Fraunhofer
IZM

FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

ANNUAL REPORT 16/17

CONTENT

PREFACE

DEAR FRIENDS AND PARTNERS OF FRAUNHOFER IZM, DEAR READERS,

Our strategic development continues to pursue the aim of turning modern integration technologies into high-quality systems – by this measure, 2016 was another successful year. By merging reliability validation and environmental assessment with a deep understanding of future-oriented technologies and efficient manufacturing processes – and with a good dose of know-how in developing complex systems with optimized functions – we are able to put these assessment types successfully into practice. This makes us unique in Germany and places us in a leading position around the world. From a systems technology point of view, it is particularly important that we research and develop integrated hardware solutions for sensoring, data processing, and data transmission, as well as for energy supplies.

Let me illustrate with some highlights from the last twelve months:
In March, our integrated battery development and assembly line opened. It enables the smallest microbatteries to be manufactured with a high degree of precision and the best possible power density – no customer requests are left unfulfilled.

Since June, the four Berlin-based Fraunhofer institutes FOKUS, HHI, IPK, and IZM have pooled their expertise within the new Berlin Center for Digital Transformation. With the Transfer Center Hardware for Cyber-Physical Systems (CPS), IZM has taken on responsibility for the development and setup of modular sensor, high-frequency, and photonic systems in order to support companies in with digitization by means of adapted system integration.

In parallel, IZM-ASSID is working within the successful »Functional Integration for Micro-/Nanoelectronics« Center of Excellence in Saxony, which also deals with the enhancement of IC technologies. This allows us to work intensively on making contributions to all the aforementioned areas of modern system integration.

The Oberpfaffenhofen Training and Analysis Center has become part of the Fraunhofer Research Institution for Microsystems and Solid-State Technologies EMFT on January 1, 2017. We thank all our staff for their many years of work and wish all of them much successful in the future.

For us, cooperation is an indispensable source of constant further development of our institute. We have once again proven the effectiveness of our networking with industry and within the world of research with a whole host of extraordinarily successful projects. Our scientists, for example, are part of the European flagship project Human Brain, where a technical reproduction of the brain is being built, and the brain is to be simulated using computer-based models. Thanks to our many years of expertise in 3D packaging, we are able to assist the development of the hardware platform.

With the core partners Osram Opto Semiconductors and Infineon, we have also been able to develop a smart LED car headlamp. Thanks to our setup technology, we were able to increase the resolution of the LED lighting systems by a factor of one thousand.

Another highlight is our involvement in the sustainablySMART project, which is concentrating on increasing the service life of smartphones. Within this EU-project, we are responsible for developing sustainable technologies for component recovery and product design.

Indeed, our projects have long been making a contribution to improving product recycling and to promoting the recycling economy. This was also the aim of the largest specialist conference on sustainability in electronics – Electronics Goes Green – which we organized in Berlin in September and which welcomed almost 400 attendees from 35 countries.

Our successful involvement in numerous funding projects and industrial projects helped us raise our operating budget to 29.5 million euros, most of which was down to industrial cooperations. This shows that our research produces results that are at the cutting edge, are application-oriented, and cover a wide range of topics. The boundaries between microelectronics, microsystem technology, and software are becoming increasingly blurred. The ability to nevertheless pick up on current trends and to help actively develop these trends has always been one of our strengths. That is why, when it comes to packaging, Fraunhofer IZM follows trends in the area of fan-out packaging (wafer and panel), an extremely future-oriented manufacturing technology that uses large substrate dimensions and offers great market potential. We founded an international panel-level packaging consortium in which this technology, with the assistance of many interested industrial partners – including Intel –, is being further enhanced and developed into an industrial manufacturing process.

To ensure that good ideas do not run out of experts who can put them into practice, the institute makes a comprehensive contribution to developing up-and-coming talent, e.g. with the career orientation event Girls' Day, the Talent Take Off network for the gifted, and our international summer school. In order to allow an even wider public to benefit from our knowledge and skills, we have also considerably broadened the range of events the institute offers: This year, with tutorials, lab courses, technology days, and project workshops, we will invite all interested parties from research and development to benefit from our results in a dialog. The event dates for the whole year can be viewed in an online event calendar.

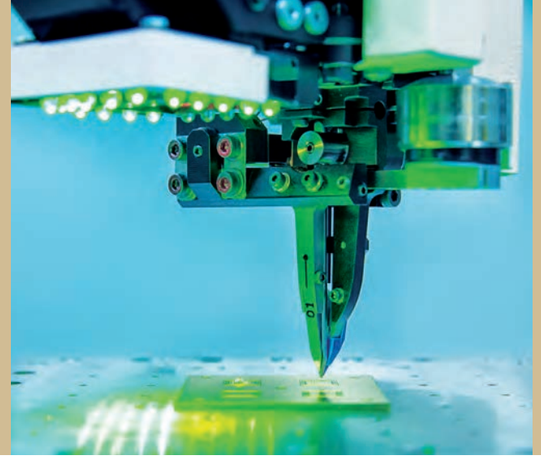
This small insight into our wide spectrum of results and services is perhaps enough for now. Before I close, please allow me to express my thanks to all project partners from industry and research (particularly the TU Berlin), to our contacts in federal and state ministries, and to our project sponsors, for their outstanding collaboration, their continued confidence, and their readiness to help us shape the future of technology. Last but not least, my heartfelt thanks go to our staff for their untiring dedication and uninterrupted flair for innovation; they are the bedrock of our successes over the past year and of our continued development.

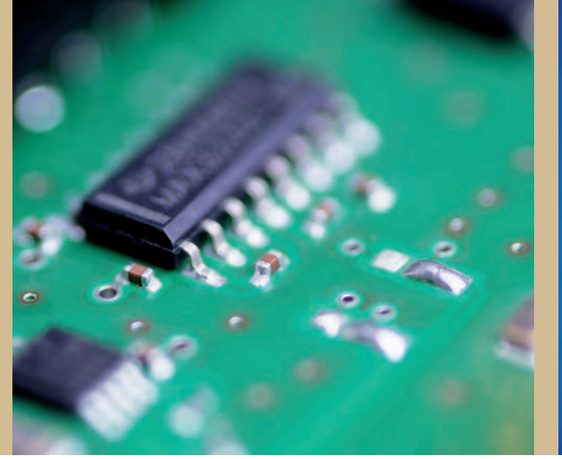
I hope that reading the new annual report gives you plenty of food for thought, as well as enjoyment.

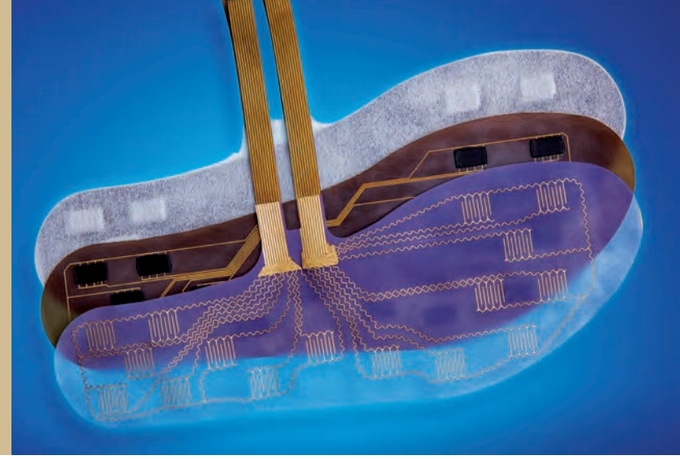
Yours,

Prof. Klaus-Dieter Lang

FRAUNHOFER IZM







FRAUNHOFER – A STRONG NETWORK

Fraunhofer-Gesellschaft
Fraunhofer IZM is one of 69 Fraunhofer Institutes conducting applied research predominantly in the realm of science and engineering, because research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

The majority of the more than 24,500 staff are qualified scientists and engineers, who work with an annual research budget of more than 2 billion euros. Of this sum, 1.9 billion euros is generated through contract research.

More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding.

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.

Fraunhofer Group for Microelectronics
The Fraunhofer Group for Microelectronics, founded in 1996, is a leading European R&D service provider for smart systems. It combines the expertise of currently 18 Fraunhofer institutes with a total of more than 3,000 employees and a combined budget of roughly 381 million euros.

The wide spectrum of services is grouped into seven cross-institute technological core competences: design for smart systems, semiconductor-based technologies, sensors and sensor systems, power electronics and system technologies for energy supply, quality and reliability, system integration technologies, and RF and communication technologies.

Centers of Excellence
Goal of the Centers of Excellence »Functional Integration of Micro- / Nanoelectronics« is above all to support SMEs in Saxony with sensor and actuator technology, measurement technology, and mechanical engineering and construction by rapidly transferring research results into innovative products. The Fraunhofer Institutes ENAS, IIS, IPMS, and IZM, as well as the TU Dresden and Chemnitz and the HTW are also members.

The »Berlin Center for Digital Transformation« is a cooperation between the four Berlin Fraunhofer institutes FOKUS, HHI, IPK und IZM. Its work focuses on technologies and solutions that advance increasing digitalization and networking in all areas of life.

FRAUNHOFER IZM – FROM WAFER TO SYSTEM

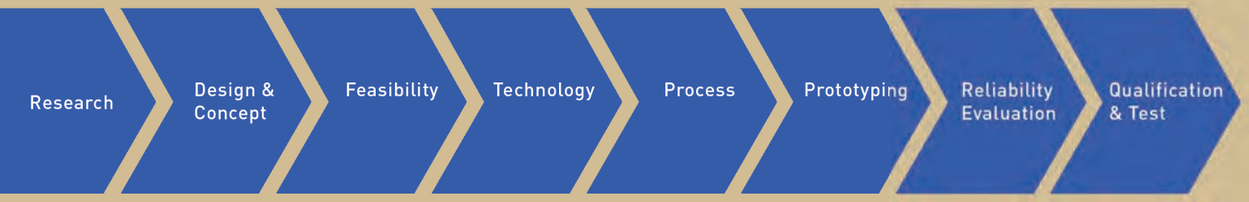
Fraunhofer IZM specializes in applied research that meets the needs of industry. Our four technology clusters

- Integration on Wafer Level
- Integration on Substrate Level
- Materials & Reliability
- System Design

cover all aspects of developing and integrating reliable electronics. The technologies and product solutions we develop are easily transferred to industrial processes. Moreover, the institute's equipment and infrastructure, to which all our customers have equal access, have been specifically assembled to approximate real-life industry conditions as closely as possible. We even introduce technologies on-site if requested. Our customer portfolio is as varied as the countless application areas for electronics. Although Fraunhofer IZM works with leading semiconductor firms and material, machine and equipment suppliers, we are equally focused on providing the next generation of electronics and microsystems for the automotive, medical engineering, safety & security sectors and even the lighting and textile industries.

Our customers have a business development team of three competent managers at their disposal. They pool the resources from different departments, which ensures that the full breadth of applicable technologies is always available. The accumulated know-how is then fed into collaborations that help companies produce game-changing innovations. Fraunhofer IZM works closely with scientific institutes globally on basic research questions. In particular, we have maintained close ties with the Technische Universität Berlin since Fraunhofer IZM's founding. The relationship is reflected on an organizational level with the post of Fraunhofer IZM Director including appointment to a TU professorship.

The institute has a staff of over 370 and saw a turnover of 29.5 million euros in 2016, of which 85.5 percent was derived from contract research. Apart from its headquarters just north of Berlin Mitte, it also maintains the institute branch »All Silicon System Integration Dresden« (ASSID) in Dresden/Saxony.



HOW TO MAKE THE MOST OF FRAUNHOFER IZM

The success of our contract research model may well be due to our emphasis on treating our customers as partners and active participants in the research and development process. We can help you integrate electronics and microsystem technology into your products by developing innovative packaging and integration technology tailored to your requirements and caveats. Uncomplicated, direct access to our highly qualified, interdisciplinary research team and cutting-edge laboratory equipment ensure you get the right results.

Technology transfer in contract research

Our most common type of cooperation with industry is contract research for individual companies. For example, a Fraunhofer IZM customer might seek our help in launching a product innovation, improving a workflow, or qualifying and certifying a process. Together with the customer, we begin by broadly sketching out viable solutions and the possible parameters of cooperation with Fraunhofer IZM. We understand that transparency is paramount in any working relationship, so the associated expected expense and effort is addressed at the very beginning. Many a successful cooperation project has been kicked off with a preliminary and usually free-of-charge ideas workshop. Only once the main goal and the parameters of the cooperation are decided and the contracts have been concluded does Fraunhofer charge for its research and development. No surprise then that at Fraunhofer IZM the customer retains ownership of the contractually negotiated project's results, including the any patent and property rights or know-how developed by Fraunhofer IZM during the cooperation.

Pooling resources

We are also well-placed to help you achieve extremely ambitious goals. For example, large-scale development often requires pre-competitive research. In these cases, teaming up with companies and research institutes and public funding support is more effective than operating solo. Thanks to our wealth of experience and knowledge of the microelectronics industry in Germany and abroad, we can set you on the path to turning your wildest product development dream into a game-changing, commercially released innovation by helping you recruit like-minded partners from industry and research. Our institute specializes in helping industry conquer research and development challenges. The best starting point for working with the institute is contacting the Fraunhofer IZM Marketing division – we refer you to the right department, identify the scientists that can offer your project idea the most know-how and schedule technical discussions and workshops with our experts for you.

Multi-sensor system to monitor the posture, integrated into textile

COOPERATION WITH UNIVERSITIES

To effectively realize its research targets Fraunhofer IZM has formed strategic networks with universities in Germany and abroad. The following pages provide an overview of our most important cooperation projects. Close collaboration between Fraunhofer institutes and universities throughout Germany and internationally has always been a cornerstone of Fraunhofer's ongoing success. Universities bring their innovativeness and their expertise and know-how in basic research to the table, while Fraunhofer contributes excellence in applied research, outstanding technical infrastructure, continuity in human resources and long-standing experience in international projects.

Cooperation with Technische Universität Berlin
Fraunhofer IZM's close relationship with the TU Berlin's Forschungsschwerpunkt Technologien der Mikroperipherik is proof-positive of this collaborative model and dates back to the institute's very founding in 1993. In the 1990s, the institute became one of the world's leading research institutes for packaging technology.

