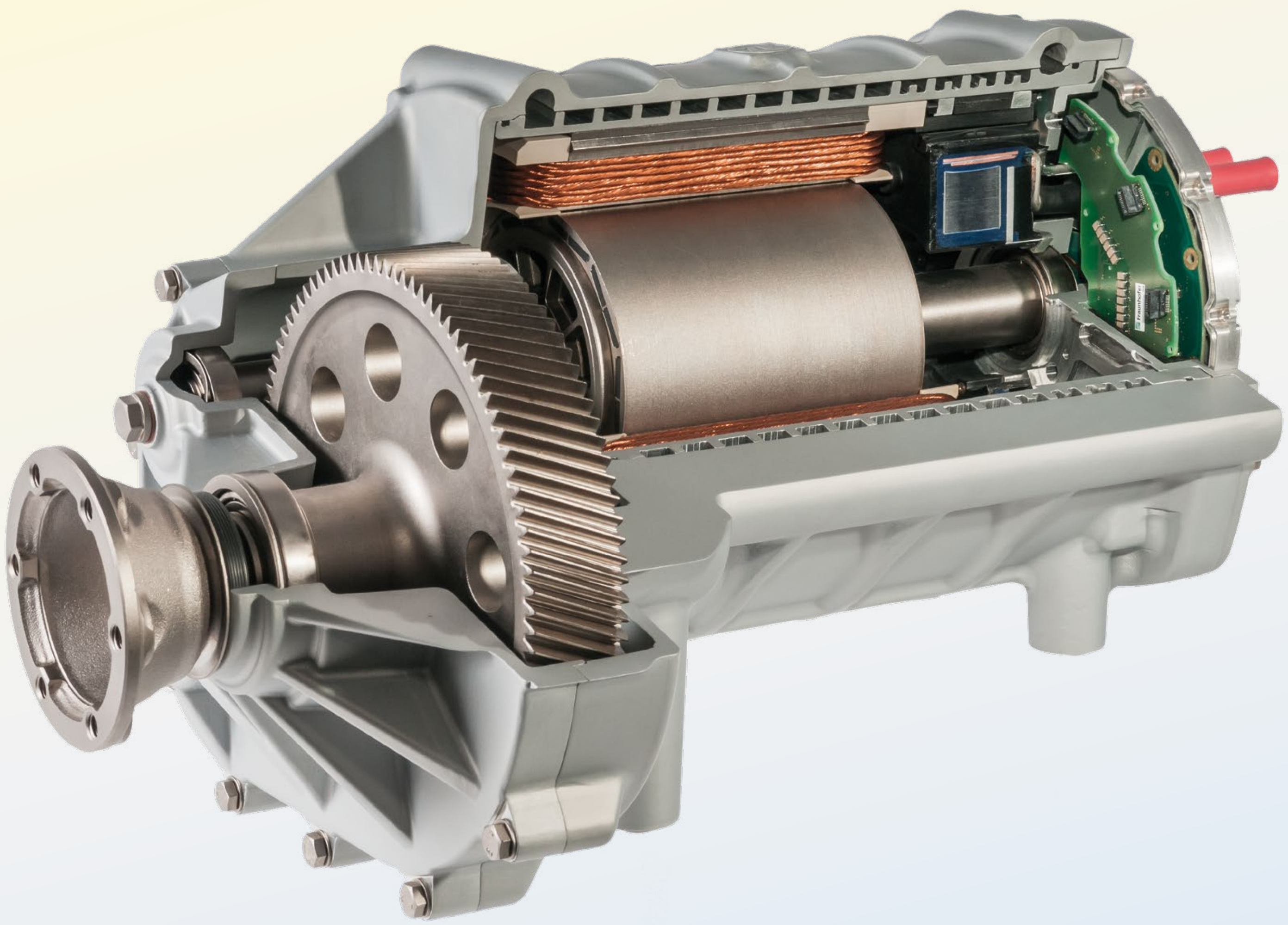
The integrated traction drive installed in the vehicle is notable for its two mechanically integrated motor drives with directly attached power inverters using intelligent power modules with 650 V IGBTs and separated field-oriented control for each e-motor. This allows the free distribution of torque to each drive wheel on the axle. In total, each wheel has a drive power of 80 kW and a top torque of 2000 Nm at its disposal. The modular concept of the inverter is ready for using new SiC MOSFETs and higher DC-link voltages up to 800 V.

Intelligent energy storage and distribution

The heart of the high-voltage on-board electrical system is a battery system based on lithium-ion cells with a rated voltage of 355 V. The integrated battery management system designed at Fraunhofer IISB guarantees reliable operation, and the modular internal system structure means that the energy storage system can be adapted to various power, energy, and vehicle classes. A DC/DC converter with 3.5 kW replaces the car's conventional alternator and supplies the 12 V on-board electrical system from the high-voltage battery. A non-insulating high-performance DC/DC converter always provides the drive system with the optimum operating voltage up to 450 V, depending on the driving conditions.

Universal charging options

A proprietary AC charger integrated in the energy storage allows flexible recharging at both public charging stations and any outlet with up to 3.7 kW, or at DC charging stations. The highlight is an inductive charging system on the front of the vehicle that can be used to allow contactless charging of the IISB-ONE with up to 3.5 kW. The system is notable for the highest standards of user convenience, a high position tolerance, low costs, and a high degree of efficiency of up to 97 % with a weight of only 3 kg.



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Simplified component integration

The integration of subsystems to form a reliably functioning vehicle is a challenge, due to the variance in available communication interfaces and protocols. For this reason, an adaptable vehicle control system was developed at Fraunhofer IISB. This allows for a simple communicative link between various prototype systems to form an overall vehicle. An additional layer of software abstraction makes dealing with the different control units easier for the user. The vehicle control system coordinates and monitors the drive-train and energy-storage systems and guarantees a safe vehicle operating state at all times.

EMiLE – The Next Level of Mechatronic Power Electronic Integration

In the BMBF funded research project EMiLE, ten partners from the German industry and research-institutes are working on the next level of an innovative drivetrain solution for tomorrow's e-mobility. The project focusses on compact and efficient electric vehicle traction-drives with a high degree of integration of electric machine, power electronics, and gearing, which are perspectively suitable for large scale production.

High power density, high efficiency and cost minimization are benefits of the realized Smart Stator Tooth – structure within the drive unit. Each Smart Stator Tooth (SST) consists of a motor segment and an electronics assembly. Twelve SST form one PMSM stator and the corresponding inverter. Each tooth electronic is built up of an IGBT full bridge power-module, phase current sensor, current control loop, gate driver unit, and a fault detection block.

The stator windings are directly connected to the AC terminals of the power module, thus minimizing space and reducing the number of parts. The advanced SST control functionalities have two objectives: First, a failure in one phase power module does not lead to a full system failure. Second, after detecting faulty parts, the remaining SST can be used to actively compensate the influence of the failure. In summary, the drive system is fail-operational.

1 *Multiphase drivetrain system with Smart Stator Teeth (SST).*
© Fraunhofer IISB

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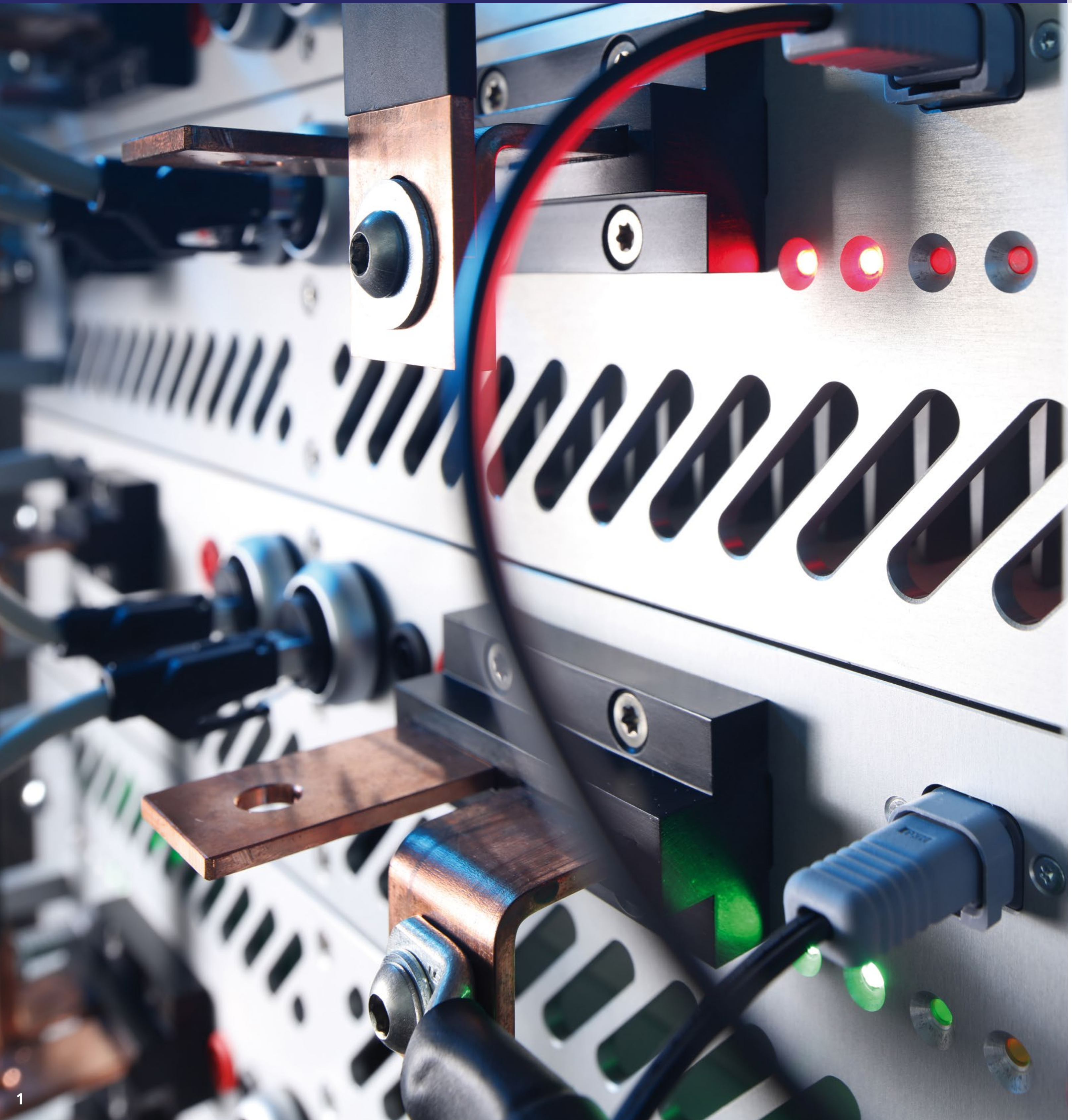
ENERGY ELECTRONICS



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 40 researchers and a similar number of students.

The Applications working group, headed by Mr. Markus Billmann, supports our customers in the case of 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 Nürnberg (EnCN), one of our two branch labs in Nuremberg.

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 working group, headed by 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.

The Leistungszentrum Elektroniksysteme (LZE) was launched in 2015. Within this center for electronic systems, which is unique in Germany, the two Fraunhofer institutes IIS and IISB, the University of Erlangen-Nürnberg, and industrial partners from the metropolitan region of Nuremberg concentrate their competences in the fields of electronic system research and engineering.