Since 2011, the traditional double appointment of Fraunhofer IZM Director and Head of the Forschungsschwerpunkt Technologien der Mikroperipherik has been held by Professor Klaus-Dieter Lang. As of January 2017 Martin Schneider Ramelow, head of department at Fraunhofer IZM, also holds a professorship at TU Berlin. Both institutions research and develop smart system integration with a joint goal, namely to integrate components that may have been manufactured using very different technologies on or in a single carrier substrate. In pursuit of these joint goals, the Forschungsschwerpunkt, in cooperation with Fraunhofer IZM, is focusing on basic research into assembly and interconnection technology for sensors, microelectronics and micro-system technology. Key areas of research include:

- Packaging for miniaturized systems
- Material flow analyses for electronics
- Design systems

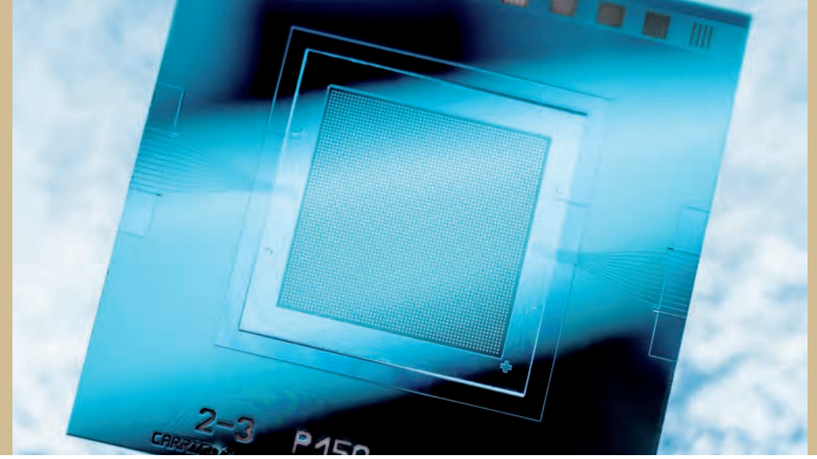
Fraunhofer IZM also supports teaching at Technische Universität Berlin by offering students additional seminars and the opportunity to participate in national and international research projects.

Fraunhofer IZM-ASSID cooperates with the Electronic Packaging Laboratory (IAVT) at TU Dresden
Within the framework of the joint Assistant Professorship between Fraunhofer IZM-ASSID and TU Dresden (Electronic Packaging Laboratory, IAVT), junior professor Iuliana Panchenko and her research group work on new materials and technologies for fine-pitch interconnects 3D/2.5D Si modules. The main research fields are a) low temperature interconnects with Cu/In microbumps, b) nanoporous interconnects based on SLID with Cu/SnAg microbumps as well as c) Cu passivation with self-assembled monolayers (SAM) for Cu/Cu bonding. Cu/In microbumps (In: approx. 2-5 µm) enable bonding below 200 °C (melting point In: 156 °C). An In plating tool for a homogenous deposition on small substrates was successfully installed at IAVT. It is planned to integrate the In plating approach into 300 mm wafer line processes in cooperation with Fraunhofer IZM-ASSID. Moreover, it is important to gain a comprehensive understanding of the material system and the occurring intermetallic compounds in order to successfully realize Cu/In bonding technology. Beside plating and bonding technologies for small substrates, IAVT also focuses on the interface characterization and material analysis for Cu/In.

Obsolescence as challenge for sustainability
The young researcher group Obsolescence is a joint project between the Center for Technology and Society and the Forschungsschwerpunkt Technologien der Mikroperipherik (both at TU Berlin) and Fraunhofer IZM. It is funded by the German Ministry of Research and Education (BMBF) as part of the key research topic socio-ecological research. As a first step the drivers in the electronic fabrication affected by obsolescence will be identified. In the second step, scenarios and measures will be developed that allow long lifetime of electronic products in terms of technology, cost, politics and societally.

The BMBF junior research group »Obsolescence«, a joint project by the TU Berlin and Fraunhofer IZM

Some of Fraunhofer IZM's other university partners
AGH University of Science and Technology, Krakau, Poland
Imperial College London, Great Britain
KU Leuven, Belgium
San Diego State University, United States
Technical University of Delft, The Netherlands
Technical University of Eindhoven, The Netherlands
Bologna University, Italy
Cádiz University, Spain
Tokyo University, Japan
Twente University, The Netherlands
Uppsala University, Sweden
Vienna University, Austria
University College London, Great Britain
University of New South Wales, Sydney, Australia
University of Freiburg
Brandenburg University of Technology, Cottbus
Kiel University
Friedrich-Alexander-Universität Erlangen-Nürnberg
Humboldt University, Berlin
University of Bonn
Technical University of Chemnitz
Technical University of Darmstadt
Berlin University of the Arts
Heidelberg University
Paderborn University
Potsdam University
Rostock University



INTERNATIONAL RESEARCH COOPERATIONS

A More-than-Moore (MtM) pilot line for Europe
The European project ADMONT – »Advanced Distributed Pilot Line for More-than-Moore Technologies« (ECSEL JU) provides a novel approach for innovation in all sectors. ADMONT supplies system integrators with a modular system for combining distinct technologies at wafer level while providing a vital and necessary platform for new products. This encompasses not only process technology but also design and modelling capabilities. ADMONT aims at reducing manufacturing times for base components to 75 percent and system costs to 70 percent of what can be achieved today. Within the joint project with 14 European partners, Fraunhofer IZM-ASSID focuses e.g. on approaches for the TSV-last integration for MEMS (CMUT) and OLED chips. Here, design rules for the TSV integration for these new products have been established. First tests investigating a gentle separation (stealth dicing) and die to wafer assembly of OLED chips have been successfully completed. The project started in May 2015 and runs for four years.
www.admont-project.eu

EU flagship project Human Brain
Approximately 250 researchers from 23 countries are working together trying to achieve the ambitious goal of simulating the human brain. A key strategy of the collaboration, which runs under the title Human Brain Project (HBP), is to realize so-called neuromorphic computing platforms where limits of conventional technology approaches are overcome. Fraunhofer IZM's task is to develop technologies needed to attach interconnection systems to silicon wafers and between the wafers. The institute's many years of experience in developing 3D packaging technologies is a key prerequisite for taking on this design challenge.
www.humanbrainproject.eu

CarrICool – Interposer-based 3D system solutions
Within the European project CarrICool, processes and technologies for the robust manufacturing of modular and scalable interposers using the smart implementation of sophisticated More-than-Moore components are being developed. The new techniques are advancing the System-on-Chip (SoC) and System-in-Package (SiP) evolution and are crucial to improving 3D and beyond-CMOS device integration density. The modular concept combines various microelectronic approaches e.g. interposer technologies, silicon photonics, CMOS technologies, power supply/inductors as well as thermal loss management with respect to integrated water-based cooling concepts. The project with nine European partners is funded by the EU with approx. four million euros and will end in June 2017.
www.carrICool.eu

Green Economy: highly efficient power electronics
Gallium nitride (GaN) components are suitable for a significant reduction of energy loss which arises, for example, during the charging of batteries for electric cars or when feeding solar energy into the network. Within the joint project »E2CoGaN – Energy efficient converters based on GaN-semiconductors«, partners from industry as well as several research institutions are investigating materials and circuitry that could be used as a basis for energy-efficient and cost-effective GaN power electronics. In this project, Fraunhofer IZM is developing a new embedding technology into silicon wafers for a very compact module integration.The planar module design facilitates an excellent thermal management through an efficient spreading of dissipated heat and is also well-suited for double sided cooling. E2CoGaN involves 22 partners from ten European countries.
www.e2cogan.eu

European Packaging, Assembly and Test Pilot for manufacturing of advanced system-in-package
The joint project EuroPAT-MASIP aims at establishing a competitive and future-oriented European manufacturing environment for Advanced Semiconductor- and Smart-System-Packaging & Test to strengthen Europe's position in the production of innovative and future semiconductor products. The project was mainly initiated by the Special Interest Group »SEMI integrated Packaging, Assembly, and Testing« (SiPAT). Fraunhofer IZM focuses within this project on highly integrated Fan-Out Wafer-level (FO-WLP) packaging. Here, RDL first FO-WLP – designed as ultra-thin package suitable for high-density wiring and IO counts as well as Chip-first FO-WLP with focus on the integration of MEMS components and multi-sensor integration are considered. The consortium of the European joint project consists of 12 industry partners, 13 SMEs and three R&D institutions from nine European countries. The project started in 2017 and runs for three years.
https://goo.gl/DUxGrz

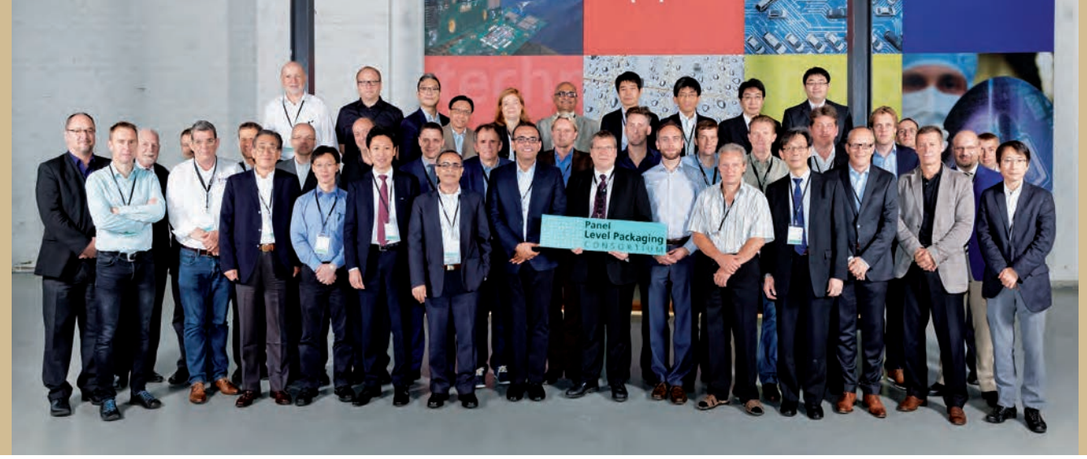
Long-standing cooperation with the University of Utah
Fraunhofer IZM has been closely cooperating with the University of Utah in various projects concerning the miniaturization of neural prostheses (brain-computer interfaces - BCI) since 2005. Based on two projects on neural prostheses, where Fraunhofer IZM was responsible for the integration of wireless communication among the BCI modules, the scope of the cooperation was broadened to include work on long-term stable neural implants, optical stimulation (»optogenetics«) and micro-integration of complex signal processors. These transatlantic research projects also allow Fraunhofer IZM to support US-companies in the field of neural prostheses by strengthening their technological portfolio for commercial products.

CloseWEEE – closing cycles
As a member of the joint European CloseWEEE project, Fraunhofer IZM is reaching out to the recycling industry and the manufacturers of plastics and electronics for a four-year co-operation. Its intention is to close the remaining gaps in the recycling of device batteries and to develop a coherent technology and process chain that reintegrates PC and ABS plastics as critical resources in new products. The international partners in this and other projects include Gaiker and Tecnalia from Spain as well as Philips. Fraunhofer IZM supports CloseWEEE by developing an information platform for recyclers, advising on questions regarding product design, and coordinating the overall project.

Cooperation with the University of Tokyo
The long-standing cooperation with Professor Tadatomo Suga and his microsystem integration and packaging laboratory at the University of Tokyo is still going strong. The partners co-operate to identify basic research needs and combine their technological know-how to deal with industry commissions.

Fraunhofer IZM-ASSID joins DRESDEN-concept
Fraunhofer IZM-ASSID has recently become a member of the network DRESDEN-concept. The total number of 24 partners from culture and science includes no fewer than seven Dresden-based Fraunhofer Institutes. The cooperation within the network aims at enabling the partners to develop and exploit synergies in the fields of research, education, infrastructure, administration and transfer.

Self-alignment on silicon interposer using mechanical stops in the CarrICool project



INDUSTRY CONSORTIUM FOR FUTURE PRODUCTION TECHNOLOGIES

From fan-out wafer to panel-level packaging
Fan-Out Wafer Level Packaging (FOWLP) is one of the most innovative packaging trends in microelectronics, with exceptional potential for miniaturizing both package volumes and thickness combined with higher performance.

The FOWLP technology is based on a reconfigured, molded wafer with embedded chips and a thin film redistribution layer to form a complete SMD-compatible package.

Advantages of FOWLP:

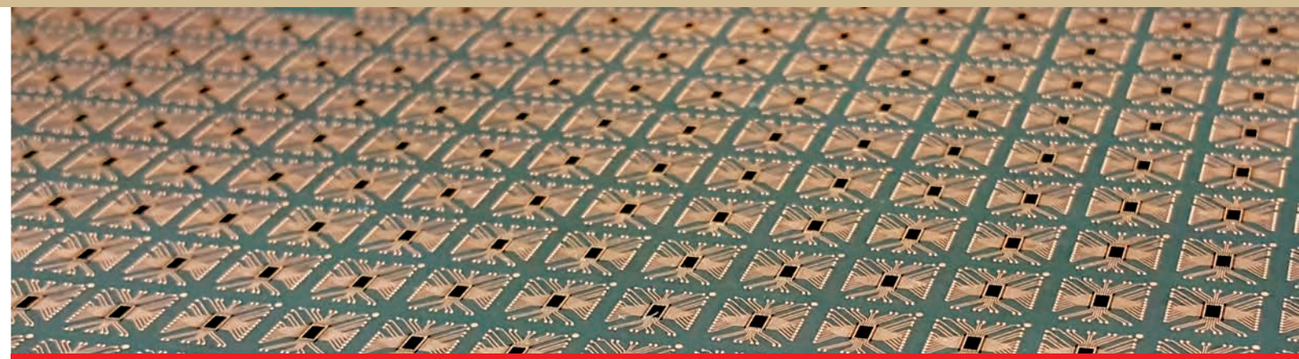
- Exceptionally thin package requiring no substrate
- Low thermal resistance
- Excellent RF performance achieved by short and planar connections with bump-less chip connections instead of e.g. wirebonds or soldered contacts
- Substantial reduction of inductance compared to FC-BGA packages
- Optional integration of functional components like capacitors, resistors, inductors, or antennas in the redistribution layer
- Design of multi-chip packages and systems-in-package (SiP)

Higher productivity can be achieved and packaging costs can be brought down by the current trend to move from wafer to panel formats, scaling FOWLP up to Fan-out Panel Level Packaging (FOPLP). Common panel sizes can reach 610 x 457 mm² (24 x 18 inch standard in PCB production) or larger.

Going beyond its intensive and productive work in publicly funded projects and direct cooperation with industry partners, the Fraunhofer IZM has set up a global industry consortium to take Fan-Out Panel Level Packaging to the next stage in its evolution by reaching out to partners along the entire value chain, including end users and OSATs (Outsourced Semiconductor Assembly and Test). Sixteen high-profile enterprises from the United States, Japan, Taiwan, and Europe have already joined as full members with extensive participation rights or supply chain members actively working on production technology and materials application.

With Fraunhofer IZM as the development hub in Berlin, the consortium is committed to powering the transition to a new global production standard.

The founding members of the Panel Level Packaging Consortium at their first meeting in Berlin on June 28, 2016

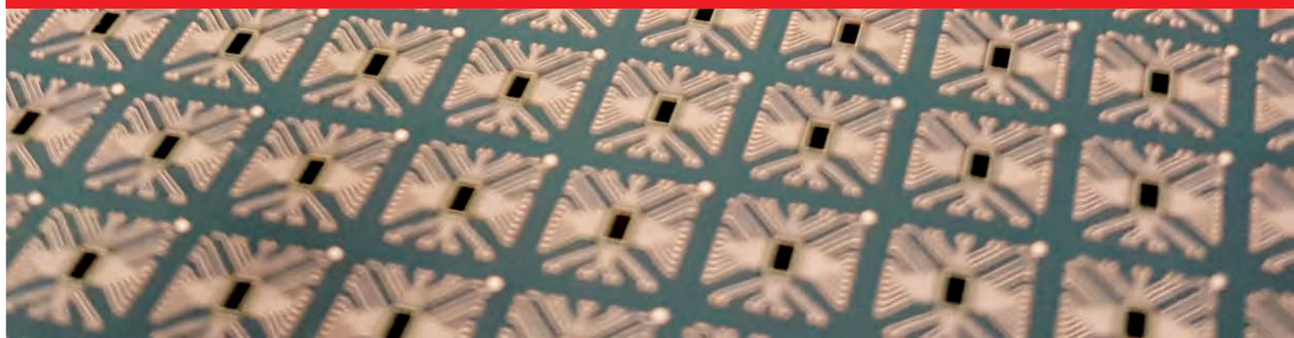


Members of the Consortium
Full Members:

- ASM Pacific Technology Ltd.
- Austria Technologie & Systemtechnik AG
- Brewer Science, Inc.
- Evatec AG
- Hitachi Chemical Company, Ltd.
- Intel Corporation
- Merck KGaA
- Nanium, S.A.
- Semsysco GmbH
- Unimicron Technology Corp.

Supply Chain Members:

- Ajinomoto Group
- Atotech Deutschland GmbH
- FUJIFILM Electronic Materials U.S.A.
- Mitsui Chemicals Tohcello
- ShinEtsu Chemical
- Süss MicroTec AG



BUSINESS UNITS & COOPERATION

// INVISIBLE, INDISPENSIBLE – FRAUNHOFER IZM'S TECHNOLOGIES AT WORK

Marketing & Business Development

Complex project initiatives move across the boundaries of disciplines and competences. They benefit from the business expertise of Fraunhofer IZM's Marketing & Business Development department that represents the industry's specific needs in all functional areas of the institute and coordinates the work on innovative solutions. We are here to assist you in the strategic development of new areas with complex and ground-breaking technologies.

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AUTOMOTIVE / TRANSPORTATION

On the go safely, reliably and comfortably

Modern traffic systems have to be safe, environmentally friendly and cost-efficient. High-performance, reliable and, in some cases, highly miniaturized systems are key goals for developers creating innovative forms of transport and traffic systems for road, rail, sea and air.

Transportation has been a key priority and competence area across Fraunhofer IZM departments since the institute's very beginning. The institute helps OEMs, Tier1 companies and particularly their suppliers integrate the latest electronics into vehicles quickly and efficiently. We develop future-proof, reliable solutions, including prototypes, which improve the safety and comfort of conventional, hybrid and electric engines and systems. Our portfolio covers every type of transportation, be it niche market or mainstream power horse – we even develop technology for the comparatively small lot sizes and specialized parameters of the rail industry.

In aeronautics, our research and development meets the industry's stringent safety and reliability requirements and finds new solutions for integrating advanced technology into comparatively limited build space and weight. We also bring cutting-edge technology to the shipping industry by packaging the latest technology advances into solutions that operate reliably in harsh maritime conditions.

Fraunhofer IZM is the right address for all stages of development, from the initial idea, to the start of manufacturing, through to ensuring availability after commercial release.

Pixelated LED light source for front headlights

The companies Daimler, HELLA, Hueck & Co., Osram, Osram Opto Semiconductors and Infineon Technologies, together with the Fraunhofer institutes IZM und IAF, have developed an active matrix LED light source. The collaboration was made possible by the BMBF (German Federal Ministry of Education and Research) project µAFS (grant number: 13N12512).

Fraunhofer IZM worked together with Osram Opto Semiconductors, Infineon and to produce an innovative LED chip. Here, LED arrays with 1,024 pixels were mounted onto an active driver capable of controlling each pixel individually. The size of this LED chip component is about that of a finger nail. The combination of three such LED-components allows a resolution of 3,072 pixel per headlight.

The development was tested using two different approaches: thermocompression bonding using nanoporous gold and reflow soldering using highly reliable gold-tin. Both assembly techniques were applied successfully with high yield and facilitated a robust interface for subsequent LED processes. The headlight was integrated into a test vehicle and presented at a press conference held to mark the completion of the project.

Services:
We provide the following services for the automotive and transportation sector:

- Power electronics
- Sensor and actuator technology
- Reliability management and assurance
- Robust design

3D flip-chip-assembly chip-to-wafer by AuSn soldering or thermocompression bonding with naporous gold for pixelated LED light sources

MEDICAL ENGINEERING

Higher performance and smaller, finer geometries!

Over the past years, the innovation potential of microelectronics has led to considerable progress in medical technology.

- Pain therapies are no longer solely based on medication, but are carried out carefully and effectively with neuro-stimulators
- Bean-sized pacemakers can be inserted minimally invasive at the place of stimulation
- Therapies against depression and high blood pressure use smallest electro-stimulators to alleviate the illnesses

Many of the innovations that have improved the lives of patients are the result of advances in microintegration technology. Diagnostics is another area that greatly benefits from such progress. The healing of chronic wounds can be monitored online; small micro cameras which can be swallowed like a pill as well as state-of-the-art CT scanners would not have been possible without miniaturization of sensors and electronics.

Fraunhofer IZM has been front and center in this development process for 20 years. Our know-how in microtechnology and innovative integration processes helps manufacturers realize innovative new medical engineering products, that meet all legal requirements. With the Medical Engineering business unit manufacturers and research partners have a one-stop contact for all of Fraunhofer IZM's services in this area, which allows them to select a technology that is precisely tailored to their individual requirements. Of course, Fraunhofer IZM also performs customized reliability analyses, bio-compatibility assessments, as well as the risk assessment according to ISO 14971 standards, which is required for the development of new products. All these services are based on an understanding of the relevant processes, materials and application-specific failures. Often simulation models that draw on this background data are also used.

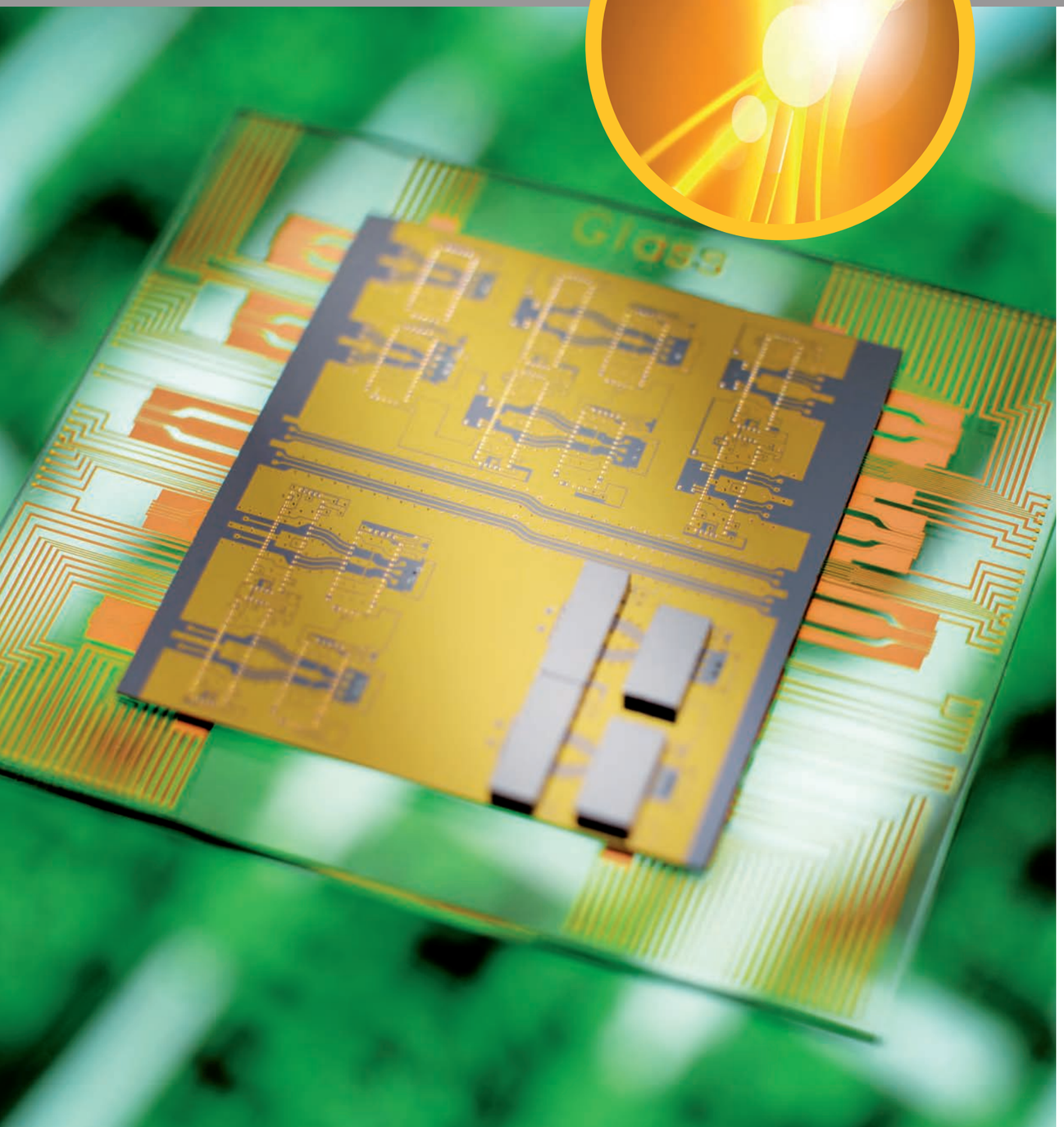
Project examples in medicine

Fraunhofer IZM works both on public projects and within bi- and trilateral collaborations with medical engineering partners from Europe and further afield. Within the European ECSEL project InForMed, for example, the chip-in-tip technology for treatment and diagnostic catheters is being developed and prepared for deployment in a pilot series. Within the HORIZON 2020 project »PoC-ID,« point-of-care diagnostics, which uses microfluidic platforms and optical technologies, as well as nanoscale sensors, helps carry out routine diagnostics at the patient's bed. Sensors that record muscular exertions in the hand using measuring sensors integrated into textiles and actuate electronically control micropneumatics to support the user's actions (»assistive support«) are being developed within the BMBF PowerGrasp project. The aim of the project is to support users with limitations in their gripping ability with an active glove – Fraunhofer IZM is contributing its experience in textile-integrated electronics and miniaturization to the development of the system's actuation. An e-textile-based intelligent knee-brace to facilitate the rehab process was developed in the MOTEX project. Even with fast movements the knee brace measures the knee's angle in real-time. The data can be visualized in a training app that guides the patient through rehab exercises.

Services:

- Packaging and reliability analyses for miniaturized medical devices/implants
- Lab-on-substrate for patient-oriented laboratory diagnostics
- Improved functionalities for smart prostheses
- Wearables for medical use
- Textile- and structure-integrated electronics functionalities to support the digitization process in every field of medical diagnostics and treatment

Knee brace with textile stretch sensor



PHOTONICS

Photonic systems for greater versatility

Phototonics have established themselves as an essential pillar of modern and efficient lighting, ultra-high-speed data transmission and processing, and modern sensor technology for environmental, traffic, industrial, and medical applications. Fraunhofer IZM possesses substantial expertise covering packaging and interconnection solutions for photonic and optoelectronic systems, including their miniaturization and reliability in diverse practical applications.

The integration of electronics for control and signal processing functions facilitates a close interaction of different semiconductor technologies and calls for new packaging and interconnection technologies in order to meet the electrical and thermal requirements as well as securing the optical functionality. This is particularly the case with imaging and display applications with high pressure for miniaturization and resulting high power densities, such as adaptive lighting with high resolution headlights.

Services:

- Development of assembly and interconnection technologies for system integration of micro-electronic and photonic components
- Demonstration and prototyping
- Simulation, design, and test (optical, electrical, thermal
- and mechanical)
- Qualification, failure, and reliability analyses

Photonic interconnects for data centers

Modern data centers face increasingly challenging operating conditions in terms of the expected capacities, speeds, and costs. Mastering these challenges needs the integration of photonic interconnects in their communication technology.

Encouraged by recent successes in the development of new photonic interconnect technologies and data center architectures, Fraunhofer IZM is committed to unifying the many strands of innovation in optical system solutions into improved and holistic photonic technologies.

In the flagship PhoxTroT project, Fraunhofer IZM and its 20 partners from across Europe have broken new ground with novel photonic solutions for data centers and signal transmission via a single light path. This makes the technology a perfect fit for handling the extreme data rates that are common in data centers.

The L3Matrix project builds on this with its development of a switching matrix using silicon photonics (SiP) and an integrated laser with more than 100 modulators and ASIC. The technology is powerful enough to overcome current latency and bandwidth limits.

The independent photonics platform PhoxLab will record recent progress in the field for the future and help visualize and benchmark photonic components and solutions.

Photonic 3D interposer with electronic and optical add-ons assembled on a glass substrate

INDUSTRIAL ELECTRONICS

Industrial Electronics – safe and reliable!

In recent years Fraunhofer IZM's industrial electronics specialists have concentrated on the visionary concept of Industrie 4.0. Particular emphasis was placed on the work on cyber physical systems (CPS) and autonomous, specifically high-reliability radio sensors that record and process the relevant monitoring and/or video data on site and distribute it via standard interfaces when and where the user needs it. Industrie 4.0 means much more than CPS integration: »The future brings the intelligent collection, recording, and distribution of data by objects and human beings at the same time« (Fraunhofer IAO, study on »The Future of Manufacturing«).

Flexible access to monitoring data is particularly vital both for location-bound controlling and management processes and ERP systems and for on-demand access via mobile devices in inspection, maintenance, or repair scenarios. In their work, the IZM researchers remember that people will remain the first and foremost controllers and decision-makers despite the advent of intelligent new technologies.

Services:

- Design, technology development and optimization, reliability tests, and technology transfer for highly integrated modules on circuit board substrates, flex-rigid, flex, and metal or ceramic substrates
- Packaging and interconnection technology for industrial electronic products
- Integration of (active and passive) electronic components in fabrics or compound materials and embedding technology for ultra-thin systems and high-security applications (invisible electronics)
- Antenna and circuit designs for industrial electronics
- Design and prototype manufacture of autonomous multi-channel radio sensors for automation solutions

ASTROSE® - reliable, autonomous wireless sensor network

The ASTROSE® wireless sensor network for monitoring high voltage power lines has proven its real-world capabilities under harsh and rugged conditions in the pilot installation of 59 sensor nodes on a line crossing the Harz mountains. The monitoring system continues to evolve and develop further and is introducing new features and applications.

Another important milestone is the evolution of the ASTROSE® communication technology for the transmission of external user data. The system passes its data wirelessly along the power lines, forming a radio chain that does not require separate wireless infrastructure. The proprietary and fully encrypted ASTROSE® communication technology feeds the data from the field directly into the grid operator's infrastructure.