The pilot phase of the LZE is funded by the State of Bavaria, the Fraunhofer Society, and the industrial partners. One of the four launch projects addresses the topic "DC Backbone with power-to-gas coupling".

For very large energy storage systems, technologies that use chemical energy carriers, such as, e.g., liquid organic hydrogen carriers (LOHC), are superior to electrical batteries for reasons of

1 *Multilevel converters – a key technology for solving the challenges of the "energy revolution".*
© K. Fuchs / Fraunhofer IISB

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

ENERGY ELECTRONICS

1 *Switchgear cell for a modular multilevel low-voltage converter.*
© Fraunhofer IISB

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cost and safety. Only the size of the tank defines the storage capacity, which allows a very flexible and cost-effective upscaling to almost any amounts of energy. To operate such a storage within an electric grid, a lot of power electronics is necessary, e.g., to connect an electrolyser and fuel cells to a DC backbone.

The EC project DCC+G had a highly successful conclusion. The final meeting was held at IISB, which provided its DC-grid infrastructure as a demonstration platform in the project and integrated the contributions of the partners therein.

The EC project AVTR was also finished successfully. Fraunhofer IISB was responsible for the novel fully redundant battery system. The main objectives concerned the battery system, its battery management system, and the battery, specifically cell monitoring.

The work on the Bavarian state-funded projects EnCN and SEEDs is well on schedule.

At the end of 2015, the preparations began for the extension of the headquarters building in Erlangen. Within tract B, the department will get an ultra-modern medium-voltage test facility (20 kV, 2 MVA). Additionally, our 380 volt DC power technology will be used and tested there on a larger scale.

The Energy Electronics department nowadays covers the entire range of electrical power conversion, from power supplies on the building infrastructure level, to grid and energy generation systems of the highest power. It 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 31 supervised bachelor's and master's theses, 14 scientific publications, and 15 lectures. In addition to our very well accepted monthly colloquium on power electronics, three seminars were organized for 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.

Modular Multi-Level Inverters

Power electronic converters are a key component for transforming the electrical power supply into a complete regenerative system. This concerns the entire chain of electrical power supply, from generation to transport and distribution, up to the consumers. New modular multilevel converters (MMC) make it possible to control the flow of energy in the system with a very high flexibility and efficiency. One application example is high-voltage direct-current (HVDC) transmission lines. Four of these HVDC lines based on modular multilevel technology are in operation off the German North Sea coast alone, to connect offshore wind farms with the grid; further systems are currently in planning or construction. Systems based on this technology are also a cornerstone for the long-distance transport of energy along the German north / south axis according to the current grid expansion plan.

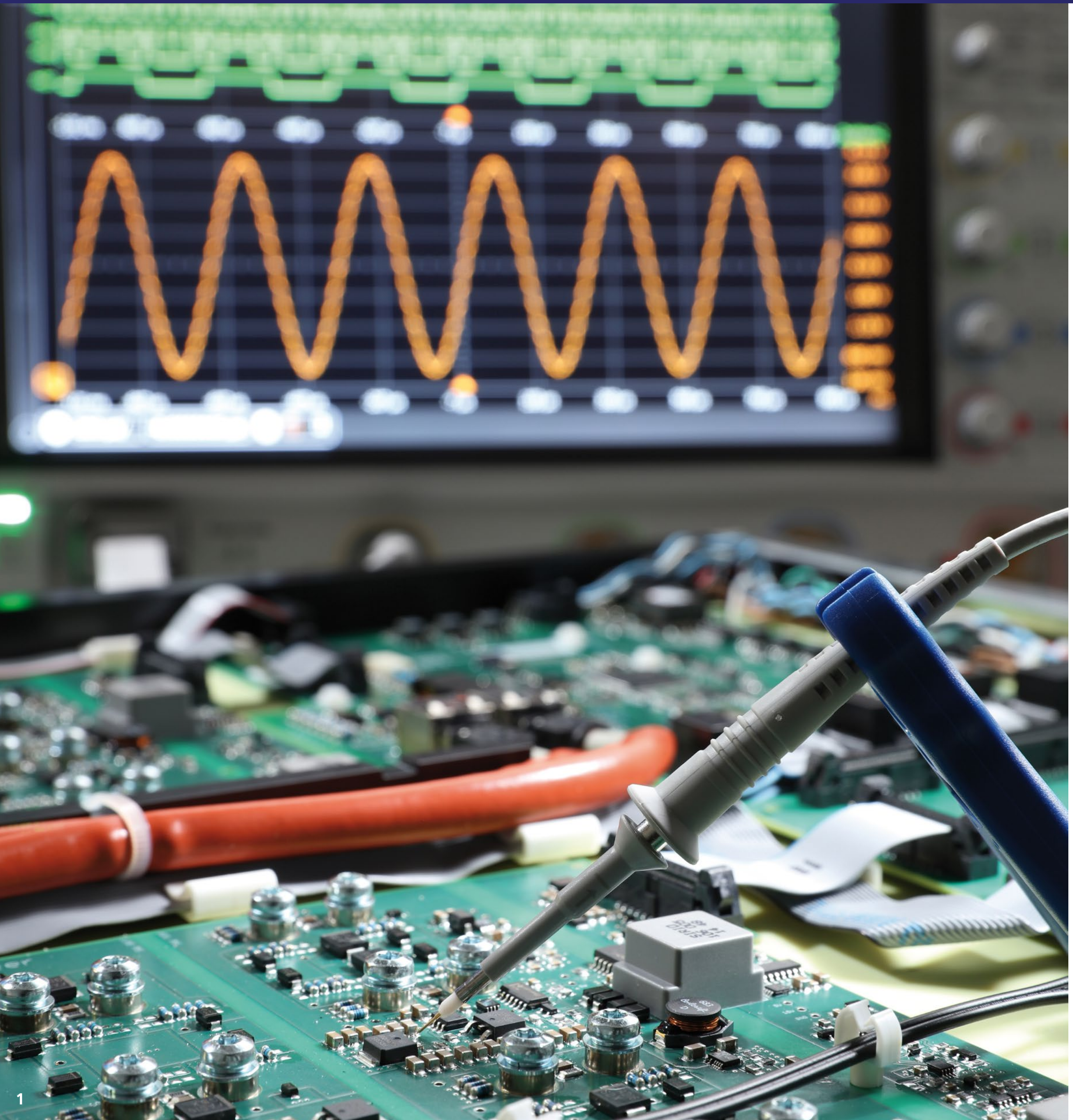
Modular multilevel technology has become established in the HVDC application field within a very short time, due to its considerable system advantages, and it will continue to triumph in further application fields in the future as well. In the power grid, these include, in addition to HVDC lines, the static power factor correction (SVC) as well as the bidirectional coupling of networks with a different frequency or stability.

One focus of the work at Fraunhofer IISB is the development of innovative solutions for modular multilevel converters.

An example of this is a completely new module design with a specially coordinated integrated circuit packaging. After all, state-of-the-art systems are based on high-voltage power semiconductors in classic module housings with an insulated baseplate, as are used nowadays in industrial drives and railway traction applications. At the same time, modular multilevel technology makes a number of special requirements of power semiconductors in comparison to other applications, but it also allows considerably more degrees of freedom in other places. This creates considerable optimization potentials for modular multilevel converters in the design of switchgear cells.

A special challenge is the high lifetime requirements for energy industry applications with operating lifetimes of over 40 years. Since the entire "power electronics" industry sector is only around 40 years old, there is practically no field experience for such long time periods. Therefore an important aspect is the early qualification of new assembly concepts and technologies through accelerated aging tests and adapted aging models. The primary objective is to try out technologies that will make it possible to considerably reduce the overall system costs in the future through an adapted and simplified assembly.

MMC technology is becoming increasingly attractive for applications in the low- and medium-voltage range as well. These applications include, in addition to railway technology, shipbuilding and industrial drive technology, for example, the medium-voltage coupling of large photovoltaic parks.



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To re-evaluate under what conditions MMC technology can be economically used in the low-voltage range, a complete MMC low-voltage system based on switchgear cells in the form of 19” switch cabinet slide-in modules was developed and assembled at IISB.

In the course of the institute expansion at the main location of Erlangen, which is currently under construction, IISB will have a medium-voltage test bay for power up to 3 MW and voltages up to 30 kV, starting in 2018. The central component of this test bay is an arrangement of highly dynamic, low-disturbance MMC systems that can be operated as a source or sink. A higher-level control system will make it possible to simulate any desired network states in the laboratory and test systems with greater power. The MMC systems are very sturdy, and the output values have a very low portion of harmonics due to the precise switching stages. Due to their modularity, these inverters are very scalable and thus easy to adapt to different testing tasks. The energy stored in the individual cells allows a wide setting range with highly dynamic output values, so that even irregular network states can be reproduced well. The application of such systems in a laboratory environment thus allows very extensive and versatile testing.

The comprehensive and very successful research activities at Fraunhofer IISB form the basis of a long-term, strategic cooperation with Siemens in the framework of Campus Future Energy Systems (Campus FES). The objective of this industry cooperation is the consistent further development of MMC technology.

1 *The control of activation complexity is a key to opening up the low-voltage range and power to MMC technology.*
© K. Fuchs / Fraunhofer IISB

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LZE – A Joint Initiative of the University of Erlangen-Nürnberg, Fraunhofer IIS and Fraunhofer IISB

Text: Ilona Hörath / Translation: Saskia McDonagh, by courtesy of Fraunhofer IIS

The course is set: now the Leistungszentrum Elektroniksysteme (LZE) (High Performance Center for Electronic Systems) is embarking on its mission to establish itself as the leading center for electronic systems in Germany.

Energy saving and energy efficiency – this strategic collaboration between research and industry is focused on nothing less than these key economic and social topics of the future. Something is happening at the heart of the Nürnberg Metropolitan Region about which others can only dream: worldclass research with a well-defined practical orientation.

Thursday, November 19, 2015. The Leistungszentrum Elektroniksysteme (LZE) hosts its first Tech Day. High-level visitors have registered for the event in large numbers: some 100 representatives of industry and business – from medium-sized companies to global corporations – have turned up. Among the crowd are representatives from big-name industrial companies, leading automotive manufacturers and suppliers, internationally renowned manufacturers of sporting goods, automation technology manufacturers, small energy technology businesses, and companies from the textile industry. “What we show our partners and potential customers at the Tech Day is targeted world-class research with a well-defined practical orientation,” explains Prof. Albert Heuberger, Director of the Fraunhofer Institute for Integrated Circuits IIS in Erlangen.

Showcasing mature prototypes

At the Fraunhofer Institute for Integrated Systems and Device Technology IISB, Prof. Heuberger and the Director of Fraunhofer IISB, Prof. Dr. Lothar Frey, jointly lead a tour through a small but excellent exhibition. At four stands, researchers from both Fraunhofer institutes and the University of Erlangen-Nürnberg proudly present the mature prototypes of their current LZE projects. “They are our lighthouse projects,” says Professor Frey with a smile. “They demonstrate that our teams can tackle complex electronic systems with a unique range of expertise.” Total initial investment for the LZE amounts to € 10 million and comes in equal parts from the Bavarian Ministry of Economic Affairs and the Fraunhofer-Gesellschaft, while a further € 5 million comes from joint projects with industry.