The bridge between the grid and the control systems is formed by the special ASTROSE® server and data engine, developed in the last two years. The server receives the wireless data from the radio chain and stores it efficiently in its integrated database. The client-server architecture allows users to retrieve the data that is relevant for them via the operator's established infrastructure, such as the control lines used to manage power transmission in the grid.

The ASTROSE® communication technology is constantly being developed further and tested for its potential for other applications, such as the transmission of local weather data. Further research and development projects are being prepared to test the technology's applicability in other critical closed IT-infrastructures.

Energy-autarkic sensor system for monitoring the pitch of overhead power lines

ENERGY

The key to reduced energy and resource consumption

Power electronics is the technology for developing intelligent and flexible power supplies and controls for the many different applications that use electricity. Switching power supplies, electric drives in road and rail vehicles, and large industrial drives have to function as efficiently as possible to conserve our natural resources. Using power electronics, energy from renewable sources can be processed into a form suitable for the existing electrical grid.

Fraunhofer IZM develops these innovative and reliable power electronic systems. We research the possibilities opened up by the new semiconductor materials silicon carbide (SiC) and gallium nitride. The materials require higher temperatures of up to 250 °C, which has to be factored into the packaging design. Thanks to their properties, SiC semiconductors are almost perfect switches. High switching speeds combined with parasitic capacitances and inductances within the package and at the component connections create unwanted oscillation that can hamper chip function. However, EMC-optimized package design can help reduce losses and keep interference to a minimum. A good connection to the installation environment is also important.

We have the skills and know-how required at every stage of the development chain, from system design, to packaging, thermal management, electromagnetic compatibility, through to reliability and damage analysis.

Services:

- Miniaturization and system integration
- Thermal Management
- Electromagnetic compatibility
- Reliability
- Innovative packaging technologies
- Complete systems, prototypes

System development for fast-switching semiconductors

With the high current increase rates of silicon carbide or gallium nitride semiconductors switching frequencies of a power converter circuit can be increased dramatically. Due to the parasitic inductivities caused the module structure this can lead to considerable surges in voltage when switching off. This can have a destructive effect on the chip and lead to additional oscillations that dramatically increase switching losses. As part of various projects, Fraunhofer IZM is doing research into a holistic solution: Manufacturing technology; electrical, thermal, and mechanical layout; EMC issues, and the optimum driving of fast-switching semiconductors are the focuses of the investigations. This is all carried out within circuit board technology and, depending on the power class, with or without DCB (direct bonded copper substrate).

The projects »Very Fast Switching« (VFS, which is ECPE-funded), »High-frequency, High-current Components for Use in Medical Engineering and Photovoltaic Inverters in the MW Class« (HHK, funded by the Federal Ministry of Education and Research (BMBF)), and »Smart Photovoltaic Inverter Box« (Smart-PVI-Box, BMBF-funded) concentrate first and foremost on the actual packaging, the material development and analysis, and the investigation into how powerful SiC and GaN semiconductors really are. Switching frequencies of up to 250 kHz have been implemented thus far. The optimization of the driver was investigated in the ECPE-funded project »Advanced Driver.« The high and low side of a half bridge are (actuated) driven without dead time. This prevents the parasitic body diode of the SiC MOSFET being flooded with charge carriers, meaning that no reverse recovery losses arise. The energy supply to the driver board itself is capacitive. Furthermore, the overall power loss was reduced by recuperating the energy from the charge reversal of the gates using a transformer integrated into the circuit board.

Inside view (model) of a 90A embedded power module (HHK-Project)

SEMICONDUCTORS & SENSORS

Wafer level 3D integration and sensor manufacturing

This business unit has a focus on the integration and development of new sensors. Besides that 3D integration allows the realization of complex, heterogeneous system-in-package (SiP) solutions. The decisive advantages offered by such a 3D system setup can be summarized as follows:

- High degree of miniaturization and improved shape factor
- Improved performance and increased energy efficiency due to higher signal rates as well as greater bandwidths due to much shorter lines
- Multifunctionality due to the heterogeneous integration of components from various manufacturing technologies (sensor, storage, ASIC, and transceiver)
- System partitioning
- Faster product realization (time to market)
- Reduced cost due to parallelization of setup technologies
- Increased reliability due to new sensor concepts

Fraunhofer IZM offers its customers a closed implementation chain – from concept, process development, and characterization to reliability validation and prototyping of new sensors, hermetic sensor packages, and 3D systems. All processes necessary to the realization of sensors and wafer-level packages are available, including the formation of through-silicon vias (TSVs).

To match the various customer needs, new sensors and 3D systems such as image sensors, sensor nodes, eGrains, etc., are set up and characterized for different application cases. Fraunhofer IZM – in close cooperation with manufacturers of equipment and materials – is working on continuous improvement of technologies.

Sensor development at Fraunhofer IZM

SOI-based high-temperature pressure sensoring

Industry's demand for pressure sensors for use in tough ambient conditions has been growing dramatically for the last few years. For engine applications (e.g. inlet and outlet pressure measurement), the focus is on factors such as the high deployment temperature, the measuring dynamics, and resistance to the many media that need to be measured. Applications in the plastics processing industry (e.g. for reactive injection molding and extrusion or nozzle pressure) require, in addition to high operating temperatures, a particularly robust steel membrane for measuring viscous, abrasive, and aggressive media. Certain metrological problems (e.g. in the areas of mechanical engineering, motor vehicles, plastics processing, deep drilling tests, combustion pressure measurement) require pressure sensors with an operating temperature range of over 300 °C. The aforementioned Si pressure sensors are not suitable for such »high-temperature« applications (max. operating temperature approx. 120 °C) due to the pn isolation of the piezoresistors (this also applies to the four-terminal gauge). For this reason, Fraunhofer IZM has developed piezoresistive SOI silicon pressure sensors where the piezoresistors are isolated from the substrate with a SiO_2 layer. The piezoresistors are made of mono- or polycrystalline silicon. In the first case, SOI wafers are the starting material. These wafers are manufactured using the SIMOX (Separation by IMplanted Oxygen) technique, the BESOI (Bond-and-Etch-back SOI) process or the SmartCut process.

Services:

- TSV formation in CMOS wafers (via-middle, via-last)
- Reverse-side contacting (BS via-last) for sensors
- Silicon and glass interposers
- 3D assembly (die-to-wafer, wafer-to-wafer)
- 3D integration of optical connectors
- Hybrid 3D pixel detector modules
- Hermetically sealed MEMS packages with TSVs
- Material and equipment evaluation and qualification
- Prototype manufacture and pilot series
- Pressure sensors

Starts on
Sept. 22, 2017

MODULAR DEVELOPMENT AND PRODUCTION LAB »START A FACTORY«

On March 1, 2017, Fraunhofer IZM inaugurated its innovative, modular development and production lab »Start a Factory«. Located in the vintage industrial surroundings of Hall 16 on Gustav-Meyer-Allee 25 - in immediate proximity to the institute's presentation and conference venues - the new laboratory facilities are intended for small enterprises and start-ups dedicated to miniature electronics and sensor technology. »Start a Factory« combines two special components: a modular and flexibly equipped development lab and the production lab for making product samples and prototypes.

In an immediate visual break from the traditional laboratory facilities of the institute, the »Start a Factory« lab forms a separate unit in refurbished shipping containers. Located within Hall 16, the containers create a distinct, but accessible venue for the project partners and users. They give them a unique opportunity for cooperative work on development projects, with Fraunhofer IZM's experts taking over only those specialized activities as part of »Start a Factory« that the companies could not cover themselves. The approach removes the need for a time and labor-intensive handover of the project's output and developments.

The containers are equipped to match the needs and purposes of each development project. The basic configuration was chosen with the needs of the institute's focus areas in information and communication, photonics, and power electronics in mind. The mission of »Start a Factory« is to assist promising enterprises in these areas and help them develop into pioneering technology beacons for Germany and beyond.

»Start a Factory« is far more than a place for cooperative product development. It is a world-first in that it brings all steps in the process together in a single place, from the development of an idea into a viable product design and the production of samples and prototypes for testing to the finished product. One unique feature is the direct integration of product development and prototyping. Mounting technology facilities for prototype construction stand at the heart of the lab, equipped to assemble even miniature components with state-of-the-art interconnection technology. The system integrates testing and inspection equipment that would not be viable for small-scale production of this nature under normal commercial conditions. Cutting-edge 3D printers are on hand to finish the products with suitable and appealing cases to match the chosen applications.

The system makes for an extremely fast transition from initial designs to real-life samples and prototypes that can be used for field tests or pitches with potential investors. After a prototype has been developed, the developers can immediately start pilot production, as particular attention is paid to keeping designs immediately scalable for industry-ready manufacturing conditions. This avoids the need to redesign products for later full-scale production. The process also considers the technical and logistical requirements of the manufacturers and service providers in Berlin.

»Start a Factory« helps small enterprises and start-ups make the leap from idea to full-scale production: It has the potential to reduce the time to market with a fully scalable solution from months to weeks. The concept is the direct result of Berlin's rise to becoming the start-up capital of Europe. Start-ups will not be the only ones to benefit from the new opportunities: All actors in the scene can enjoy its great potential. Software-oriented start-up incubators will be able to expand their reach considerably by partnering with »Start a Factory«. They can enable the start-ups they have taken under their wings to build and test real prototypes. The makers of production facilities and machines can showcase their offerings in realistic manufacturing conditions, simulating an active production process. Electronics manufacturers can use the labs to test novel production processes and take back fully validated process configurations to their own production lines. New processes can be readied for real-world use without the risk of downtimes or stoppages.

With the »Start a Factory« lab, Fraunhofer IZM is becoming a backbone of Berlin's inventor and entrepreneur community.

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FRAUNHOFER IZM LABS & SERVICE

Wafer-Level-Packaging-Linie
Fraunhofer IZM operates two process lines in Berlin (975 m²) and Dresden (ASSID, 1000 m², ISO 9001) that offer our customers various wafer-level packaging services, e.g. CSP, interposer, thin film substrates as well as system in package approaches from development stage to prototyping and small volume production. Different substrate materials (e.g. silicon, A III/B V, ceramic and glass) can be processed. The cleanrooms are class 10 to 1000 and can handle wafer sizes of 4", 6" and especially 8" (200 mm) as well as 12" (300 mm).

Process Modules:
- Cu-TSV integration (via-middle-, via-last-, backside-via process)
- Silicon plasma etching – DRIE (TSV, cavities)
- Thin-film deposition (sputter, CVD)
- Photolithography (incl. photo resists, polymers)
- High-density thin-film-multilayer (Cu-RDL)
- Wafer level bumping (Cu-Pillar, SnAg, Ni, Au, In, AuSn)
- Wet-chemical processes (etching, cleaning)
- Wafer thinning und thin wafer dicing (blade & stealth)
- Wafer bonding – permanent
- Wafer bonding – temporary (support wafer, thin-wafer handling)
- Wafer level assembly (D2W)
- AOI, metrology

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PCB Prototyping Process Line
The new prototyping and process line can handle substrates with a maximum size of 610 mm x 456 mm and features:
- High-precision component placement
- Vacuum lamination press for multilayer fabrication and component embedding
- UV laser drilling and structuring
- Mechanical drilling and milling
- Photolithographic patterning using laser direct imaging and dry-film photo resist
- Horizontal spray development of ultra-fine line structures
- Horizontal spray etching and photoresist stripping
- Automatic and manually operated galvanic equipment

The technology can be easily transferred to conventional industrial manufacturing environments.

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Micro Battery Lab
The laboratory is fully equipped for the fabrication and coating of battery electrodes and for the electrochemical characterization of battery systems. There is a 10-meter battery development and assembly line, capable of producing miniature, custom-designed micro batteries with unparalleled precision. The batteries can either be assembled on a common substrate (up to 200 mm) or individually (reel-to-reel). Further high-purity gas containment units are available for alternative electro-chemical systems as well as ionic fluids.

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Electronics Condition Monitoring Laboratory (ECM)
ECM specializes in function tests on electronic systems under environmental stress beyond purely thermomechanical strain. Combined testing processes are employed, such as vibration combined with humidity and/or temperature. The component's condition is determined precisely during testing using degradation-dependant parameters and by recording the stresses. The resulting data are compared with failure models and used for the design and testing of monitoring structures and to assemble condition indicators.

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Qualification and Test Center (QPZ) for Electronic Components
The Qualification and Test Center focuses on application-specific qualification of new solder alloys and packaging solutions for electronic components on a wide variety of substrates. All tests are carried out according to DIN EM, IEC, IPC and MIL standards. Component inspections and failure analyses after testing include the investigation of structural alteration, intermetallic phase growth, crack propagation using metallography, SEM/EDX analysis or focused ion beam (FIB) preparation. QPZ is now offering online, optical failure analysis based on the IPC-A-610 standard. The new service provides companies that experience component failure during manufacturing or shortly after deployment in the field with fast, sound advice on the component problem and its possible cause.

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Laboratory for Textile-integrated Electronics
Fraunhofer IZM's TexLab researches and develops new interconnection technologies for stretchable and textile substrates. The demands concerning functionality and system reliability are always determined by the designated application. With its extensive assembly and analytics equipment from the realm of microelectronics the TexLab is excellently equipped for advanced R&D activities.

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Assembly Lab
In this Lab we have advanced equipment for automatic flip chip and die bonding and for assembly at wafer level. Placement of components is possible from 300 mm wafers to 300 mm wafers for 3D integration. Preferable joining methods are pick & place followed by reflow soldering, thermocompression and thermosonic flip chip bonding. In photonics we mainly focus on 1 µm bond accuracy using AuSn solder. For sensor applications we work on low temperature bonding technology based on indium or on nanoporous gold NPG (gold nanosponge). In power electronics main activities are related to embedding of components into thick silicon interposer (eSI) and transient liquid phase bonding TLPB. Specialties are membrane bonding, atmospheric plasma surface preparation, mechanical stud bumping for single chip prototyping.

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Further laboratories include:
- Flip Chip Line
- Die and Wire Bonding Center
- Thermo-mechanical Reliability Lab
- Photonics Lab

Innovation Center AdaptSys

AdaptSys – the Center for »Multifunctional Microelectronics for Innovative Micro- and Nano-Integration Technology in the Development of Application-Oriented Systems« at Fraunhofer IZM in Berlin, funded by the European Union, the Land Berlin, the BMBF and the Fraunhofer-Gesellschaft fosters the development of highly complex electronic systems for different areas of application. Furthermore, system integration technologies can be evaluated down to the nanometer scale.

SYSTEM INTEGRATION

Substrate Line

In the substrate area panel-size substrates with a size of 460 x 610 mm² can be prepared for resist and PCB lamination, solder resist and cover lays can be applied and developed after exposure. In our bonding lab high-precision module assembly is carried out under inert gas. New equipment in the 480 m² cleanroom allows surface preparation for assembly at reduced bonding temperatures.

Our services include:

- Embedding of passive and active components
- Multilayer lamination of PCBs substrates
- Realization of smallest vias, mechanically as well as with a laser
- Quality assessment and X-ray microscopical analysis

Wire Bonding Lab

- Processing of Au-, Al- and Cu-based bonding wire materials for thin and heavy wire bonding
- Assembly of power modules using Al/Cu- and Cu-heavy wires for quality and reliability analyses
- Assembly of sensor packages using Cu-ball/wedge bonding for lead frames and Au/AlSi1 wires for chip-on-board (COB) processes

Soldering Lab

- Vapor phase soldering in combination with vacuum enables the manufacturing of void less large area solder joints for power electronics
- Fluxless soldering of printed circuit assemblies (PCA) using active gas in oxygen free Nitrogen or vapor phase atmosphere
- Hermeticity test
- Leak testing including Helium bombing up to a pressure of 10 bar

Photonics Lab

- Laser structuring of glass layers with optical waveguides for electro-optical boards (EOCB)
- Shack-Hartmann-characterization of micro lenses and micro lense arrays
- Optical and thermal characterization of LEDs and LDs
- Research and development of optical packaging processes with an accuracy of up to 0.5 µm

Mold Encapsulation Lab

The mold encapsulation lab offers various encapsulation processes, related material and package analysis and reliability characterization tools as a one-stop-shop.

- Compression molding on module-, panel- and wafer-level
- Compatibility to PCB-based and thin film RDL application
- 3D-redistribution by through mold vias (TMV)
- Transfer molding of leadframe-based SiPs and of SiPs organic substrates (MAP molding)
- Rapid tooling for feasibility studies with real live prototypes
- Transfer molding of large volume packages
- Rheological assessment of mold compounds
- Sensor packages with exposed sensor areas by film molding

Transfer to industrial production is guaranteed due to use of production equipment.

MATERIAL ANALYSIS

AdaptSys has considerably enhanced Fraunhofer IZM's material analysis competences in the micro-nano transient area. A »PicoIndenter« allows the in-situ emperimental REM investigation of the microscopic material behavior. Focused Ion Beam technology (FIB) enables high-resolution structural analyses on the nanometer-scale of 3D packages. EBSD-EDX micro analysis software facilitates a deeper understanding of compound materials' structure-property correlation. A high resolution EDX-detector with 80 mm² provides fast processing of element analyses.

Moisture Lab

- Comprehensive simulation-based reliability assessment of humidity-induced phenomena in micro-electronic components and systems
- Evaluation of surface properties and thin layers through REM, especially under the influence of water with JPK's »NanoWizard 3« Bio-AFM
- Analysis methods for sorption, permeation and diffusion of water in materials
- Investigation of humidity-induced swelling behavior and the change in thermo-mechanical and dielectric properties
- Molecular-dynamic simulation

Long-term Testing and Reliability Lab

- Fast temperature cycling tests in the range from -65 °C to 300 °C
- Temperature storage up to 350 °C

Power Lab

- Characterization of power modules and power electronic devices
- Active cycling of power modules for lifetime assessment
- Calorimetric measurement of the effectiveness of highly efficient devices

DESIGN

Advanced System Engineering Lab

- Measuring station up to 50 GHz for antennas and antenna systems
- RF Lab
- Dielectric material characterization 1 MHz up to 170 GHz
- Measuring electrical properties of digital data transfer systems (up to 32 Gbit/s)
- Localising EMC-hot spots with near field probe up to 6 GHz
- Investigation of RF-properties of active and passive systems (impedance up to 3 GHz / S-parameter measurement up to 220 GHz)

High Frequency Lab

- Electric and functional characterization of assembly technology and electronic modules for applications down into millimeter wave bands
- Free-space measuring station for up to 170 GHz
- Temperature-controlled on-wafer stations for the measurement of miniaturized structures and assemblies
- Automated measuring station for the characterization of integrated antennae up to 50 GHz

Microelectronics Lab

- Development and qualification of mechatronics systems and energy-efficient wireless sensor systems
- PXA for range calculation, conformity checks, and failure analyses; allows the recording of very fast signals (from 162 µs)
- High-performance 3D printer (Fortus 360 mc) for prototype and small-series package development (materials: ABS-M30, PC, and nylon)

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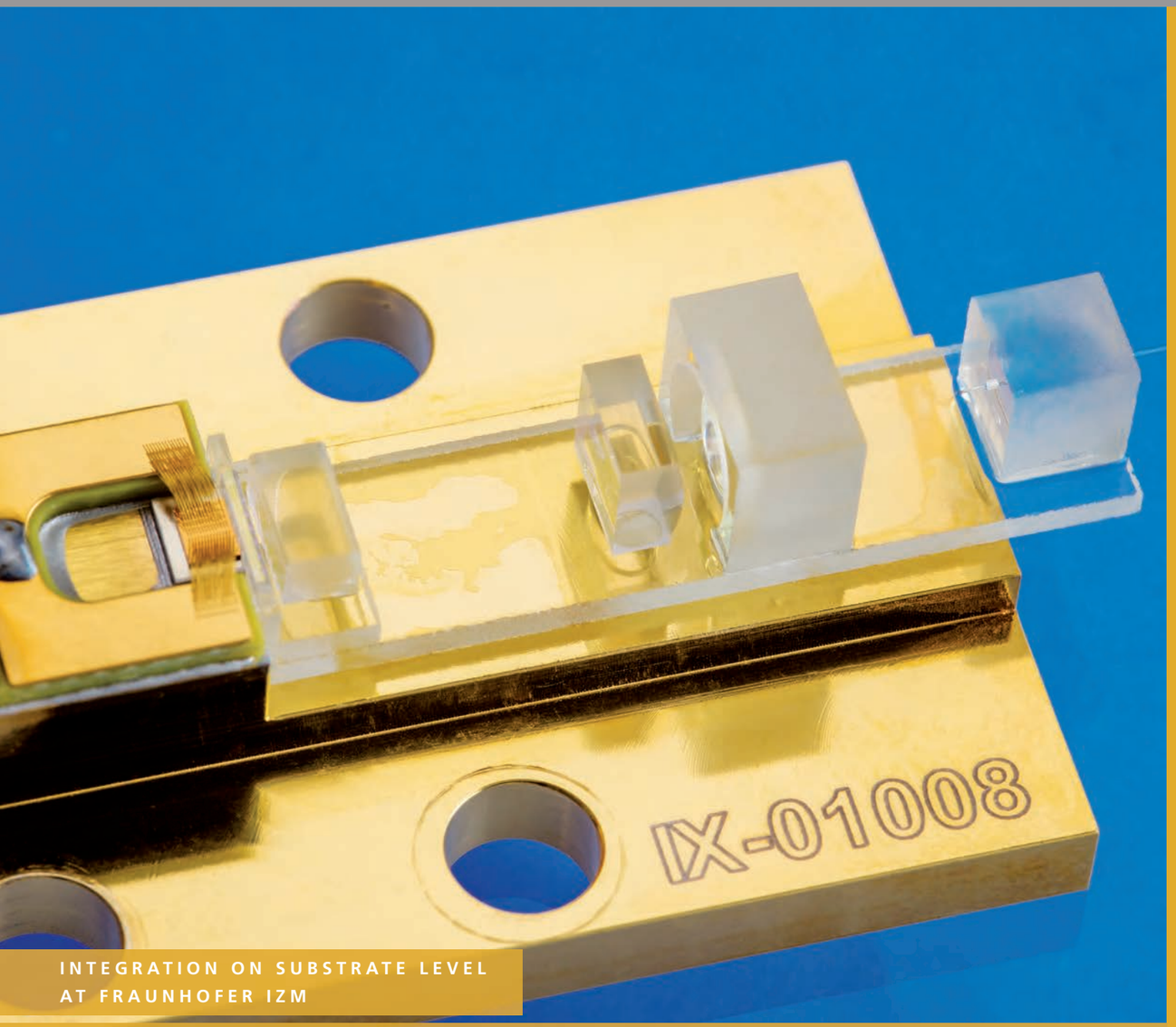
FRAUNHOFER IZM CORE COMPETENCIES





RESEARCH CLUSTER
INTEGRATION ON SUBSTRATE LEVEL



INTEGRATION ON SUBSTRATE LEVEL AT FRAUNHOFER IZM

Fraunhofer IZM works at the forefront of modern substrate technology development. The institute's unique assembly facilities combine cutting-edge assembly equipment with complete large-scale circuit board (24" x 18") production. In addition to the current development capabilities such as high-precision assembly, embedding, and high reliability encapsulation solutions, the institute is currently working on innovative panel-level-packaging (PLP) technology. PLP allows the continuous production of systems-in-packages (SiP), modules, and miniaturized systems for large-format applications. This enables Fraunhofer IZM to go beyond technology and process development and offer the direct production of prototypes, sample series and model processes for immediate application by industry partners.

HIGHLIGHT 2016

Photonic assembly: Active alignment of laser modules

Close cooperation between the Optical Interconnection Technology working group and its industrial partners Eagleyard and FISBA Photonics has led to the successful conclusion of the publicly funded ProFIT development project MEMo. The aim of the project was to develop a new type of automated assembly concept to couple a multi-emitter laser-chip module to an optical fiber with a core diameter of less than 100 µm, for example for medical applications at a wavelength of 1470 nm, and with optical powers of up to typically 10 W.

Fraunhofer IZM's main task was to develop the setup and adjustment processes of the special micro-optics needed for laser beam formation and efficient fiber coupling on the optical bench within the laser module. The processes are executed on a specially enhanced industrial active alignment machine, promising very good usability of the results. Active alignment means, on the one hand, that the laser chip is operated at full power with this laser module setup. On the other hand, during the sequential assembly of the total of four micro-optics needed for beam formation, the current adjustment status is monitored using a high-resolution infrared camera and is converted into fast, precise control signals for a fine-tuning actuator. This actuator can move and turn the lens it is holding through six degrees of spatial freedom at sub-micrometer levels of precision, or a few arc seconds, respectively, which is what is required for optical adjustment within the module.

The project also developed a setup concept in which both the micro-optic bench to be equipped, as well as the holding tools on the fine-tuning actuators, are manufactured from laser-cut stacked glass. Laser structuring available at Fraunhofer IZM makes this approach highly adaptable and quick in turn-around. Additional complex optical setups that use the thin-glass concept are being planned; there are also plans to use structured metallization to embed (opto-)electronic components directly.

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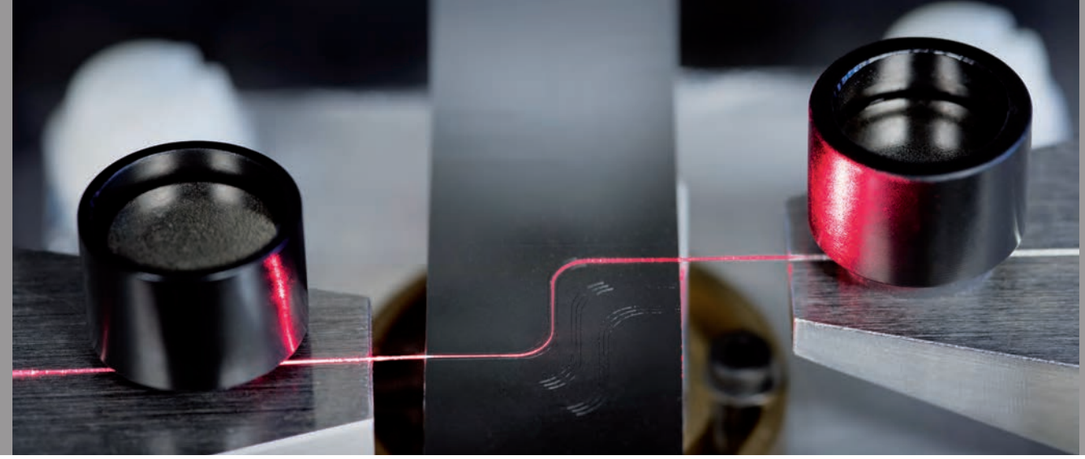
Assembly of a fiber-coupled multi-emitter laser on a hybrid bench



SYSTEM INTEGRATION & INTERCONNECTION TECHNOLOGIES

The Department

The System Integration and Interconnection Technologies (SIIT) department with its 150 scientists and technical staff offers services ranging from consulting to process development and systematic technological solutions. The department develops processes and materials for interconnection technologies on board, module and package levels, as well as for integrating electrical, optical and power-electronic components and systems.

Our focus is on interconnection and encapsulation technology for electronic and photonic packaging, including:

- New solders, adhesives, types of wire and bumps
- Bumping techniques (electroless Ni / (Pd) / Au, stencil printing, mechanical stud or ball bumping)
- SMD, CSP, BGA and µ-optic assembly
- Flip-chip techniques (soldering, sintering, adhesive joining, thermocompression and thermosonic welding)
- Die attachment (soldering, sintering and adhesive joining)
- Wire and ribbon bonding (ball / wedge, wedge / wedge, heavy wire and ribbon)
- Flip-chip underfilling and COB glob topping
- Transfer and compression molding on lead frame, PCB, wafer and panel
- Potting and conformal coating, hot-melt encapsulation
- Chip embedding
- Fiber coupling and optical interconnection to planar waveguides, fiber lenses and laser joining
- Manufacturing of optical wave guides
- Thin-glass and silicon photonic packaging
- Automation of microoptic mounting

Trends

The department meets the challenges of electronic and photonic packaging by combining system development with advanced interconnection technologies.

Our work on trends in future applications extends to:

- Design of multifunctional boards and interconnection technologies
- Panel level packaging technologies based on PCB and molding processes
- High-resolution 3D package analysis using X-ray CT
- Heterogeneous packaging of system in packages (SIPs), such as MEMS, ICs, opto, RF and passive packages, and
- 3D-SIPs with embedded components and power ICs
- Evaluation of new surface materials for low-cost assembly technologies
- High and low temperature interconnection technologies
- Expansible electronic systems on PU basis
- Development of jetting processes for high high-viscosity-materials, e. g. die attach and glob top
- Miniaturized electronics and fiber optics for modern medical diagnostic and therapeutic technologies
- Integration of ultra-thin chips in foldable flex modules, multilayer and security cards
- Alternative solder and sinter technologies for power
- module assembly
- Multifunctional (electrical, optical, fluidical) packages and substrates based on thin glass layers
- LED modules and white light conversion
- Multifunctional optical sensor systems
- Silicon photonics and microwave photonics system design

RESEARCH & DEVELOPMENT HIGHLIGHTS

PhoxTroT

Large data centers and super computers are soon to become significantly more cost-efficient, energy-efficient, and powerful. This was the ambitious aim of Fraunhofer scientists and their 20 partner teams from commerce and research within the EU's »PhoxTroT« project. The key to achieving this is optical data transmission: Over the last four years, the project partners did research into new synergies between existing approaches and developed new technologies and strategies.

Laser light propagation through a polymer waveguide structured on Si

Enormous data centers such as those operated by cloud providers are extremely energy-hungry: The average server farm, for example, constantly consumes 260 million watts in order to process mountains of data that might run into multiple petabytes. That's enough to power a city of 200,000 households. The pressure to save energy is thus considerable. This fact moved the EU to launch the PhoxTroT project, which was led by Fraunhofer IZM in Berlin. The intention of the research is to reduce energy consumption by at least 50 percent while also increasing the capacity of optical data connections from one to two terabits per second (Tb/s). That would also be enough to reduce costs noticeably.