1 *LZE project “Low-Power Electronics for Sports and Fitness Applications”: scientists are developing an advanced prototype for vital signs and movement data out of the T-shirt. The T-shirt simultaneously records positional and movement data as well as vital signs such as ECH and respiration data.*
© K. Fuchs / Fraunhofer

2 *Dr. Bernd Fischer, Strategic Planning, Fraunhofer IISB.*
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“Targeted world-class research with a well-defined practical orientation”

Standing at one of the stations is project manager Dr. Nadine Lang, who holds a PhD in biophysics. The monitor on the table shows the data curves for various vital signs. Beside the monitor lies a white T-shirt. Lang explains what makes the FitnessSHIRT special: “We’ve developed a new method of measuring and recording various health data using smart textiles.” Anyone who sets out on a run or hops on a bike to meet their fitness target for the day is familiar with the dilemma: a device attached to a tightly fitting measurement harness shows the pulse rate, but is the breathing rate OK too? Does the heartbeat actually change with the physical exertion? “Thanks to the sensor electronics integrated in the FitnessSHIRT, the pulse, breathing activity, and movement intensity can be simultaneously recorded, evaluated, and displayed on an app,” explains Lang, who enjoys climbing and cycling in her free time. Now the project team under Lang has combined the FitnessSHIRT’s sensor technology with the radio-based real-time positioning technology RedFIR®, which was also developed and subsequently refined at Fraunhofer IIS. This means that the shirt can record positional and movement data at the same time as ECG and breathing. In addition, the scientists have developed new kinds of algorithms that enable users to interpret and analyze ECG signals, such as heart rate variability. Lang explains: “As a result, you can do things like ‘track’ a whole soccer team in real time. Coaches receive a package of useful data for every player.” Yet “Low-Power Electronics for Sports and Fitness Applications” is just one technological field in which researchers at the LZE are continuously working.

A pioneering collaboration that acts as a beacon

In January 2015, the LZE began its two-and-a-half year pilot phase. The joint initiative between the Fraunhofer-Gesellschaft, its two Erlangen-based institutes Fraunhofer IIS and Fraunhofer IISB, the Friedrich-Alexander University Erlangen-Nürnberg (FAU), further non-academic research institutions, Siemens, and other partners from industry is a pioneering collaboration that acts as a beacon. “We see the LZE as a pioneering model for the Nürnberg Metropolitan Region,” says Professor Heuberger. “We’re building on longstanding, fruitful collaboration between the Fraunhofer institutes and the university and are also using the unique concentration of research and industry in the field of electronic systems in the Nürnberg-Erlangen-Fürth triangle.”

Such exceptionally favorable circumstances do not exist anywhere else in Germany. Without complex electronic systems, future high-tech applications are inconceivable – whether in automotive manufacturing, in plant engineering, or in automation, energy, medical, or health technology. The commercial potential is huge precisely when – as with strategic collaborations such as the LZE – the focus is on clever solutions for smart power grids, medical engineering, electromobility, Industry 4.0, or energy efficiency. Working together with industrial partners, the LZE has big ambitions: “We want to generate traction beyond the Nürnberg Metropolitan Region

1 *LZE project “Wireless Power and Data Transfer in Systems with Fast-Moving Parts”: the goal of the project is the inductive – and therefore contactless – transfer of energy together with data transmission in fast-moving components.*
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LEISTUNGSZENTRUM ELEKTRONIKSYSTEME

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and to attract national and international attention," says Professor Frey. Accordingly, Frey stresses that the LZE is "much more than just a large-scale collaborative project."

Major topics of the future

The LZE is specialized in the key economic and social topics of the future: energy saving and energy efficiency. Full of passion and ingenuity, the center is taking a twin-track approach from the start. On the one hand, it is developing new types of low-power electronics designed to minimize energy consumption. Examples include the sophisticated technology in the FitnessSHIRT and in other sport and fitness applications. Other scenarios involve equally clever solutions for energy-saving integrated circuits and energy-efficient data transmission in complex communication networks, as required, for example, in Industry 4.0. On the other hand, the LZE's activities are also focused on coming up with pioneering power electronics for applications such as powertrain technology and the future energy supply – so that electrical energy can be converted and distributed efficiently and cost effectively.

An example of this is "Wireless Power and Data Transfer in Systems with Fast-Moving Parts," a project that hardly anyone knows better than Thomas Heckel. On a yellow-painted, industrial-use robotic gripper arm, Heckel points to a thick wiring harness that winds along the robot axis from the base all the way to the tip of the gripper arm. "It's all pretty cramped, as you can see. Classic industrial robots are unable to turn flexibly in order to screw, weld, or record measurement values, because the wiring harness is in the way. That's a drawback for manufacturing." Furthermore, the cable harness weighs up to 40 kilograms, which causes the movement of the arm to be unbalanced. But how do you make the power supply cheaper, the data transmission more reliable, and the entire electronic system smaller and more compact? "Our vision is to get rid of the cables and to develop a functional inductive technique for energy and data transmission." And this is precisely what the project manager and his team have achieved. An induction transmitter coil only 7 millimeters thick is fitted in the gripper arm along with a ball bearing. The electronics required is smaller than a matchbox and can be tucked away neatly in the robot's base. "I was fascinated by the idea of bringing a long-known, conventional technology such as induction to a completely new application and at the same time creating something new," says Thomas Heckel. "We've brought the power electronics to a certain degree of maturity," he emphasizes confidently. "Now we want to introduce them into practice." He and his team have already begun to develop the technology for an inductive plug connection. Sturdy wireless plugs could be used in any situations where dirt or oil could incapacitate electrical contacts, such as in food production and in the chemical industry. The plugs could also be used in construction and agricultural machinery, such as when a tractor and a trailer have to be electrically connected. "Electrics allow much faster steering and controlling than when using a traditional mechanical power take-off drive."

Taking these projects by Dr. Nadine Lang and Thomas Heckel alone, we see clearly how close the LZE has situated itself to practical application. "The projects highlight both the opportunities and the necessity of this approach, which is also what industry wants and expects," says Professor Heuberger. "There is huge commercial potential in the LZE," he adds. "We have lots of application ideas for our technologies and of how we can implement them with our partners," says Professor Frey.

Enthusiastic feedback from business and industry

At the LZE's first-ever Technology Day (or LZE Tech Day for short), the enthusiasm shown by representatives from business and industry for the ideas was very palpable. For example, the product and innovation manager of a leading automotive supplier wanted "to get up to speed with the latest technology and intensify our current cooperation with Fraunhofer." An industrial manager for innovation electronics judged the pilot projects presented as "very promising approaches to pursue new markets."

The excitement involved in realizing something new is also tangible in the two other LZE projects, such as "DC Backbone with Power-to-Gas Coupling" headed by Bernd Wunder. This project seeks to answer the following big questions: In the context of the energy transition and the growing scarcity of fossil fuels, how can we secure our energy requirements? And how can self-produced energy be stored cost effectively and on a major scale? Fraunhofer scientists are all too aware that lithium-ion batteries, which can hold only a limited amount of energy, are not the only solution. This is why they are collaborating with the Friedrich-Alexander University Erlangen-Nürnberg (FAU) to research coupling techniques that use a chemical carrier in liquid form. Known as a liquid organic hydrogen carrier (LOHC), it securely binds the alternative energy carrier – hydrogen – like a sponge. By means of a fuel cell, the hydrogen can then be converted back into electrical energy. This method can be used to store excess energy in summer and then release it during the winter heating period. Or it can be used to balance out load fluctuations in the power grid.

Last but not least, there is the "Energy-Independent Asset Tracking System for Logistics Applications" project, which focuses on extremely power-saving electronics solutions that are needed to make the Internet of Things possible. Using the example of a high-performance logistics application, the team of researchers led by Dr. Heinrich Milosiu has developed a special low-maintenance positioning system, which allows goods in a warehouse or in outdoor areas to be located and tracked. The researchers show how spectacularly little power this radio-based solution consumes by means of a somewhat surprising demonstrator: a glowing red strawberry repurposed into a battery. Even such a weak and simple "strawberry battery" is capable of powering the wireless receiver. Therefore, the electronics used in the logistics tags – on which the data is stored

1 *LZE project "Energy-Independent Asset Tracking System for Logistics Applications": power-saving wireless receivers – so-called wake-up receivers – require only a thousandth of the power that an LED needs.*
© K. Fuchs / Fraunhofer

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1 *LZE project "DC Backbone with Power-to-Gas Coupling": energy for the future – scientists are researching a new system for energy storage.*
© K. Fuchs / Fraunhofer

– boasts very low power consumption: under ten microamperes in fact. The researchers are already working on further reducing power consumption down to just one microampere.

Short route from basic research to application

What the LZE defines as "research in new dimensions" is not just an integrated approach to rethinking joint electronic systems research, but is also about shortening the route from basic research to industrial applications. Ideas are already being developed for how to achieve this and what the next steps should be: research structures designed along the lines of think tanks, special investment and development teams, and new high-tech start-up business models. In any event, the bright minds at LZE have already developed technologies that – as Professor Albert Heuberger puts it – "will influence people's lives today, tomorrow, and in the medium term". ■

Autarchy for Free

Energy distribution with direct current (DC) brings independence and sustainability

In the past 10 years, the costs for installing a photovoltaic system have fallen from approx. € 5000 / kWp to approx. € 1400 / kWp. There are similar developments in the area of LIB batteries, for which the price has fallen from € 800 / kWh (2005) to € 350 / kWh (2015). Current studies predict that this trend will continue in the next years.

Decreasing prices for a regenerative, decentralized energy use, in addition to the public's widespread desire for autarchy, will increasingly lead economic and strategic interests in industry and business towards further decentralization with regenerative energy systems. Therefore, in addition to the creation of adequate political framework conditions, above all the integration of regenerative sources in our existing electric supply networks is an ever more demanding challenge.

The power supply of industry, commercial buildings, and residential buildings, however, requires a very high availability. To ensure continuous availability, suitable electronic systems for autarkic power distribution, in addition to sources and storage systems, will be required in the future. To combine the multitude of different resources into one common local network, these power electronic systems in particular play an increasingly important role. Many of these electronic systems work internally with a direct current (DC). This so-called DC link is found in almost all modern electronic systems, which are nowadays connected to our electric supply networks via a highly efficient power supply unit. In contrast, photovoltaic cells and battery systems can only be operated with direct current.

LEISTUNGSZENTRUM ELEKTRONIKSYSTEME

It is thus clear that coupling with a direct current system can combine the different voltage levels with a very high efficiency and simultaneously low costs. From a technical point of view, the systems are becoming simpler, smaller, and more efficient than conventional AC-coupled systems.

However, the actual advantage of direct current technology is not the obvious elimination of numerous conversions. Other advantages, such as a reduction in complexity, a somewhat higher efficiency and slightly lower costs, also make direct current technology superior to alternate current technology but not indispensable. Is conversion then worthwhile at all?

Yes, because the easy coupling of all components with direct current makes this technology essential for future electricity grids. After all, this is the reason why a DC link with approximately 400 VDC is already present in almost all modern electronic systems in our homes to convert the mains voltage into a suitable direct voltage. Even AC motors have to be connected to the alternating current system via a DC link if modern, highly efficient frequency inverters are to be used. Precisely this characteristic of easy coupling allows a local building operator to couple and decouple distributed direct current systems from the central AC system as desired, without complex synchronization mechanisms. Direct current systems can change over between autarkic and mains-powered operation in real time; this circumstance is used, e.g., in uninterruptible power supplies (UPS), which additionally couple a battery to the DC link.