And it is light that will show us the way: This is because data transmission using light consumes only a fraction of the energy that conventional methods need. Approaches using photonic transmission already exist, and the available technologies have already been well researched. But the leitmotif is still missing. The revolutionary thing about the PhoxTroT project is that the synergies between the individual components are being researched and linked together in a new research concept according to the »mix-and-match« principle.

By the end of the project, new technologies ought to be able to answer a previously unanswerable question: How can a continuous data connection using light be assured even within different levels of the data centers? To this end, the project partners are developing three demonstrators for different hierarchical levels:

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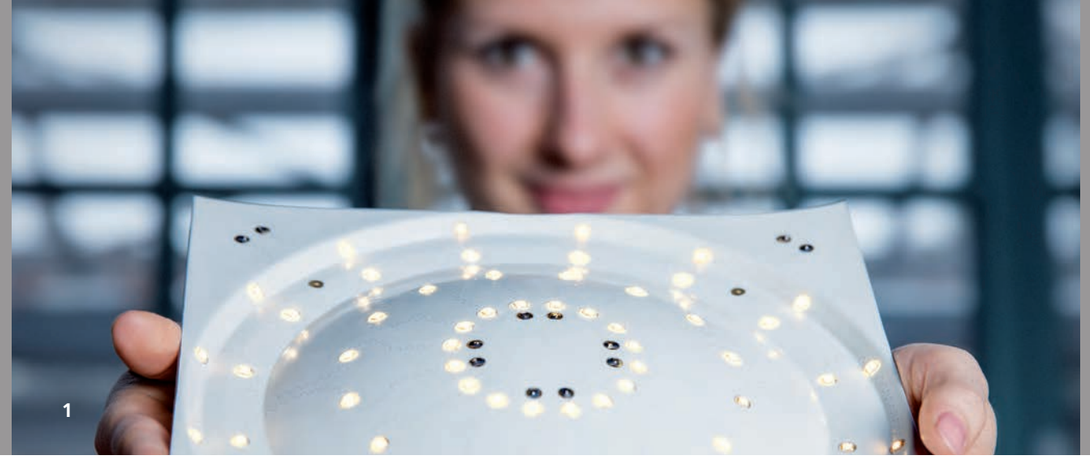

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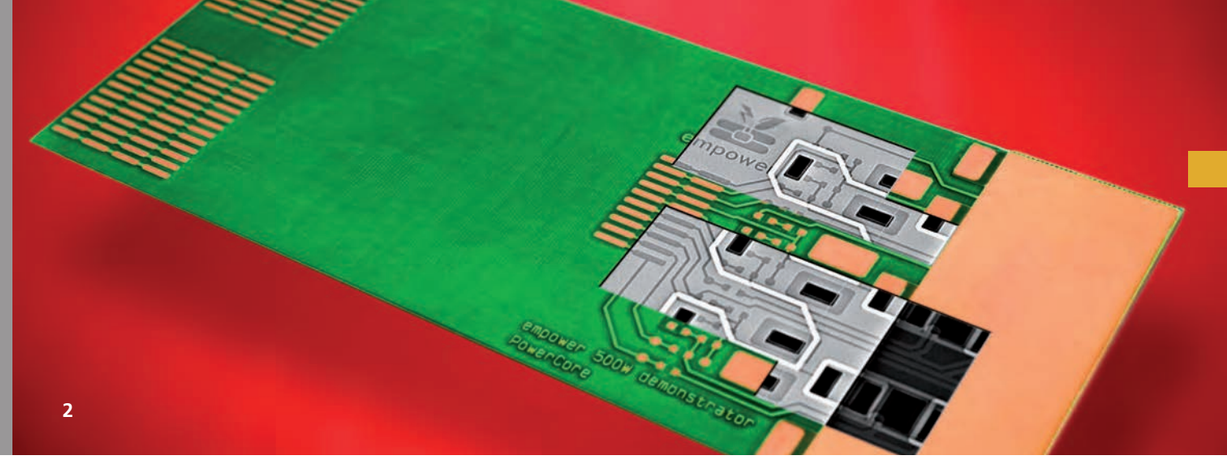

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They realized and investigated optical transmission on a printed circuit board (on-board), between boards (board-to-board), and from one server rack to the next (rack-to-rack). The combination of these interfaces will, in the near future, allow large distances to be bridged. In an additional step, the project partners developed single-mode solutions to integrate optical chips on a circuit board. Signal transmission will then be via one light path rather than several as previously. This makes this technology particularly suited to transmitting at extremely high data rates and across long distances.

Conformable electronics: new technologies for innovative products

At Fraunhofer IZM, a spectrum of technologies is bundled under the term »conformable electronics« and enhanced as a strategic »toolbox« for innovative products. The applications range from medical band aids and smart textiles to interior trims for automobiles and control panels in household appliances. The technological strategy is to apply a flat and stretchable electronic system, which is fabricated with established technologies (circuit board technology, automatic placement), to a thermoplastic carrier and then to deform the whole build-up.

The stretchable, polyurethane-based circuit boards allow stretching to up to 100 percent of the original length, or even more. After repeated stretching and contracting, fatigue fractures can occur: In the case of cyclical stretching by a few percent of the original length, tens of thousands of deflections are possible; if stretching is in the two-digit percent range, a few hundred stretching cycles are possible. If the thermoplastic matrix material used is polyurethane, it is also possible to perform a single thermoforming of the electronic system. The polyurethane film alone, however, does not offer sufficient stability to maintain the embossed form. For this reason, the stretchable circuit board is laminated onto a stabilizing polycarbonate carrier (also thermoplastic) and the two are deformed together. A system that has been fabricated in this manner can be seen in figure 1.

Modular power electronics

Miniaturization and packaging of power electronics by embedding of semiconductor switches into the build-up layers of a printed circuit board has experienced a considerable development throughout recent years. Besides commercialization and the introduction of the first products into the market, there are still a number of interesting new concepts under scientific and technological investigation.

Modular power electronics is a strategy to integrate the heterogeneous components of a more complex power system into one compact and robust module. Such modules consist – in addition to the power switches – typically of gate drivers, controllers and logic elements for measurement and control. Finally, coolers for effective heat distribution are another essential part of such a system. The requirements with respect to thermal, voltage, and current load that each system component has to withstand are, however, quite different. Therefore, each type of sub-module can be realized by an individual technologically and economically optimized embedding approach. Since embedded modules are inherently flat, with copper contacts on the top and bottom of the package, they are ideally suited for area covering or stacked mounting onto a base module followed by subsequent lamination and typical printed circuit board processing.

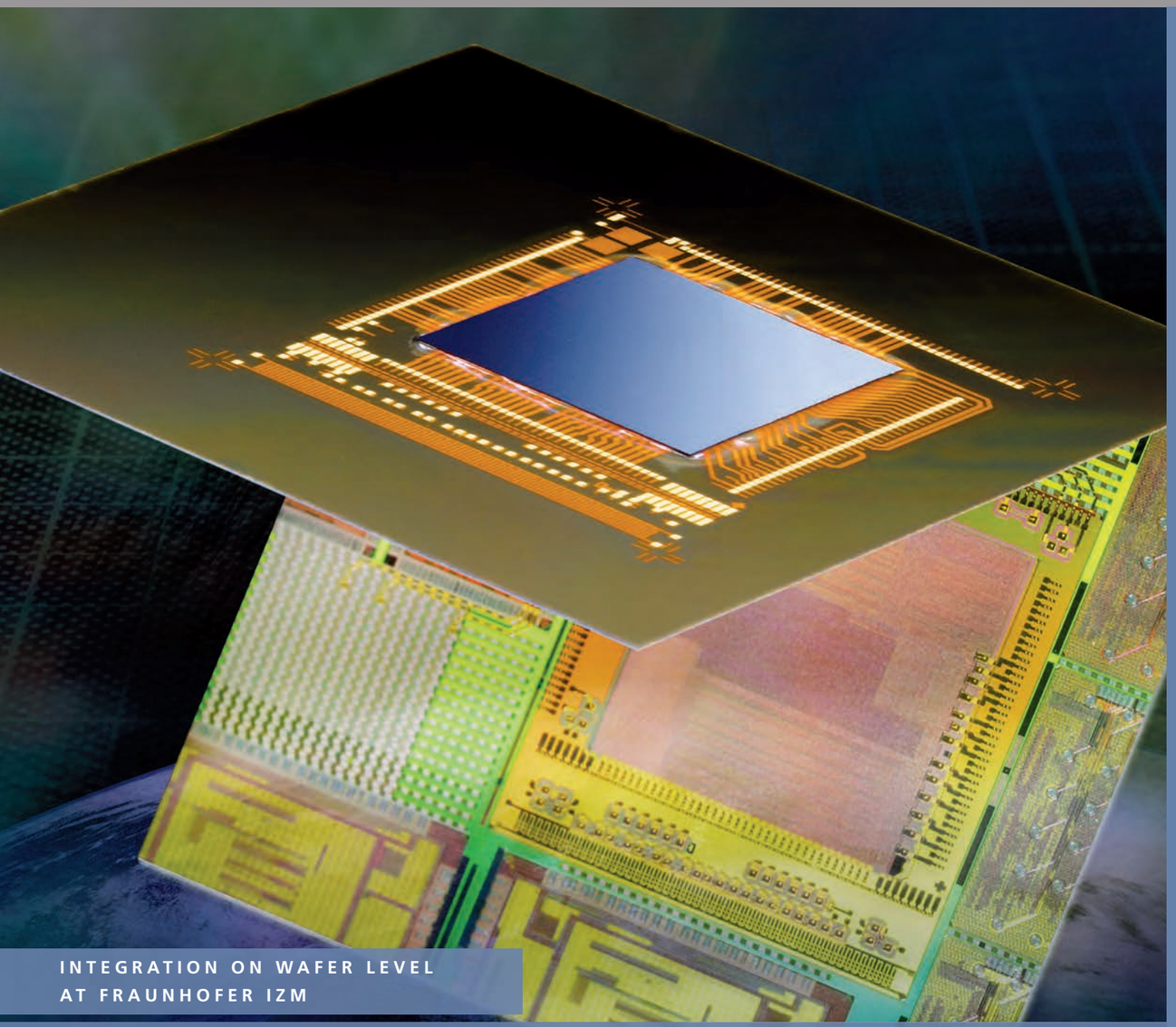
The core process of system integration into the frame of modular power electronics is a combined process of low-pressure sintering base on silver nanoparticles and lamination of printed circuit board build-up layers with high thermal conductivity. Sintering is used to realize a thermally and electrically highly conductive interconnect between the embedded modules, while the laminated epoxy-based build-up warrants a mechanically robust and insulating interface that encapsulates the electrical interconnects tightly.

Modular power electronics is compact and efficient to manufacture. Moreover, such modules can easily be combined and rearranged for different use cases. For example, the power rating of a module can be scaled up by simply increasing the number of parallel switches and drivers in order to comply with application conditions.

1 3D luminaire: The layout of the circuitry and assembly of LEDs was performed on planar (2D) thermoplastic carrier boards. The final fabrication step was thermosforming into the spherical cap

2 Embedded module for power electronics applications (500 W). The module contains power MOSFETs and copper structures for heat spreading

RESEARCH CLUSTER
INTEGRATION ON WAFER LEVEL



INTEGRATION ON WAFER LEVEL
AT FRAUNHOFER IZM

The highest integration densities possible in heterogeneous assemblies are achieved using wafer level integration. All processing steps are carried out at wafer level after the actual front-end processes have been completed. The packages we develop have lateral widths almost identical to the chip dimensions. We also include active and passive components on the wafer in interlayers and even higher integration densities are achieved with 3D integration using through silicon vias (TSV) or using silicon interposers and TSV.

HIGHLIGHT 2016

3D process technology for innovative system in package (3D-SiP) solutions
The integration density of active components is a key factor in the development of new products. But technical boundaries and rising costs are limiting the structure size reduction. A three-dimensional stacking of chips, combined with wafer level processing, allows a functional extension and a increased complexity of electronic systems within minimum space.

The European joint project Master_3D aimed at the establishment of an integrated platform (tools, materials, processes) for the realization of three-dimensional innovative system in package (3D-SiP) solutions. Methods and technologies for highest contact density, thin silicon integration as well as new analytical and test procedures have been developed. This was done focusing on the goal to expand conventional assembly and connection technologies on wafer level into the third dimension, especially considering reliability, performance and process monitoring aspects. Within the project, IZM-ASSID achieved significant results in the development and performance increase of single processes that are technologically important for 3D integration. In cooperation with industrial partners, critical process steps were analyzed and evaluated considering real application scenarios and product requirements. Furthermore, in cooperation with tool suppliers, samples with dedicated 3D structures were produced and used for the evaluation and validation of newly developed process and inline monitoring tools.

In collaboration with NXP and Infineon, the achieved project results were applied in application-driven demonstrators which were realized with IZM-ASSID's technology line. In the NXP demonstrator, a security controller with an NFC interface (near field communication), an additional new security feature could be implemented by using 3D integration technologies. With this, the overall security level could be raised, too.

An extended understanding of the interaction of the individual processes and their effects on the electrical performance could be achieved by various, partly newly developed 3D test structures - a part of them interacting with the active components of the NXP CMOS wafer. The new 3D test structures in combination with the establishment of an enhanced test flow additionally allowed the collection of electrical data for every single 3D process module. With this, dedicated correlations of individual processes to yield detractors could be shown. Furthermore, a new concept for the integration of TSVs as a transistor gate in MOS transistors was initially successfully tested and assessed (vertical N- and P-MOS transistors).

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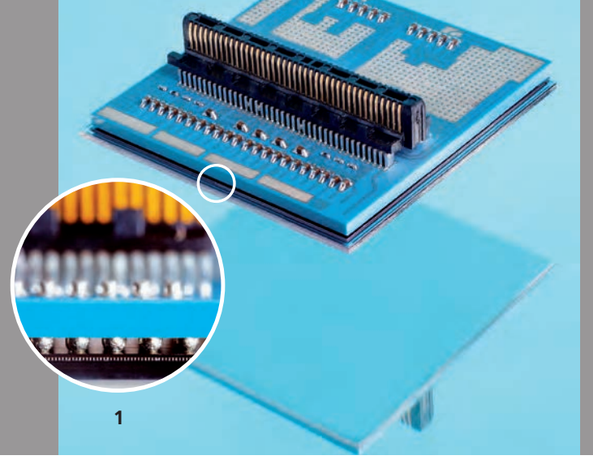
Security demonstrator with 3D integrated security controller and near field communication chip (NXP). The top side features newly developed 3D test structures which enable an extended 3D process monitoring.