Since a storage battery that only functions with direct current cannot be directly integrated in a mains or three-phase supply, it is always connected via a power electronic system. This electronic system thus decouples the two systems and is a very elegant possibility for connecting an entire direct current supply (thus instead of only one battery, photovoltaic systems and DC consumers as well) to the electric supply network. This coupling is thus achieved without additional expense (for free). With a suitable control strategy, the local direct current system can even support the supply network and output controlling power to balance the strong fluctuations in the alternating current system.

Realistically and economically, storage battery systems coupled to the three-phase or alternating current system will only be able to compensate for these fluctuations to a small extent by themselves in the coming years. The selection of a suitable storage technology thus heavily depends on the respective application scenario and its framework conditions, such as, e.g., the installation location, source and consumption profile, the capacity of the stores, the season of the year, and many other factors.

For example, the high efficiency of Li-ion storage batteries (98%) makes them a good idea for the fast and short-term compensation of electrical fluctuations at home. The low specific energy density and the high safety requirements make this technology too expensive for large electrical storage systems, though. For large storage systems in industrial companies, technologies that use a chemical energy carrier (e.g., H_2, LOHC) are an interesting option.

New types of storage systems based on liquid organic hydrogen carriers (LOHC) make it possible to implement the necessary capacity for long-term storage over several months / years by scaling the tank size. In addition to the possibility of safely storing large quantities of hydrogen at ambient conditions, LOHC is above all an economical solution for storing and transporting hydrogen on a large scale.

From an overall point of view, many advantages of LOHC and battery technology can be used in combination with Li-ion batteries; the disadvantages of the individual systems can then be (partially) compensated at the overall system level.

Since the chemical-electrical conversion of LOHC systems takes place in fuel cells or electrolyser systems, these can also be connected to a direct current system very efficiently.

Regardless of what storage technology comes, direct current is optimally suited for it. The conclusion that direct current will be a very interesting technology for current distribution in the future is thus not surprising. The convulsive adherence to entrenched structures will increasingly lead to unwanted compromises. Regenerative sources, electrical mobility, distributed power stores, or DC rapid charging are only a few obvious examples that require a drastic change to our current systems.

1 *Storage systems based on liquid organic hydrogen carriers (LOHC) make it possible to implement the necessary capacity for long-term storage in local DC backbone grids with Power-to-Gas Coupling.*
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Samstag/Sonntag, 14./15. November 1992 / Seite 1

STADT ERLANGEN

Eine sehr persönliche Entscheidung stand mit am Beginn der stürmischen Entwicklung der Erlanger Mikroelektronik

Nur zehn Tage Urlaub waren viel zu wenig

Die Grundsteinlegung für Fraunhofer-Institut im Südgelände kennzeichnet den vorläufigen Höhepunkt einer langen Reihe von Schritten

„Nur zehn Tage Urlaub im Jahr hätte ich laut Vertrag gehabt. Das war mir einfach zu wenig", erinnert sich Prof. Heiner Ryssel heute, warum er 1985 zwei finanziell sehr lukrative Angebote von US-Unternehmen ablehnte und statt dessen einen Erlanger Stiftungslehrstuhl für Elektronische Bauelemente annahm.

Damit begann gleichzeitig Ryssels „Karriere" als leitender Wissenschaftler der Fraunhofer-Gesellschaft (FhG), die für solche Positionen stets Forscher mit enger Hochschulanbindung auswählt.

Die gestrige Grundsteinlegung eines Fraunhofer-Instituts — *siehe Bericht im allgemeinen Teil der heutigen EN* — kennzeichnet nun den vorläufig letzten Schritt der parallelen Entwicklung von universitärer und außeruniversitärer Mikroelektronik in Erlangen. Deren wichtigste Schritte sollen im folgenden noch einmal kurz skizziert werden.

● Dezember 1983: Aufgrund einer Denkschrift der Friedrich-Alexander-Universität (FAU) Erlangen-Nürnberg beschloß der Bayerische Landtag den Ausbau des Bereichs Mikroelektronik in Erlangen. Gleichzeitig wurde bei der Industrie- und Handelskammer (IHK) Nürnberg ein industrieller „Förderkreis für den Ausbau der Mikroelektronik an der FAU" gegründet. Zusätzlich zum Lehrstuhl für Technische Elektronik von Prof. Dieter Seitzer (seit 1970) sollten weitere Lehrstühle auf dem zukunftsträchtigen Gebiet der Mikroelektronik geschaffen werden.

● März 1984: Der Förderkreis und die IHK gründeten das Zentrum für Mikroelektronik und Informationstechnik, ZMI genannt. Es sollte die mittelständische Industrie bei der Einführung der Mikroelektronik unterstützen.

● April 1984: Der Förderkreis Mikroelektronik einigte sich mit dem Freistaat Bayern auf die Einrichtung eines Stiftungslehrstuhles für Elektronische Bauelemente, der von beiden Seiten mit jeweils 1,5 Millionen Mark anfinanziert wurde. Der Freistaat Bayern verpflichtete sich, den Lehrstuhl nach Ablauf von fünf Jahren voll zu übernehmen. Auf den Lehrstuhl wurde im März 1985 Prof. Heiner Ryssel berufen.

● Juli 1985: Das ZMI wurde von der FHG übernommen und existierte als zunächst auf fünf Jahre befristete Fraunhofer-Arbeitsgruppe für Integrierte Schaltungen (AIS) weiter: Sie gliederte sich in zwei Abteilungen: AIS-A für Angewandte Elektronik (Prof. Dieter Seitzer) und AIS-B für Bauelementetechnologie (Prof. Heiner Ryssel).

● Oktober 1988: Die FfG beschloß die Gründung eines Fraunhofer-Instituts in Erlangen. Das bedeutete die Umwandlung der befristeten Arbeitsgruppe in eine dauerhaft von der FhG finanzierte Einrichtung.

● November 1989: Der Senat der FhG beschloß, für Ryssels Abteilung B der AIS einen eigenen Neubau zu errichten. Die mit 57 Millionen Mark veranschlagten Baukosten sollten je zur Hälfte der Freistaat Bayern und der Bund tragen.

● Juli 1990: Die AIS-Abteilung A wurde offiziell in den Rang eines eigenständigen Fraunhofer-Instituts erhoben und heißt seitdem Institut für Integrierte Schaltungen (IIS). Für die AIS-Abteilung B, die den Namen AIS weiter trägt, ist dieser Schritt im Juli 1993 vorgesehen.

● Mai 1992: Nach jahrelangem zähen Ringen um die Finanzierung und nach rekordverdächtiger Bauzeit von nur knapp zwei Jahren Bauzeit wurde die Reinraumtechnologiehalle der Universität Erlangen-Nürnberg für den Lehrstuhl Ryssel eingeweiht. Als eine der größten und modernsten Reinraumhallen in Europa bietet sie optimale Voraussetzung auch für die Forschungen der AIS. hlo

Bei der Grundsteinlegung zum neuen Fraunhofer-Institut (von rechts): „Hausherr" Prof. Heiner Ryssel, Hans-Ulrich Wiese, Vorstand der Fraunhofer-Gesellschaft, Ministerialrat Hans-Dieter Lentrodt, Wirtschaftsminister August Lang, Uni-Rektor Prof. Gotthard Jasper, Kanzler Thomas Schöck und Oberbürgermeister Dietmar Hahlweg. Foto: Böhner

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30 Years of Fraunhofer in the Nuremberg Metropolitan Region

1985 – 2015: Fraunhofer institutes in Erlangen together celebrate their anniversary

30 years after their foundation, the Fraunhofer Institute for Integrated Circuits IIS and the Fraunhofer Institute for Integrated Systems and Device Technology IISB have together made the Nuremberg Metropolitan Region one of the most successful locations in which the Fraunhofer-Gesellschaft is represented.

From their shared origins, the two institutes have independently pursued their interests in developing strong and close ties as partners to Bavarian industry, exploiting synergies that provide a real boost to their home region. The two institutes and Friedrich-Alexander-Universität Erlangen-Nürnberg cooperate closely and pool their expertise to create a research location of unique status throughout Germany.

The institutes not only supply industry with excellent know-how and highly qualified personnel; their research activities also create hundreds of valuable high-tech jobs in the region.

All this came from modest beginnings: On July 1, 1985, the Fraunhofer-Gesellschaft acquired ZMI GmbH and incorporated it into its newly established Fraunhofer Working Group for Integrated Circuits AIS in Erlangen as an Applied Electronics department with 20 employees. Prof. Dieter Seitzer was the director, supported by his deputy Dr. Heinz Gerhäuser. A second department, Device Technology, was founded at the same time. It had 15 employees and was headed by Prof. Heiner Ryssel. These two departments grew into today's IIS and IISB, respectively. The foundations were laid in those early days for what still characterizes the two Fraunhofer institutes today: a focus on electronics, cooperation with industry, a close connection to the university, and the enthusiastic commitment of their employees.

The foundation of IIS and IISB was heavily supported by the Bavarian Ministry of Economic Affairs, the Nuremberg Chamber of Commerce and Industry, and the "Förderkreis für die Mikroelektronik e.V.".

For 30 years, IIS and IISB have been innovators in the fields of microelectronics, power electronics, information and communications technology, and semiconductor technology. Their latest joint initiative is the Leistungszentrum Elektronikssteme LZE, which was founded in 2015 together with the University of Erlangen-Nürnberg and industrial partners.

1 *Newspaper article about the cornerstone ceremony for the Fraunhofer IISB in 1992.*
© Text: L. Hoja
© Foto: B. Böhner

Fraunhofer IISB Annual Conference 2015 – “Halbleitertechnologie im Wandel“ (Semiconductor Technology in Transition)

30 years of cooperation in the value added chain of semiconductor technology

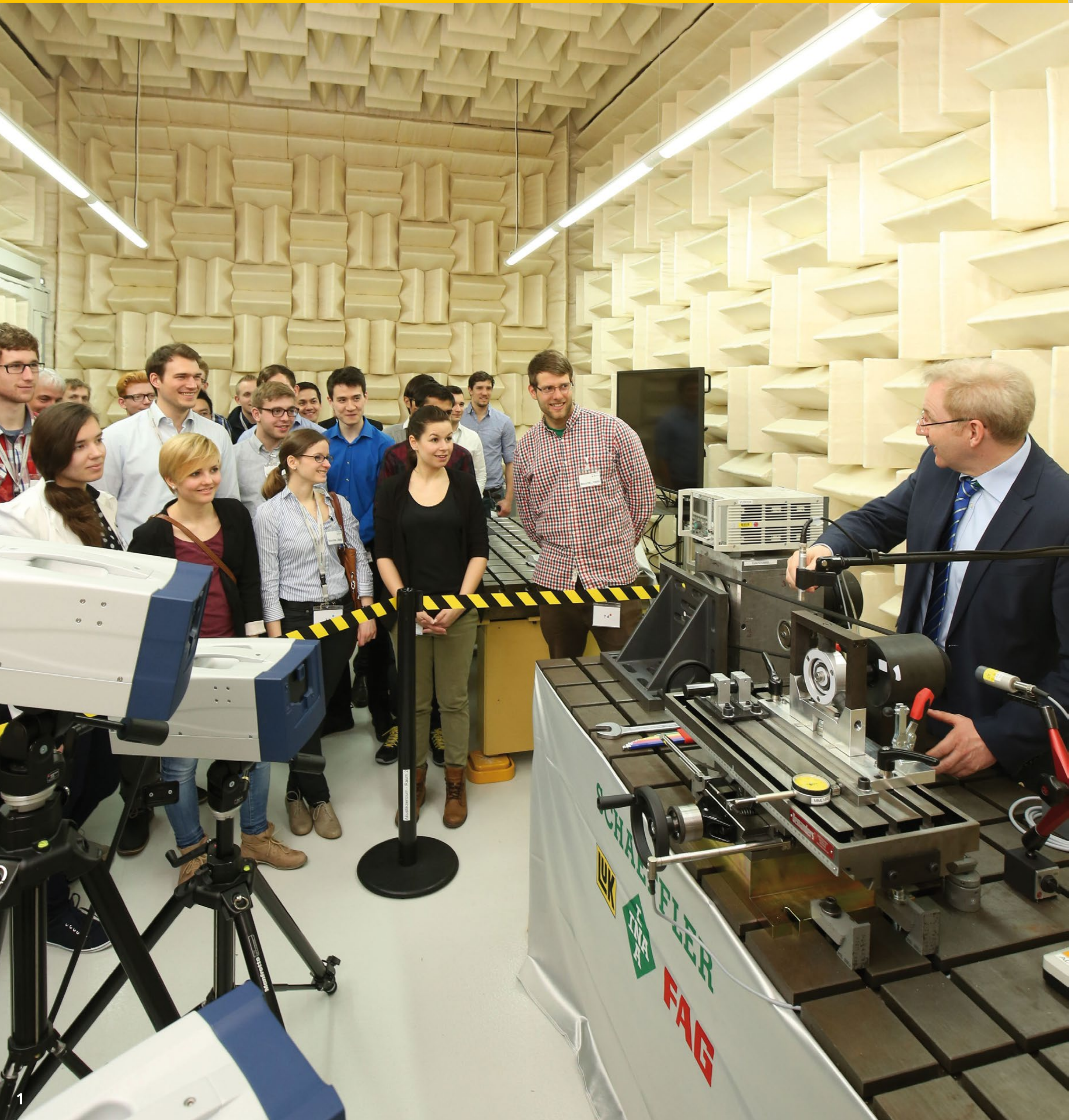
Since its foundation 30 years ago, Fraunhofer IISB has offered its partners a wide variety of possibilities for developing manufacturing equipment and systems, optimizing process flows, implementing technologies, as well as analyzing wafers, processes, and devices. Starting from proven and successful approaches, the future development and application potentials of semiconductor technology were highlighted at the annual conference 2015.

For example, the institute director, Prof. Lothar Frey, was able to greet around 150 guests at the IISB on November 20. In an introductory lecture, Prof. Lothar Pfitzner – the long-standing director of the Department of Semiconductor Manufacturing Equipment and Methods at the IISB – looked back at 30 years of cooperation in the valued added chain of semiconductor manufacturing. Dr. Andreas Wild (ECSEL Joint Undertaking, Brussels) examined this chain in respect to the relationship between equipment and applications. The topic of exploitation and its treatment in so-called “road maps” was discussed in the presentation of Ines Turner (CONVANIT, Dresden, Germany). This was followed by technical presentations by Dr. Georg Roeder, Alexander Tobisch, Helene Richter, and Dirk Lewke on different aspects of equipment and process technology.

After a welcoming address from the mayor of Erlangen, Dr. Florian Janik, and the subsequent lunch, Prof. Heiner Ryssel looked back at 30 years of Fraunhofer IISB as the former director of the institute and praised the efforts of Prof. Pfitzner in building and developing the IISB. In recognition of Prof. Pfitzner’s accomplishments, Institute Director Prof. Lother Frey presented him with the “Fraunhofer Taler” award in the name of the Fraunhofer-Gesellschaft board of directors. Presentations by Dr. Martin Schellenberger, Dr. Markus Pfeffer, as well as by Dr. Wolfgang Aderhold (a former IISB employee, now at Applied Materials, Santa Clara, USA) on selected topics from the fields of process control and contamination analysis rounded off the scientific program.

The last “agenda item” was when the employees of the department of semiconductor manufacturing equipment and methods formally thanked their boss of many years, Prof. Pfitzner. In addition to various other gifts, Dr. Schellenberger and Dr. Pfeffer presented him with two objects of art symbolizing a 2-inch and a 450-mm wafer. Finally, the guests were given the opportunity for laboratory tours, and the culmination was a cozy get-together with local Franconian culinary specialties.

1 *From left to right: Prof. Lothar Pfitzner, the long-standing head of the IISB Department of Semiconductor Manufacturing Equipment and Methods, Prof. Lothar Frey, the director of IISB, and Dr. Florian Janik, the mayor of Erlangen, during the Fraunhofer IISB Annual Conference.*
© K. Fuchs / Fraunhofer IISB



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DRIVE-E Study Prizes and Academy 2015

The motto of this year's DRIVE-E program was back to the roots: In 2010, the first year of the event, the student recruitment program for electrical mobility, initiated by the German Federal Ministry for Education and Research (BMBF) and the Fraunhofer-Gesellschaft, started in Erlangen, Germany – and this year it came back. From March 8 to 13, 2015, fifty students selected by a jury as well as this year's DRIVE-E study prize recipients dealt with the theory and practice of electromobility again at the DRIVE-E Academy at the Fraunhofer Institute for Integrated Systems and Device Technology IISB.

How can we make progress in electromobility with energy-efficient driving and high-performance batteries? Answers to this were provided by the student papers awarded the DRIVE-E study prizes. BMBF State Secretary Stefan Müller and Fraunhofer Board Member Prof. Alexander Verl handed out the awards to four young junior scientists at the Museum for Industrial Culture in Nuremberg on March 12, 2015. The award ceremony was the high point of last year's DRIVE-E Academy, which was held in Erlangen from March 8 to 13, 2015.

Prof. Dr. Peter Gutzmer, Board Member for Technology and Deputy Chairman of the Board of Schaeffler AG, emphasized the importance of innovation and a sound education in his speech: "Not only the large automobile manufacturers, but we as suppliers also rely on smart young scientists to improve existing concepts and develop new approaches to efficient and electrically mobile driving. I am excited about the high level of talent at the DRIVE-E – and optimistic that this will help us continue to be the leader in knowledge and technology."

First place in category I (study, project, and bachelor's theses), worth 4000 euros, was awarded to Takashi Maximilian Beheim, a master's student in electrical engineering at the Technical University of Munich since October 2014, with his bachelor's thesis on the topic of optimizing the operating strategy for three-phase asynchronous machines as vehicle drives. "As a result of this careful analysis of electric drives, the range of an electric vehicle can be effectively increased with an unchanged battery capacity," said Alexander Verl in his laudatory speech.

In category II (degree and master's theses), Max Falk from Technische Universität Dresden secured first place, worth 6000 euros. His diploma thesis dealt with the topic of energy-saving route planning. He included data from a traffic management system in the selection of a route. This makes it possible to reduce the energy demand by using favorable traffic situations. "The jury chose Max Falk because his thesis took into account a very important, promising aspect, and we are excited about the innovation potential," is how Stefan Müller explained the jury's decision. The thesis is part of the "Schaufenster Elektromobilität Bayern-Sachsen" (Showcase for Electrical Mobility Bavaria-Saxony) program supported by the German federal government.

1 *External excursion to visit Schaeffler Technologies in Herzogenaurach during the DRIVE-E Academy 2015.*
© K. Fuchs / Fraunhofer IISB

2 *Participants of the DRIVE-E Academy 2015 in Erlangen with several electric vehicles during a test drive at the ADAC test track in Schlüsselfeld.*
© G. Meier / Fraunhofer IISB

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DRIVE-E was jointly initiated in 2009 by the BMBF and the Fraunhofer-Gesellschaft. The student recruitment program on the topic of electromobility consists of the DRIVE-E study prize and the DRIVE-E Academy. With the DRIVE-E study prize, the organizers honor excellent, innovative student theses on electromobility. The annually held DRIVE-E Academy offers an exclusive insight into the theory and practice of electromobility. Since 2012, DRIVE-E has been carried out in partnership with a different university each year. Information on the recruitment program and the conditions of participation can be found at www.drive-e.org.

1 *"Electrotainment at the IISB" during the "Long Night of the Sciences 2015". © K. Fuchs / Fraunhofer IISB*

The Long Night of the Sciences 2015

Every two years, the Fraunhofer IISB presents itself in Erlangen at the "Long Night of the Sciences – Nuremberg, Fürth, Erlangen", as they did again last year on October 24.

An expanded offering was able to captivate more than 2000 visitors. The program, which was offered in cooperation with the Chair of Electron Devices of the University of Erlangen-Nürnberg, comprised topics from the world of nanostructures (such as, e.g., during a tour of the clean room) to crystals to electromobility and the energy networks of the future.

High points included live demonstrations with the electric motocross motorcycle of the "TechFak EcoCar" team of the University of Erlangen-Nürnberg. The "TechFak EcoCar" team currently consists of around 20 students from various fields who test electromobility, design state-of-the-art electric vehicles, and work in cooperation with the Fraunhofer IISB.

More Efficient Solar Cells Thanks to Better Crystals

Fraunhofer IISB organizes an international photovoltaics conference in Bamberg

From May 5 - 8, 2015, 140 international experts from industry and science met for the 8th international conference "Crystalline Silicon for Solar Cells - CSSC" in the world heritage city of Bamberg. After Japan (2006), China (2007), Norway (2009), Taiwan (2010), USA (2011), France (2012), and Japan (2013), the conference was held in Germany for the first time. Under the auspices of the Deutsche Gesellschaft für Kristallwachstum und Kristallzüchtung e.V. (German Society for Crystal Growth and Crystal Growing, DGKK), the CSSC-8 was organized by Dr. Christian Reimann from the Fraunhofer Institute for Integrated Systems and Device Technology IISB in Er-

8th International Workshop on Crystalline Silicon for Solar Cells

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langen, Dr. Stephan Riepe from the Fraunhofer Institute for Solar Energy Systems ISE in Freiburg, and Dr. Wolfram Miller from the Leibniz Institute for Crystal Growth (IKZ) in Berlin.

The tenor: progress in the area of silicon crystallization and crystal separation processes leads to a further increase in the efficiency of solar cells and to a related reduction in cost for generating photovoltaic current.

A highlight of the CSSC-8 was the presentation of the Ulrich Gösele Young Scientist Award. This year's prize winner, Dr. Bing Gao from Kyushu University in Japan, has dealt with the numerical calculation of silicon crystallization processes. In Japan, his excellent scientific results have already led to the implementation of a special variant of quasi-mono technology on a research scale.

In addition, the German Society for Crystal Growth and Crystal Growing (DGKK) presented the CSSC-8 Best Poster Award to Mr. Patatut from the French research institute CEA-INES and his coauthors for the excellent poster "Online quantitative chemical analysis of molten photovoltaic silicon for refining process monitoring", which introduced an innovative procedure for analyzing contamination in liquid silicon.

The participants used the conference for extensive discussions, developing new ideas, and formulating specific approaches for a more energy-efficient production of photovoltaic systems, as well as for reducing the production costs in relation to the attainable electric power.