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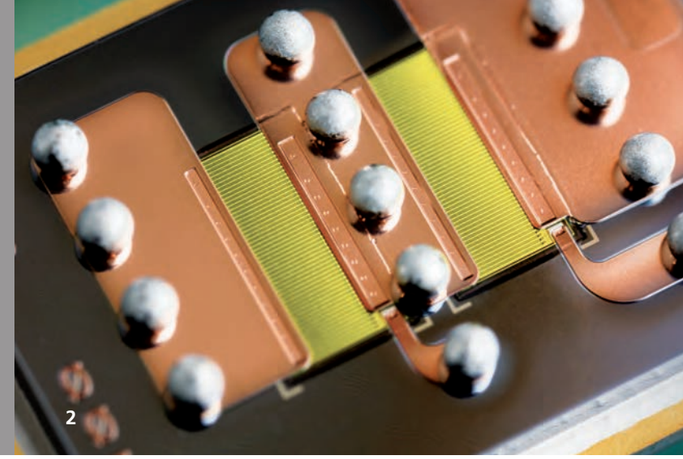

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WAFER LEVEL SYSTEM INTEGRATION – ALL SILICON SYSTEM INTEGRATION ASSID

The Department

The research activities of the department »Wafer Level System Integration« and its staffs at Fraunhofer IZM in Berlin and at »ASSID - All Silicon System Integration Dresden« focus on technologies for wafer level system integration and packaging. The process lines allow high flexibility regarding the processing of 8"-12" wafers and are characterized by a high adaptability of the individual processes. The process line at IZM-ASSID is particularly tailored to realize production-related and industry-compatible development and processing (ISO 9001).

The focus of the scientific work is on:

- Wafer level packaging and CSP
- 3D wafer level system in package (WL SiP)
- TSV interposer
- High-density redistribution
- Ultra-fine pitch micro-bumping
- Pre-Assembly (Thinning, Dicing, Singulation)
- Die to Wafer (D2W) assembly
- 3D wafer level stacking

R&D services for customers from industry include process development, material evaluation and qualification, prototyping, low-volume manufacturing as well as process transfer. Newly developed technologies are individually adapted to customer-specific requirements.

Trends

The merging of technologies for »More Moore« and »More than Moore« is of high importance for the development of micro systems. Furthermore, cost efficient solutions for the overall system have to be developed and realized. Also, a joint view at design, technology and reliability aspects is of increasing significance. This constitutes a particular challenge for the heterogeneous integration of devices into a multifunctional, miniaturized and reliable wafer-level system-in-package while simultaneously considering cost optimization.

Respectively, the research and development goals are aligned to the following:

- Evaluation and implementation of new material, e. g. polymeric dielectric (< 200°C curing)
- Development and realization of adapted fine-pich interconnect structures (µ-bumps, Cu-Pillar, Cu-Cu) on chip/substrate level
- Development of new interconnect structures and systems (low temperatures, low force) for ultra-thin chips and wafer stacks
- BEoL-compatible TSV integration (via middle, BS via, via last) for 3D systems
- Heterogeneous integration based on interposers (silicon, glass)
- Adapted pre-assembly technologies (wafer thinning/dicing) and thin wafer handling processes
- Development of highly reliable manufacturing-compatible 3D assembly technologies (D2W/W2W)

RESEARCH & DEVELOPMENT HIGHLIGHTS

Fabrication of 3D hybrid pixel detector modules based on UFXC32k readout chips with TSVs

Fraunhofer IZM Berlin and AGH University of Science and Technology Krakow have worked together in a joint project to fabricate 3D pixel detector modules. The modules are based on UFXC32k (Ultra Fast X-Ray Chip with 32k Channels) read out chips (ROCs) which are processed with though silicon vias (TSVs). The ROCs have 32,768 pixel IOs featuring a pitch of 75 µm, 87 peripheral chip IOs and a total size of 2 cm². A typical front side via last integration scheme was used to implement 100 µm deep copper filled TSVs into the 200 mm wafers with the ROCs. A micro bumping process was performed at the front side of the ROC wafers to enable their subsequent flip chip bonding to the corresponding silicon sensor tiles. Since the backside of the ROCs was processed with BGA pads, the sensor tiles with the assembled ROCs could be bonded directly with their backside onto LTCC boards that provide the circuit periphery and interface to the next system level. The vertical signal feeding enabled by the TSVs in the ROCs avoids the necessity of wire bond interconnects coming from the edge of the ROCs. This enables a more dense assembly of the ROCs in larger arrays with minimized gaps between them.

Planar embedding technology for GaN power electronics modules (Si-Bed)

In the fields of power supply and electromobility Gallium Nitride (GaN) components offer advantages especially with respect to increasing miniaturization and electronic performance. For a successful miniaturized integration, the package needs to enable an extended operation temperature including spreading of dissipated heat and also reduce parasitic inductivities and capacities usually induced by wire bonds in common packaging solutions. Within the project E2CoGaN, Fraunhofer IZM develops on its wafer platform a dedicated process for the packaging of GaN power electronics components at wafer level using a novel planar embedding technology. The main objective is the realization of GaN-based half bridge components for power electronics converters to facilitate ever higher efficiency. For this, bare GaN front-end processed power semiconductors (high electron mobility transistor: HEMT) are assembled and embedded into 200 mm silicon wafers structured with etched cavities. The planar full-silicon approach enables robust thermal coupling of the module to a spreader and cooler by sintering which ensures a low thermal resistance. Also, contacts on the front side are realized by means of appropriate wafer back end technologies (lithography, thin film isolation materials, thick Cu electroplating) and BGA-solder balls. This technology enables a compact, high-performance module which is, realized as a BGA component, compatible to standard mounting techniques on printed circuit boards.

1 3D hybrid pixel detector module based on sensor with two ROCs

2 GaN based half bridge realized by silicon embedding technology

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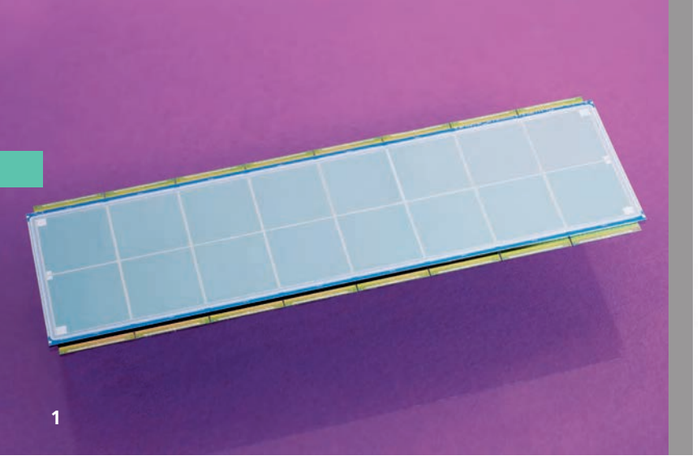

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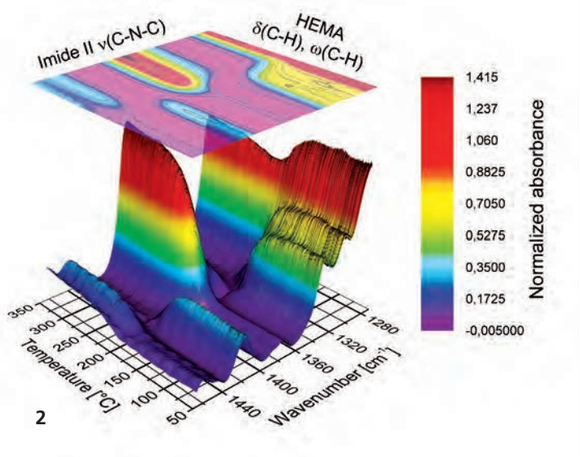

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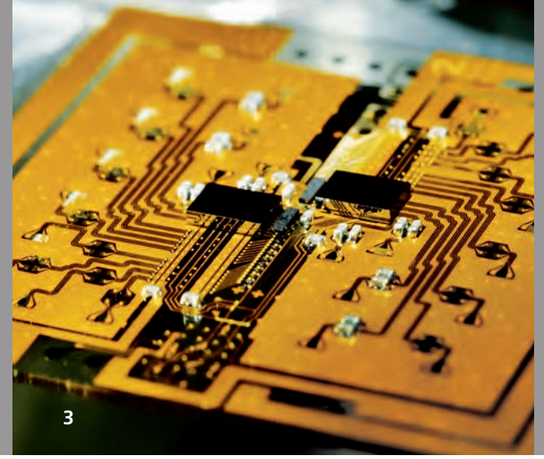

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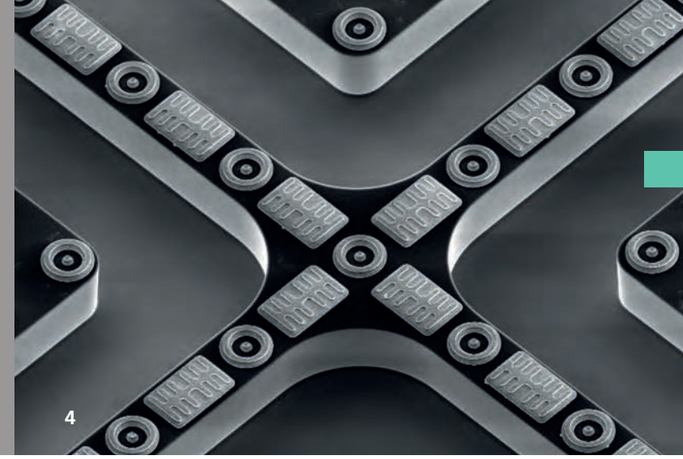

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Silicon pixel detector modules for the CMS detector-upgrade at LHC - CERN
After the observation of the Higgs boson and the award of the Nobel Prize for Physics in 2013, the Large Hadron Collider at CERN is now ready for the discovery of new particles at higher collision energy and beam luminosity. In order to fulfill the increased requirements concerning tracking accuracy and data rates, the CMS detector will now be upgraded. This means a complete replacement of the current pixel tracking detector with a new and bigger detector. For the upgrade, Fraunhofer IZM has assembled more than 300 modules for the innermost part of the CMS detector – the silicon pixel tracking detector. Each module, the base building block of this detector, consists of one sensor chip with a size of 66 x 18 mm² and sixteen readout chips which are flip-chip bonded onto the sensor. Each module has 66,560 pixels in total and every pixel on the sensor with a size of 150x100 µm² is connected to the readout cell by a 30 µm diameter solder bump. In order to achieve a high manufacturing yield, several quality assurance process steps have been established. This includes a 100 percent 2D and 3D solder bump inspection at wafer level, an electrical function test after readout chip wafer dicing together with the project partner INFN and a sensor qualification before module assembly. Finally, all modules were tested at INFN prior to further assembly of the full detector.

In-situ cure process characterization of thin film polymers for microelectronic packaging
An in-situ analytical method has been developed and applied to characterize the chemical changes during thermal curing of thin film polymers for microelectronic packaging applications. The method allows the determination of the degree of cure in dependence of temperature, time and polymer specific conditions during previous processes (e.g. lithography). Based on the experimental data, an advanced kinetic model has been developed which is able to characterize the cure process of thin polymer films in solid state. This model will help to understand and enhance the processes conditions of different polymer formulations, e. g. PI, PBO or BCB and allows the optimization of the full process chain. This addresses specifically low-temperature requirements in the field of advanced wafer-level packaging and 3D integration.
The development was carried out together with the Leibniz Institute for Polymer Research Dresden e. V. (IPF).

Process development for advanced direct oxide-oxide and Cu-Cu bonding (DBI)
The hybrid bonding technology is jointly developed by XPERI (Invensas) and IZM-ASSID on 300 mm wafer size. The DBI is an extension of Ziptronix' ZiBond® technology that allows an interconnect pitch of very few micrometers and accommodates 1.5 million connections per cm². ZiBond® is a low temperature homogeneous (e. g. oxide-to-oxide) direct bonding technology that forms strong bonds between wafers or dies with same or different coefficients of thermal expansion (CTE). The process uses leading-edge process tools and advanced CMP materials to achieve state of the art planarization performance. The electrical connection by bonding of 300 mm wafers was established by using a IZM-ASSID test chip design: 2 half chips with two neighboring daisy chains each and 6,656 interconnects per chain. A yield of > 95 percent could be demonstrated. The benefits of the DBI are: fine pitch 3D interconnect (scales from <10 µm to 1 µm or less), high bandwidth (enables increase in I/O as needed), improved performance (enhanced electrical and thermal characteristics due to elimination of micro bumps, underfill and solder), yield improvement (minimized warpage during assembly) as well as low cost (reduced process steps and simplified manufacturing process).

Glass-silicon based transceiver
Within the project HyPOT, Fraunhofer IZM, together with its industrial and academic partners, is developing a hybrid integrated glass-silicon based interposer for data communication at a wavelength of 850 nm. A glass interposer with through glass vias (TGVs) is used as a carrier for the silicon components e. g. 12 channel VCSEL, photodiode array and driver ICs. The glass interposer is processed at wafer level using state-of-the-art technology. The high frequency routing on the glass interposer is optimized for data rates up to 28 Gbit/s/channel. The glass substrate with TGVs enables a low signal loss transmission. The electro-optical components like photodiodes and VCSELs are assembled on the glass carrier with flip-chip contacts where the optical path is transmitted through the glass interposer. Fresnel-lenses are individually designed and monolithically integrated in the glass interposer for optical beam shaping. The flip-chip approach allows an improved cooling of the components from the backside.

Interposer with liquid cooling
The maximum processor performance is limited by the heat removal efficiency. Therefore, a highly effective cooling technology as well as an innovative power management are the keys to increase the computing power. Whil air cooling is limited, a liquid cooling approach can meet these high requirements by targeting at a double-sided processor cooling. Within the project CarrICool, IZM-ASSID worked on the realization of a double-sided liquid cooling technology by innovatively integrating horizontal and vertical microfluidic channels. These micro channels are integrated in an electrically full functional interposer stack with Cu-TSVs in a waterproof manner. With this, for the first time, high performance processors can be additionally and effectively cooled from the bottom side, too. In combination with the integrated cooling plate on the top side of the processor, this double-sided cooling configuration allows the dissipation of 672 W heat from a 4 cm² sized processor surface with a maximum coolant temperature increase of only 60 °C. Compared to the performance of a common kitchen hotplate, this equals a forty times higher heating power when considering the same area size!

1 *Pixel detector module for the CMS-detector-upgrade at LHC / CERN*

2 *Polyimide formation in thin films monitored by temperature dependent in-situ FT-IR spectroscopy*

3 *Glass interposer based 4-channel id-board optical transceiver*

4 *SEM image of an interposer half shell with trenches in silicon that - after bonding of both halves - form a micro channel for liquid cooling*

RESEARCH CLUSTER
MATERIALS & RELIABILITY

MATERIALS & RELIABILTY AT FRAUNHOFER IZM

Reliability and environmental compatibility have become more important in the development of electronic components and systems in recent years. Fraunhofer IZM has been combining research into the reliability of electronic components and their environmental characteristics with the development of new technologies since it was first established. Fraunhofer IZM conducts reliability analyses on the materials right through to the system as a whole using material behavior and mechanical reliability models. Apart from simulation processes, we employ laser-optical, X-ray and material tests individually or in combination.