In addition to the scientific and technological exchange, there was also enough time available to explore the world heritage city of Bamberg in the context of a guided city tour or on one's own and to enjoy the specialties of the local Franconian cuisine. The conference dinner was also very Franconian: a deputy mayor of the city of Bamberg, Wolfgang Metzner, expressed his heartfelt thanks to the organizers of the CSSC-8 there. "The city of Bamberg is very proud to be the capital of silicon photovoltaic technology for a brief time!" said Metzner.

GADEST 2015 in Bad Staffelstein

30 years of "Gettering and Defect Engineering in Semi-Conductor Technology"

In 2015, it was 30 years since the first conference on Gettering and Defect Engineering in Semiconductor Technology (GADEST) was established. Arranged by Fraunhofer IISB the 16th GADEST conference was held from Sunday, September 20th to Friday, September 25th, 2015 in Bad Staffelstein, Germany. Since 1985, GADEST has been organized biennially at typically remote sites to encourage interactions and discussions among the participants.

1 *Logo of the CSSC-8, the 8th International Workshop on Crystalline Silicon for Solar Cells, organized by Fraunhofer IISB in 2015 in Bamberg.*
© Fraunhofer IISB

2 *Group portrait of the participants of the 8th International Workshop on Crystalline Silicon for Solar Cells.*
© Fraunhofer IISB

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Bad Staffelstein is a serene little town in a beautiful landscape known as "Gottesgarten am Obermain" ("Eden on the Upper Main"). The most famous son of Bad Staffelstein was Adam Ries, a famous German mathematician born in 1492. Adam Ries introduced the Arabic numerals into European medieval calculation and for that he is generally considered to be the "father of modern calculating". This in mind the portrait of Adam Ries was pictured in the GADEST 2015 logo, designed by employees of Fraunhofer IISB.

The objective of GADEST 2015 was to examine defects in semiconductors and how they can be selectively used to improve semiconductor characteristics across the board. This ranges from theoretical principles to practical implementation in technical applications. It is essential to discuss new approaches based on the state of technology and to apply them to technically relevant problems. The two keynote presentations, the 20 invited and 46 other presentations, as well as the 36 poster contributions, correspondingly dealt with fundamental aspects as well as technological problems related to defects in semiconductor materials. The topics there ranged from crystal growth to nanoelectronics to photovoltaics and power electronics. As in the previous GADEST conferences, ample time was available for discussion and informal interactions between scientists and engineers coming from all over the world and representing different disciplines.

Foundet by the former Institute for Semiconductor Physics in Frankfurt an der Oder, former German Democratic Republic, the GADEST conferences are also traditionally meeting places for scientists from east and west. From its beginning, it was intended as an international forum for experts in the field of semiconductor technology, semiconductor device physics and defect physics with participants from academia as well as from industry. The GADEST 2015 especially benefited scientifically from the participation of Prof. Klaus von Klitzing, the 1985 Nobel Prize winner in Physics, and Prof. Martin Green, who received the "Right Livelihood Award" ("Alternative Nobel Prize") in 2002 for his contributions to photovoltaics.

The next GADEST conference will be held in 2017 in the country of Georgia.

Acum 2015 Best Paper Award for Fraunhofer IISB Scientist

Andreas Roßkopf, research associate at the Simulation department of the IISB, was presented with the Best Paper Award in the "Systems and Multiphysics" category at the ANSYS Conference & CADFEM Users' Meeting (ACUM) 2015, which was held from June 24 to 26 in Bremen, Germany.

1 *Logo of the GADEST 2015, the International Conference on Gettering and Defect Engineering in Semiconductor Technology, with the portrait of Adam Ries. The famous German mathematician was born in Bad Staffelstein in 1492.*
© Fraunhofer IISB

2 *Group portrait of the participants of the International Conference on Gettering and Defect Engineering in Semiconductor Technology, organized by Fraunhofer IISB in 2015 in Bad Staffelstein.*
© G. Meier / Fraunhofer IISB

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He received the award for his paper on winding losses in power electronic systems with high-frequency litz wires, in which he developed a method for the efficient simulation of complex power electronic systems that can be applied to coil systems for the inductive charging of electric vehicles.

10 Years of Fraunhofer THM in Freiberg

Successful research for the local semiconductor material industry

The Fraunhofer Technology Center for Semiconductor Materials THM in Freiberg, Germany, has been successfully doing research in the field of electronic material manufacturing for 10 years together with local industry.

Fraunhofer THM was founded in 2005 with the objective of supporting the research activities of the semiconductor industry concentrated in Freiberg, in close cooperation with the two parent institutes Fraunhofer IISB in Erlangen and Fraunhofer ISE in Freiburg. For this purpose, THM operates a crystallization and wafer technical center in the immediate vicinity of the Freiberg semiconductor companies.

The technical center was financed by funds from the European EFRE program, the German Federal Ministry for Education and Research, and the Free State of Saxony, and it was officially opened in 2012. Today, Fraunhofer THM employs 35 people, including students. Research focuses on a more economical manufacturing of crystal materials with simultaneously improved material properties, such as, e.g., silicon for microelectronic and photovoltaic applications or gallium nitride for energy electronics, as well as for the wafers made of them.

On the occasion of the 10-year anniversary, Dr. Simone Raatz, a member of the German parliament and the deputy chairperson of the Committee for Education, Research and Technology Assessment there, visited Fraunhofer THM and informed herself about the previous and future development. Dr. Raatz, a qualified university lecturer in chemistry, has followed and accompanied the development of Fraunhofer THM for more than a decade. During her latest visit, she intensively discussed research policy topics in general and the development of Fraunhofer THM in particular with the two directors of Fraunhofer THM, Dr. Jochen Friedrich and Prof. Dr. Hans-Joachim Möller.

A current research highlight is the activities for producing gallium nitride crystals, which are needed for especially powerful light-emitting diodes, long-lasting laser diodes, and reliable transistors.

The successful development of Fraunhofer THM was also confirmed by an evaluation by external experts that took place in autumn of last year.

The research and development of semiconductor materials will continue to be the focus at Fraunhofer THM in the future as well. With the technologies based on this and taking into acount the decline of the solar industry in Germany, the THM is continually developing new research fields together with the Technischen Universität Bergakademie in Freiberg and other partners. In particular, they have started to study the potential of new materials for energy recovery and for battery applications.

Semiconductor materials and innovative topics, such as, for example, energy materials, ensure that Fraunhofer THM will continue to establish itself as a research institute. The THM will thereby continue to make an important contribution to strengthening Freiberg as an industrial and research location in the future as well.

1 *From left to right: Dr. Jochen Friedrich, spokesman of the Fraunhofer THM, Dr. Simone Raatz, member of the German Bundestag and the deputy chairperson of the Committee for Education, Research and Technology Assessment, and Prof. Hans-Joachim Möller, deputy spokesman of Fraunhofer THM, discussing research policy topics in general and the development of Fraunhofer THM in particular.*
© M. Borrmann / Fraunhofer THM

NAMES AND DATA

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Guest Scientists

Abd Alaziz, A.Q.
March 25,2015 - June 30, 2015
Syria
TU Darmstadt
SSRM characterization of FIB inducted damage in SiC

Chen, T.
December 1,2014 - March 31,,2015
Germany
TUBA Freiberg

DiBendedetto, L.
December 14, 2015 – December18, 2015
Italy
University of Salerno
Charakterisierung von SiC-Bauelementen und Teststrukturen

Fried, M.; Juhansz, G.; Major, C.; Petrik, P.; Herczeg, Z.
November 16 - 24, 2015
Hungary
MFA Budapest
Aufbau eines linienbasierten Ellipsometers im Reinraum des Fraunhofer IISB (EU-Prjekt SEA4KET)

Jae-Seop, L.
August 21, 2015 - August 26, 2015
Korea
Kwangwoon University

Repiso, E.
January 18, 2015 - January 31,2015
Spain
University of Madrid
Schulung Crysmas, Simulation Kristallzüchtung

Rivadeneira, M.
April 20, 2015 - June 26, 2015
France
Polytech Grenoble
Creation of a Python-interface to communicate with a battery system via CAN

Röth, J.
March 04 - April 30, 2015
Germany
Hochschule Anhalt
Entwicklungsarbeiten zum Thermischen Lasterstrahl-Separieren (TLS)

Rugen, S.
March 26, 2015 - March 27, 2015
Germany
University of Bremen / IALB
Kapazität-Spannungsmessung an MOS-Strukturen auf 4H-Sic

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

Se-Hoon, P.
August 21, 2015 - August 26, 2015
Korea
Kwangwoon Universty

Shen, L.
October 12 - December 31, 2015
China
Shanghai Institute of Microsystem and Information Technology (SIMIT), Chinese Academy of Science (CAS)
Modeling of AIGaN power devices

Spitzenberger, A.
March 16, 2015 - April 17,2015
Germany
TUBA Freiberg
Entwicklung eines innovativen Heizerkonzepts für eine Züchtungsanlage zur Ammonothermalsynthese

Yan, S.L.
September 30, 2015 - October 1, 2015
China
Shanghai Institute of Microsystem and Information Technology, Chinese Academy of Science (CAS)
Simulation of AIGaN power devices

Patents

Allenstein, F.; Koitzsch, M.; Lewke, D.; Tobisch, A.; Zühlke, H. U.:
Verfahren und Vorrichtung zur Trennung eines flachen Werkstücks in mehrere Teilstücke
WO2013EP02191

Alzner, K; George, D; Kraft, S.; Schletz, T; Schmid, T.:
Leistungshalbleitermodul und Verfahren zur Herstellung desselben
DE102012204159

Dietrich, M.; Friedrich, J.; Reimann, C.; Trempa, M.:
Method for producing silicon blocks
TW000000I468560B

Dorp, v. J.; Erlbacher, T.; Frey, L.:
Elektrisches Überbrückungselement, insbesondere für Speicherzellen eines Energiespeichers
EP2642582

Friedrich, J.; Reiman, C.; Schneider, V.:
Wiederverwendbarer Tiegel aus einer Siliziumnitrid-Keramik sowie dessen Verwendung bei der Herstellung eines mono- oder multikristallinen Halbmetallkörpers aus einer Schmelze
DE102013109024A1

Lukas, S.; Jank, M.:
Verfahren zur Herstellung einer Dispersion von Nanopartikeln
DE102010034293

Oriwol, D.; Trempa, M.; Reimann, C.:
Method for producing silicon ingots
TW000000I490378B

Content

Schellenberger, M.; Lewke, D.:
Station arragenments for processing and / or measuring semiconductor wafers, and also processing method
US20150037122

Tobisch, A.:
Verfahren und Vorrichtung zur Messung der Ablenkung von Lichtstrahlen durch eine Objektstruktur oder ein Medium
DE102014002084

Zühlke, H. U.; Koitzsch, M.; Lewke, D.; Tobisch, A.:
Verfahren und Vorrichtung zur Trennung eines flachen Werkstücks in mehrere Teilstücke
WO2015/010862

Participation in Committees

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

Erdmann, A.
- Senior Member of SPIE
- Member of European Optical Society (EOS)
- Conference co-chair of Optical Microlithography Conference at SPIE Advanced Lithography Symposium, San Jose, US, February, 2015
- Program committee member of Micro- and Nanoengineering conference (MNE), The Hague, NLD, September, 2015
- Conference co-chair of Computational Optics Conference at SPIE Optical Design Europe Symposium, Jena, GER, September, 2015
- Member of Editorial Board Advanced Optical Technologies Journal, De Gruyter

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

Friedrich, J.:
- President of Deutsche Gesellschaft für Kristallwachstum und Kristallzüchtung e.V. (DGKK)
- 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
- Technical Program Committee member of International Conference on Silicon Carbide and Related Materials (ICSCRM 2015)
- Session chair at International Conference on Silicon Carbide and Related Materials (ICSCRM 2015)

Lorenz, J.
- Member of the Electrochemical Society
- Member of the Institute of Electrical and Electronics Engineers (IEEE)
- Member of the Technical Program Comittee, ESSDERC 2015, Graz, AUT, September 14-18, 2015

Meissner, E.:
- Reviewer for Journal of Crystal Growth and Materials Chemistry and Physics, physica status solidi Rapid Research Letters, The Journal of Supercritical Fluids
- Co-Chair of the 9th International Workshop for Bulk Nitride Semiconductors, IWBNS-IX Korea 2015
- Expert Panel Member for the Research Council of Norway

Pfeffer, M.
- Member of the "Factory Integration Working Group" (FITWG) of the "International Technology Roadmap for Semiconductors" (ITRS)
- Member of Semicon Europe Semiconductor Technology Programs Committee (STC)

Pfitzner, L.
- Honorarprofessur an der Universität Erlangen-Nürnberg, Fachbereich Elektrotechnik
- Mitglied des Strategischen Beirats des Österreichischen Bundesministeriums für Verkehr, Innovation und Technologie (BMVIT) für die Inititative "Intelligente Produktion"
- Chair of IPWGN (International Planning Working Group of Nanoelectronics)

Content

Continuation: Participation in Committees

- Chairman of the "Yield Enhancement Workung Group" (ITWG) of the "International Technology Roadmap for Semiconductors" (ITRS)
- Chair of the Executive Committee and the 7th International Conference on "450 mm - Status and Overview", Dresden, GER, October 7 - 8, 2015
- Member of the Program Committee of the 7th International Conference on "450 mm - Status and Overview", Dresden, GER, October 7 - 8, 2015
- Member of the Program Committee of the ISSM 2016, Tokyo, Japan, December 12 - 13, 2016
- Chairman of the "Yield Enhancement Working Group" (ITWG) of the ITRS (International Technology Roadmap for Semiconductors) Conference, Palo Alto, CA, USA, July 11 - 12, 2015
- Mitglied der VDE/VDI-Gesellschaft für Mikroelektronik, Mikro- und Feinwerktechnik, Fachbereich "Halbleitertechnologie und Halbleiterfertigung", Leiter des Fachausschusses "Produktion und Fertigungsgeräte"
- Mitglied der VDE/VDI-Gesellschaft für Mikroelektronik, Mikro- und Feinwerktechnik, Fachbereich "Halbleitertechnologie und Halbleiterfertigung", Leiter der Fachgruppe 1.1 "Geräte und Materialien"
- Co-chair of SEMI Task Force "Environmental Contamination Control" (currently inactive)
- Co-chair of the Standardization Committee "Equipment Automation Standards Committee" of SEMI
- Member of the "Global Coordination Committee" of SEMI
- Member of the "European Planning Group for 450 mm Technology ("EEMI450")

Pichler, P.
- Member of the Scientific Commitee of Symposium Z "Nanomaterials and processes for advanced semiconductor CMOS devices" of the E-MRS 2015, Lille, FRA, May 11-15, 2015
- Member of the Executive Committee of the GADEST conference series
- Conference chairman GADEST 2015, Bad Staffelstein, GER, September 20-25, 2015

Reimann, C.:
- Co-Chair of International Workshop on Crystalline Silicon for Solar Celles (CSSC-8)
- 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"

Schellenberger, M.
- Member of the Technical Programme Committee of the ESSCIRC-ESSDERC Conference
- 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

1st MAP's Spring School on Semiconductor Crystal Growth (MAPS)
Büchenbach, GER, April 1 - 2, 2015

2nd International Freiberg Conference on Electrochemical Storage Materials
Freiberg, GER, June 11 - 12, 2015

2. Netzwerktreffen "Printed Electronics Franken"
Erlangen, GER, November 15, 2015

8th International Workshop on Crystalline Silicon for Solar Cells
Bamberg, May 5 - 8, 2015

9th International Workshop for Bulk Nitride Semiconductors, IWBNS-IX
KOR, 2015

12. Weimarer Optimierungs- und Stochastiktage 2015
Weimar, GER, November 5 – 6, 2015

13th Fraunhofer IISB LIthography Simulation Workshop
Behringersmühle, GER, September 10 – 12, 2015

14. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.6 "Prozesskontrolle, Inspektion und Analytik"
Erlangen, GER, March 4, 2015

37. Nutzertrefen der GMM-VDE/VDI-Fachgruppe 1.2.4 "Heißprozesse und RTP"
Erlangen, GER, March 25, 2015

38. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.4 "Heißprozesse und RTF"
Regensburg, GER, November 25, 2015

41st International Conference on Micro&Nano Engineering
The Hague, NL, September 21 – 24, 2015

53. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.2 "Ionenimplantation"
Erlangen, GER, March 26, 2015

Content

Continuation:

Conferences, Workshops, Fairs, and Exhibitions

54. Nutzertreffen der GMM-VDE/VDI-Fachgruppe 1.2.2 "Ionenimplantation"
Regensburg, GER, November 26, 2015

ANSYS Conference & CADFEM Users' Meeting (ACUM) 2015
Bremen, GER, June 24 – 26, 2015

ANSYS Electronics Simulation Conference (AESC)
Munich, GER, February 10 – 11, 2015

BRAMAT-2015, 9th International Confrence on Materials Science & Engineering
Brasov, ROU, March 5 – 7, 2015

ICSCRM 2015, 16th International Conference on Silicon Carbide and Related Materials
Giardini Naxos, ITA, October 4 – 9, 2015

CSTIC 2015, China Semiconductor Technology International Conference
Shanghai, CHN, March 15 – 16, 2015

"Custom-tailored SiC Services" during the 16th International Conference on Silicon Carbide and Related Materials
Giardini Naxos, ITA, October 04 - 09, 2015

DGKK-Arbeitskreis - Industrielle Kristallzüchtung
Freiberg, GER, November 02 - 03, 2015

DGKK Preisverleihung "Wer züchtet den schönsten Kristall"
Nuremberg, GER, February 03, 2015

E-MRS 2015 Fall
Warsaw, POL, September 15 – 18, 2015

E-MRS 2015 Spring
Lille, FRA, May 11 – 15, 2015
EIPBN 2015
San Diego, US, May 26 – 29, 2015

ESSDERC 2015 Workshop "Variability – From Equipment to Circuit Level"
Graz, AUT, September 18, 2015

ESSDERC 2015
Graz, Aut, September 14 – 18, 2015

EuroSimE 2015
Budapest, HUN, April 19 – 22, 2015

Firmenkontaktmesse ContactING 2015
Nuremberg, GER, November 12, 2015

Focus Session "Yield & Manufacturing" at the 45th European Solid-State Device Conference (ESSDERC 2015)
Graz, AUT

Forum Life Science 2015
München-Garching, GER, March 11 – 12, 2015

Fraunhofer IISB-Jahrestagung 2015 "Halbleiterfertigung im Wandel"
Erlangen, GER

Fraunhofer Wissenschaftscampus
Erlangen, GER, March 3, 2015

Freiberg Silicon Days, part of the 66. Freiberg Research Forum BHT 2015
Freiberg, GER, June 18 - 19, 2015

GADEST 2015
Bad Staffelstein, GER, September 20 – 25, 2015

GMM-VDE/VDI-Fachgruppe 1.2.3, Abschneide und Ätzverfahren, Fachausschuss 1.2: Verfahren, Nutzergruppentreffen PVD, PECVD und Ätzen
Erlangen, GER, December 8, 2015

GMM-VDE/VDI-Fachgruppe 1.2.3, Abschneide- und Ätzverfahren, Fachausschuss 1.2: Verfahren, 18. Qorkshop der GMM-Fachgruppe 1.2.3 Abschneide- und Ätzverfahren
Erlangen, GER, December 9, 2015

ICPST-32
Chiba, JPN, June 24 – 26, 2015

ICSCRM 2015
Giardini Naxos, ITA, October 4 – 9, 2015

jDGKK Meeting
Halle, GER, March 11 – 12, 2015

Kolloquium zur Halbleitertechnologie und Leistungseletronik
Erlangen, GER, 2015

Lange Nacht der Wissenschaften 2015
Erlangen, GER, November 24, 2015

Lithography Workshop
Ketchum, US, June 21 – 26, 2015

MNE 2015
The Hague, NL, September 21 – 24, 2015

NIL Idustrial Day 2015
Berlin, GER, March 19 – 20, 2015

NNT 2015, International Conference on Nanoimprint & Nanoprint Technology
Napa, US, October 22 – 24, 2015

PCIM Europe 2015
Nuremberg, GER, May 19 – 21, 2015

Schülerexkursion Emil-von Behring-Gymnasium Spardorf
Erlangen, GER, July 27, 2015

SEMICON Europa 2015
Dresden, GER, October 6 – 8, 2015

SENSOR + TEST 2015
Nürnberg, GER, May 19 - 21, 2015

SISPAD 2015
Washington DC, US, September 9 – 11, 2015

SPIE Advanced Lithography Conference (AESC)
San Jose, US, February 22 – 26, 2015

SPIE Computational Optics
Jena, GER, September 7 – 9. 2015

Publications

Alt, H. Ch.; Wagner, H. E.; Glacki, A.; Frank-Rotsch, Ch.; Häublein, V.:
Isotopic study of mid-infrared vibrational modes in GaAs related to carbon and nitrogen impurities
Phys. Status Solidi B 252, 1827 (2015)

Content

Continuation: Publications

Baer, E.; Evanschitzky, P.; Lorenz, J.; Roger, R.; Minixhofer, R.; Filipovic, L.; Orio, R. L. de; Selberherr, S.:
Coupled Simulation to Determine the Impact of across Wafer Variations in Oxide PECVD on Electrical and Reliability Parameters of Through-silicon Vias
Microelectronic Engineering 137 (2015), 141-145
DOI: 10.1016/j.mee.2014.11.014

Banzhaf, T.; Grieb, M.; Rambach, M.; Bauer, A.J.; Frey, L.:
Impact of Post-Trench Processing on the Electrical Characteristics of 4H-SiC Trench-MOS Structures with Thick Top and Bottom Oxides
Materials Science Forum 821-823 (2014) 753
DOI: 10.4028/www.scientific.net/MSF.821-823.753

Bayer, C. F.; Bär, E.; Kallinger, B.; Berwian, P.:
Thermal Simulation of Paralleled SiC PiN Dipdes in a Module Designed for 6.5 kV/1 kA
Materials Science Forum 821-823 (2015) 616-619
DOI: 10.4028/www.scientific.net/MSF .821-823.616

Bayer, C.F.; Baer, E.; Waltrich, U.; Malipaard, D.; Schletz, A.:
Simulation of the Electric Field Strength in the Vicinity of Metallization Edges on Dielectric Substrates
Dieelectrics and Electrical Insulation, IEEE Transactions on, vol. 22, no. 1, pp. 257-265, Feburay 2015
DOI: 10.1109/TDEI.2014.004285

Beltrán, A.M.; Duguay, S.; Strenger, C.; Bauer, A. J.; Cristiano, F.; Schamm-Chardon, S.:
Atomic scale characterization of SiO_2/4H-SiC interfaces in MOSFETs devices
Solid State Communications 221 (2015) 28
DOI: 10.1016/j.scc.2015.08.017

Berwian, P.; Kaminzky, D.; Roßhirt, K.; Kallinger, B.; Friedrich, J.; Oppel, S.; Schneider, A.; Schütz, M.:
Imaging defect luminescence of 4H-SiC by ultraviolet-photoluminescence
Solid State Phenomena Vol. 242 (2016) 484-489

Burenkov, A.; Lorenz. J.:
Simulation of Thermo-Mechanical Effect in Bulk-Silicon FinFETs
Material Science in Semiconductor Processing, Volume 42, Part 2, Febuary 2016, pp. 242-246
DOI: 10.1016/j.mssp.2015.07.002

Burenkov, A.; Lorenz, L.; Spiegel, Y.; Torregrosa, F.:
Simulation of Plasma Immersion Ion Implantation into Silicon
Proceedings of Conference on Simulation of Semiconductor Processes and Devices 2015 (SSISPAD2015), p.218
DOI: 10.1109/IIT.2014.6940004

Ekstrøm, K.E.; Stokkan, G.; Søndenå, R.; Dalaker, H.; Lehmann, T.; Arnberg, L.; Di Sabatino, M.:
Structure and dislocation development in mono-like silicon
Phys. Status Solidi A, 1–11 (2015)

Erdmann, A.; Evanschitzky, P.; Neumann, J. T.; Gräupner, P.:
Mask-inducted best-focus-shifts in DUV and EUV lithography
Proceedings of SPIE 9426, Paper 94260H, 11 pp.
DOI: 10.1117/12.2086346

Erdmann, A.; Fühner, T.; Evanschitzky, P.; Agudelo, V.; Freund, C.; Michalak, P.; Xu, D.B.:
Optical and EUV projection lithography: A computational view
Microelectronic engineering 132 (2015), pp. 21-34
DOI: 10.1016/j.mee.2014.09.011

Erlbacher, T.; Schwarzmann, H., Bauer, A. J.; Döhler, G. H.; Schreivogel, M.; Lutz, T.; Guillén, F.H.; Graf, J.; Fix, R.; Frey, L.;
Modeling of ion drift in 4H-SiC-based chemical MOSFET sensors
Journal of Vacuum Science & Technology B 33 (2015) 01A103
DOI: 10.1116/1.4903054

Fuegl, M.; Mackh, G.; Meissner, E.; Frey, L.:
Assessment of dicing induced damage and residual stress on the mechanical and electrical behavior of chips
Proceedings of Electronic Components and Technology Conference (ECTC), San Diego, May 26 - 29 (2015) 214-219

Gepp, M.; Filimon, R.; Koffel, S.; Lorentz, V. R. H.; März, M.:
Advanced thermal management for temperature homogenization in high-power lithium-ion battery systems based on prismatic cells
IEEE ISIE 2015; June 02-05; Rio de Janeiro, BRA

Girschikofsky, M.; Belle, S.; Förthner, M.; Fader, R.; Rommel, M.; Frey, L.; Hellmann, R.:
Optical Bragg Gratings in Inorganic-Organic Hybrid Polymers for Highly Sensitive Temperature Measurements
Proceedings SENSOR 2015, 812-814 (2015)
DOI: 10.5162/sensor2015/P5.5

Content

Continuation: Publications

Grosch J.; Teuber, E.; Jank, M., Lorentz, V.; März, M.; Frey, L.:
Device Optimization and Application Study of low cost Printed Temperature Sensor for mobile and stationary battery based Energy Storage Systems
IEEE Conference Publications, IEEE International Conference on Smart Energy Grid Engineering, 2015

Gumprecht, T.; Pfeffer, M.; Bauer, A.; Frey, L.:
Ansätze zur Implementierung einer automatisierten Prozesskontrolle beim Dickdraht-Bonden in der Leistungselektronik
Fachzeitschrift PULS Aufbau- und Verbindungstechnik in der Elektronik, Ausgabe 12/2015

Heckel, T.; Zeltner, S.; Frey, L.:
Characterization and application of 600 V normally-off GaN transistors in hard switching DC/DC converters
Power Semiconductor Devices & IC's (ISPSD), 2014 IEEE 26th International Symposium on , vol., no., pp.63,66, 15-19 June, 2014, US

Herms, M.; Wagner, M.; Molchanov, A.; Rommel, M.; Zschorsch, M.; Wuerzner, S.:
Comparative spatially resolved characterization of Czochralski-grown silicon crystal by different laser-based imaging techniques
Solid Sate Phenomena Vol. 242 (2016) 478-483

Hutzler, A.; Tokarski, A.; Schletz, A.:
High temperature die-attach materials for aerospace power electronics: Lifetime tets and modeling
IEEE Aerospace Conference 2015: March 07-14, 2015, Big Sky, MT, USA, Piscataway, NJ: IEEE,2015

Hürner, A.; DiBenedetto, L.; Erlbacher, T.; Mitlehner, H.; Bauer, A. J.; Frey, L.:
Robust Double-Ring Junction Termination Extension Design for High Voltage Power Semiconductor Devices based on 4H-SiC
Materials Science Forum 821-823 (2014) 656
DOI: 10.4028/www.scientific.net/MSF.821-823.656

Hürner, A.; DiBenedetto, L.; Erlbacher, T.; Mitlehner, H.; Bauer, A. J.; Frey, L.:
Temperature Dependent Characterization of Bipolar Injection Field-Effect-Transistor (BiFET) for Determing the Short-Circuit-Capability
Materials Science Forum 821-823 (2014) 806
DOI: 10.4028/www.scientific.net/MSF.821-823.806

Jäckle, S.; Mattiza, M.; Liebhaber, M.; Brönstrup, G.; Rommel, M.; Lips, K.; Christiansen, S.:
Junction formation and current transport mechanisms in hybrid n-Si/PEDOT:PSS solar cells
Scientific Reports 5, 13008 (2015)
DOI:10.1038/srep13008

Jelinek, M.; Laven, J.G.; Krnstoetter, S.; Schustereder, W.; Schulze, H.-J.; Rommel, M.; Frey.L.:
A DLTS study of hydrogen doped czochralski-grown silicon
Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms 365A, 240-243 (2015)
DOI: 10.1016/j.nimb.2015.07.078

Kangawa, Y.; Suetsugu, H.; Knetzger, M.; Meissner, E.; Hazu, K.; Chichibu, S. F.; Kajiwara, T.; Tanaka, S.; Iwasaki, Y.; Kakimoto, K.:
Structural and optical properties of AlN grown by solid source solution growth method
Japanese Journal of Applied Physics 54 (2015) 085501

Klimm, D.; Friedrich, J.:
Guest Editors' Preface
Cryst. Res. Technol. 50, No. 1 (2015) 1

Knetzger, M.; Meissner, E.; Derluyn, J.; Germain, M.; Friedrich, J.:
Investigations of critical structural defects in active layers of GaN-on-Si for power electronic devices
Solid State Phenomena Vol. 242 (2016) 417-420

Krach, F.; Schwarzmann, H.; Bauer, A. J.; Erlbacher, T.; Frey, L.:
Silicon Nitride, a high potential dielectric for 600 V integrated RC-snubber applications
Journal of Vacuum Science and Technology B 33 (2015) 01A112
DOI: 10.1116/1.4906082

Kreutzer O.; Maerz M.:
A simple, reliable, cost and volume saving DC-link discharge device for electric vehicles
IEEE Transportation Electrification Conference and Expo, ITEC, Dearborn, 2015
DOI: 10.1109/ITEC.2015.7165800

Kreutzer O.; Eckardt B.; Maerz, M.:
Optimum gate driver design to reach SiC-MOSFET's full potential – speeding up to 200 kV/µs
3rd Workshop on Wide Bandgap Power Devices and Applications, WiPDA, Blacksburg, 2015
DOI: 10.1109/WiPDA.2015.7369313

Lai, K. F.; Erdmann, A.:
Continuation of scaling with optical and complementary lithography. Editorial
Journal of micro/nanolithography, MEMS and MOEMS 14 (2015), No. 1, Art. 011001
DOI: 10.1117/1.JMM.14.1.011001

Content

Continuation: Publications

Lewke, D.; Schellenberger, M.:
Nachbearbeitung von teilgetrennten Bauelementen in der Halbleitertechnik
Studie, Elektronische Publikation, Fraunhofer Publica: July 11, 2015
URI: urn:nbn:de:0011-n-3475986

Lewke, D.; Dohnke, K.O.; Zühlke, H.U.; Cerezuela Barreto, M.; Schellenberger, M.; Bauer, A.J.; Ryssel, H.:
Thermal Laser Separation – a Novel Dicing Technology Fulfilling the Demands of Volume Manufacturing of 4H-SiC Devices
Materials Science Forum 821-823 (2014) 528
DOI: 10.4028/www.scientific.net/MSF.821-823.528

Liu N.; Häublein V.; Zhou, X.; Venkatesan, U.; Hartmann M.; Mačković, M.; Nakajima, T.; Spiecker, E; Osvet, A; Frey, L; Schmuki, P.:
"Black" TiO_2 Nanotubes Formed by High-Energy Proton Implantation Show Noble-Metal-co-Catalyst Free Photocatalytic H_2-Evolution
Nano Lett. 2015 Oct 14;15(10):6815-20
DOI: 10.1021/acs.nanolett.5b02663. Epub 2015 Sep 14

Liu, X.; Wegener, M.; Polster, S.; Jank, M.; Roosen, A.; Frey, L.:
Materials Integration for Printed Zinc Oxide Thin-Film Transistors: Engineering of a Fully-Printed Semiconductor/Contact Scheme,
Journal of Display Technology, Volume 12, Issue 3
DOI: 10.1109/JDT.2015.2445378

Meric, Z.; Mehringer, C.; Karpstein, N.; Jank, M.P.M.; Peukert, W.; Frey, L.:
Tunable conduction type of solution-processed germanium nanoparticle based field effect transistors and their inverter integration
Physical Chemistry Chemical Physics, Bd. 17, Nr. 34, 2015, S. 22106–22114.

Montoliu, C.; Baer, E.; Cerda, J.; Colom, R. J.:
Imporovement of Feature-Scale Profile Evolution in a Silicon Dioxide Plasma Etching Simulator using the Level Set Method
J. Micromech. Microeng. 25 (2015) 065013
DOI: 10.1088/0960-1317/25/6/065013

Nagy, R.; Burenkov, A.; Lorenz, J.:
Numerical Evaluation of the ITRS Transitor Scaling
J. Comput. Electron. 14 (2015) 192
DOI: 10.1007/s10825-014-0638-0

Noll, S.; Rambach, M.; Grieb, M.; Scholten, D.; Bauer, A.J.; Frey, L.:
Influence of annealing, oxidation and doping on conduction-band near interface traps in 4H-SiC characterized by low temperature conductance measurements
Materials Science Forum 821-823 (2014) 476
DOI: 10.4028/www.scientific.net/MSF.821-823.476

Nord S., Hilpert F., Brusius M.:
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