HIGHLIGHT 2016

Sound Life Cycle Assessments for sustainable design decisions
Electronic devices with a long service life can make an important contribution to a sustainable society. Fraunhofer IZM supports manufacturers in developing these kinds of product concepts, and in optimizing them to be environmentally friendly. The comprehensive life cycle assessment of the modular Fairphone 2 was able to demonstrate the environmental effects of producing a smartphone as well as how a modular approach can lead to a reduced environmental footprint.

The carbon footprint, as a measure of the Fairphone 2's contribution to climate change over a service life of three years, is the equivalent of approximately 44 kg of CO_2. 80 percent of this is generated in the manufacturing phase. The complex manufacture of semiconductor devices and circuit boards is responsible for most of the CO_2 production. The modularization of the smartphone also places other stresses on the environment, particularly in the case of board-to-board connectors and modular housings.

The increase in circuit board area needed for the additional plug connectors also has an effect on the environmental life cycle impacts. All the same, these environmental effects are more than compensated for if users can fix their own device should it become damaged in a simpler and cheaper way by replacing individual modules, thus keeping the device in use. Compared to the electronic parts, the display and the battery make a lesser contribution to greenhouse gas emissions, but are frequently the components that dictate the device's service life. That is why it ought to be easy to replace the battery as its capacity dwindles and the display if it gets damaged in order to keep using the electronic parts for as long as possible. Modularization also offers the ability to upgrade a smartphone to allow it to »grow« with users' requirements, instead of having to replace it with a new device. This does, however, increase the demands on a device with regard to long-term compatibility and reliability.

In any event, the lessons learned from a sound life cycle assessment make it easier to make design decisions, adapt product and business strategies, and derive priorities for eco-optimization of individual manufacturing priorities.

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How can the life-cycle assessment of smartphones be improved?

ENVIRONMENTAL & RELIABILITY ENGINEERING

The Department

Reliability and environmental requirements are meanwhile an acknowledged quality characteristic, over and beyond compliance with legal requirements. The »Environmental and Reliability Engineering« Department supports engineering developments for the market by carrying out environmental and reliability investigations, from nano-characterization through to evaluation and optimisation on the system level.

Interdisciplinary approaches are developed further and specific industrial questions are addressed:

- System reliability from the packaging technology to the product level
- Design for reliability and lifetime simulation
- Material characterisation and modelling
- Thermal design, thermal interface characterization
- Combined and accelerated load testing
- Ageing and failure analyses, sample preparation and analysis
- Testability and online-monitoring of accelerated ageing
- Methods and hardware for condition monitoring
- Reliability management in R&D
- Eco-reliability for microelectronic concepts
- Carbon footprint, Green IT, use of renewable raw materials
- Eco-design, life-cycle modelling
- Environmental legislation (e. g. RoHS, WEEE, EuP/ErP)

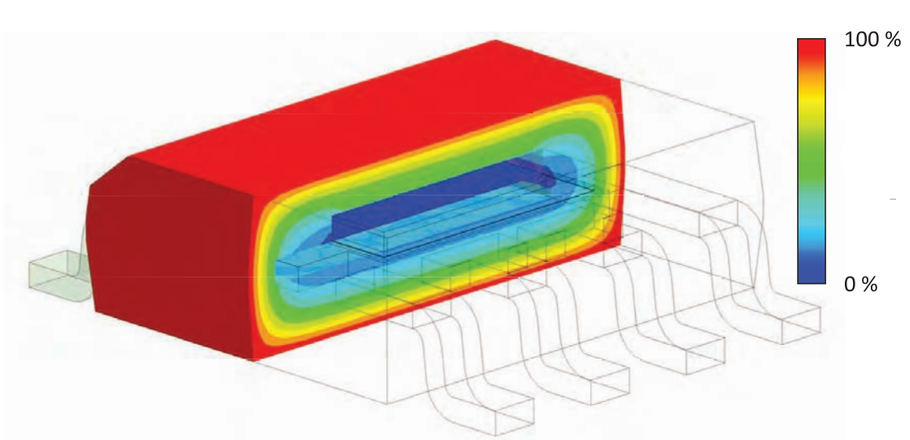
Trends

In the past, environmental protection measures focused on preventing the introduction of harmful substances into the environment and increasing the energy efficiency of manufactured goods. However, in fact, the manufacturing process itself largely determines the environmental footprint of a product in terms of energy and materials consumed. For this reason, the global focus has turned to improving energy and material efficiency by means of the so-called »circular economy«. In 2015, the European Commission released a comprehensive package of measures for this approach and it is also an increasingly hot topic in the private sector. The goal is planning and optimizing product life cycle, as part of which many aspects of the following areas require rethinking and restructuring:

- Recycling
- Processing
- Capacity for and ease of service and repair
- Modularization and Durability

Fraunhofer IZM is increasingly introducing the above aspects of sustainability and durability into its current and planned cooperation projects with partners from science and industry. Whether individually and combined, these questions are considered across the board, from efficiency evaluation, to technical implementation, right through to reliability assurance. The following application areas are of key importance here:

- Mobile devices
- ICT and network engineering
- Autonomous sensor technology (i.e. with sensors with selfsufficient power supplies)
- Power electronics
- Photonics and lighting



Calculation of moisture distribution within a package in order to evaluate the risk of electrochemical degradation

RESEARCH & DEVELOPMENT HIGHLIGHTS

Environmental impact and longevity of mobile end devices

The reliability and service life of smartphones are not only important factors in customer satisfaction; they also have direct effects on the environmental impact of the devices. This issue is becoming more important both for manufacturers and for network carriers, as the latter distribute these devices. For that reason, IZM investigated the typical service life of smartphones for Deutsche Telekom, and recommended measures designed to increase the customer usage life and to enhance the hardware tests used to ensure the devices' robustness.

Process-oriented micro-materials characterization for lifetime simulation

Correctly taking into account the mechanical properties of the materials used is an important basis for creating models that can be used to ensure thermo-mechanical reliability. This is a real challenge, particularly in the case of thin metal layers. On the one hand, the properties vary depending on the process conditions. On the other hand, these properties need to be characterized on a comparable size scale for microstructures. A procedure developed at Fraunhofer IZM is able to derive this data from a nano-indentation test using a simulation model for calibration. In 2016, great progress was made that allow this procedure to be applied to the copper vias on printed circuit boards.

Method of solving moisture and corrosion problems

Microelectronic systems and sensors are deployed in increasingly extreme ambient conditions. As miniaturization is on the rise, so is the risk of failure due to electrochemical degradation mechanisms. This also means that the demands placed on integration technologies are rising. The package must be suitably protected from external influences such as moisture and salt to ensure that the electrochemical processes on the inside are slowed down and degradation effects do not become relevant during the product lifetime. A holistic method developed over the last year combines simulations, optimization algorithms, and electrochemical measurements in a way that allows to develop application-specific solutions.

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RESEARCH CLUSTER
SYSTEM DESIGN

SYSTEM DESIGN AT FRAUNHOFER IZM

Packaging and system integration technologies are central components in all modern microelectronic systems. They determine every aspect of systems, from physical properties, to electrical functionality, through to reliability. Packaging and system integration technologies have to keep pace with ongoing miniaturization, increasing complexity, ever-higher frequencies and growing data volume. A key future task will be more precise characterization and optimization of electrical, thermal and thermo-mechanical properties. Fraunhofer IZM is uniquely placed to meet the challenge of combining excellent technology development with electrical, thermal and thermo-mechanical modeling, simulation and analysis. Moreover, Fraunhofer IZM's system design expertise bridges the gap between technological progress and the systems that can put it to use.

HIGHLIGHT 2016

Autonomous sensor nodes for agriculture and the energy industry
Poor silage not only endangers livestock: it can harm other uses, like the production of green energy. The better the ensilage process, the more efficiently biogas can be produced. Progress in the area has long been stifled by the absence of suitable sensor technology to monitor the entire process from filling the silos to extracting the finished silage. The multi-sensor technology developed by Fraunhofer IZM with partners from academia (Julius Kühn Institute (JKI), Brunswick) and industry (Esys GmbH, Berlin) makes it possible for the first time to track critical parameters like the density of the silage. Any flaws in the ensilage process or in the finished product are pinpointed and can be remedied in good time before affecting the quality of the silage. By using software standards common in harvest management applications, the sensor data can be integrated with established agricultural software and implemented immediately in everyday farm operations.

Working with the partners at JKI and Esys, several pretests were conducted to find suitable sensor for measuring pH values, temperature, and density. An energy-efficient signal processing system was developed, and a suitable body for the sensor node was designed. It communicates by wireless connection (169 MHz) with an internet bridge that forwards the data to the database on a webserver via the mobile network. An Android app for mobile use, e. g. for drivers, maps the data to the nodes on the ground. The JKI developed and stocked a trial silo to calibrate the sensor system.

One particular challenge lay in the development of the density sensor. Since the sensor nodes are meant to track density during the ensilage process itself, traditional approaches like weighing a defined amount of material were not an option. The measuring technology also had to be miniaturized. With this in mind, the measurement relies on sub-GHz resonators, using a 2.4 GHz frequency to keep costs down by allowing the use of readily available standard transceiver chips. The resonator was initially simulated, before samples were produced by rapid prototyping and put to the test under real-world conditions. The pH sensors also use standard technology, adjusted to match the device's design. After a first run of successful sensor tests, this year will see the technology put to the test in a real silage cycle.

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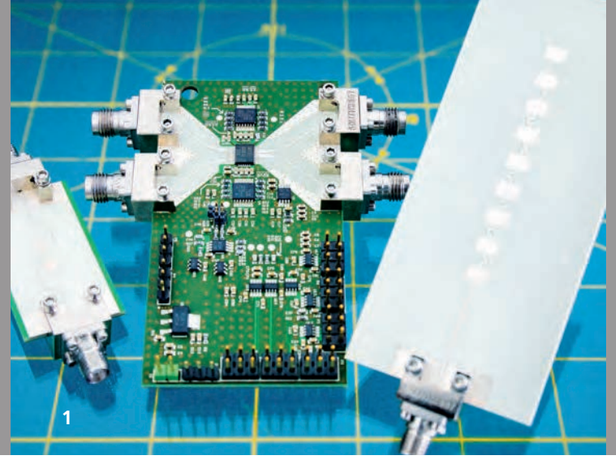
Sensor system for monitoring the ensiling process during the production of biogas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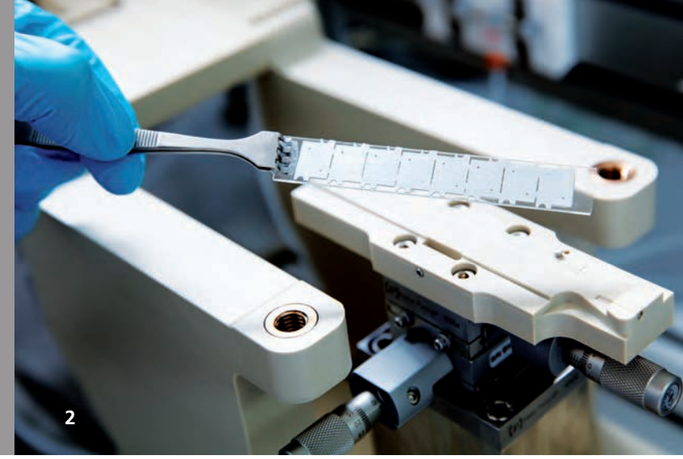
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RF & SMART SENSOR SYSTEMS

The Department

The »RF & Smart Sensor Systems« department represents the technological systems competence of Fraunhofer IZM. This covers autonomous micro-systems, whose development from the eGrain to autonomous sensor nodes and cyber-physical systems has left an indelible mark on the evolution of the Internet of Things. The focus of our work lies on:

- HF design and characterization of materials, packages, and components
- HF system integration and module design with consideration for signal and power integrity
- Development and construction of autonomous wireless sensor systems
- Development of micro batteries and power supply and management systems
- Development and realization of tools for optimized microsystem designs and server-client software architectures

The work on complex systems for communication, radar, and sensor applications builds on the technological knowhow of Fraunhofer IZM and is grounded in a systematic empirical approach (M3 approach), supported by extensive metrological equipment and practical experience with modeling tools. Optimum results can be achieved at very high speed, avoiding the need for time and cost-intensive iterations.

Trends

The Internet of Things, Industrie 4.0, cyber physical systems – these buzzwords continue to shape the nature of our work. Machine-to-machine communication with secure remote data transmission is becoming increasingly important. In sensor technology, the trend is going towards autonomous wireless sensors with operating systems designed with energy efficiency and effective data pre-processing and data economy in mind. Users are demanding close data chains from the sensor to the IT infrastructure.

Real-time capabilities, robustness, security, and high data rates are important criteria for wireless networks. 5G mobile networks and communication systems at 60 GHz offer great potential. Controllable antennae are expected to deliver additional functions, which creates new opportunities for radar sensors. As in the case of wireless interfaces, there is much potential for innovation to be found in a combination of interfaces working at different frequencies.

System design is gaining in relevance, demanding closer cooperation between circuit design and technological development. Hardware-software co-design will become the standard, as will new concepts for powering autonomous sensor nodes.

RESEARCH & DEVELOPMENT HIGHLIGHTS

Miniaturized, cost-efficient radar modules

Several economical radar modules for use in the Internet of Things have been developed in close cooperation with the Fraunhofer Institute for Open Communication Systems FOKUS and diverse small and medium-sized enterprises in a dedicated project cluster. The work focused on the RF frontend, its integration, and the passive regulation of detection ranges. An optimized mix in the controlling, feed network, and assembly and interconnection technologies guarantees small-scale and cost-efficient, but powerful modules. The assembly technologies used in the projects range from traditional circuit boards to flex and thin-film polyimide embedded technologies.

Autonomous sensors for status-based maintenance of rolling stock

New robust wireless sensors, developed in cooperation with Bombardier, GfM, IMC, Deutzer Kohle, Lust Hybrid, and the TU Berlin, monitor the state of the wheel bearings of rolling stock and report any required maintenance work. The data of an accelerometer is used for an in-depth analysis and sent wirelessly to a central server on a daily basis. An inductive harvester supplies the sensors with power, supported by efficient energy management and an energy-minimized design.

Printable battery separators for lithium ion microbatteries

Small-scale microbattery designs need printable separators. Microdispensers were used to develop a printable separator from SiO2 nanofibres and a polymer binder. Measuring 30 µm in thickness, the separator achieves ionic conductivity comparable to standard designs. At a c-rate of 2C, more than 80 percent of nominal capacity remain; the cell's cyclability is identical with regular cells. Microbatteries with an active surface of 6 x 8 mm² were designed with a capacity of 0.8 mAh.

Thermal online analysis

The innovative EDA tool for circuit board layouting calculates and visualizes a thermal map already during the interactive positioning of individual modules, based on their power dissipation. The mathematical models required to achieve this were developed in cooperation with the Environmental & Reliability Engineering department. The add-on tool helps recognize thermal problems at an early stage and prevents later unnecessary re-design cycles.

1 GHZ-radar system with directional antennae and an angular resolution of +/-4°

2 Fabrication of a lithium-ion microbattery

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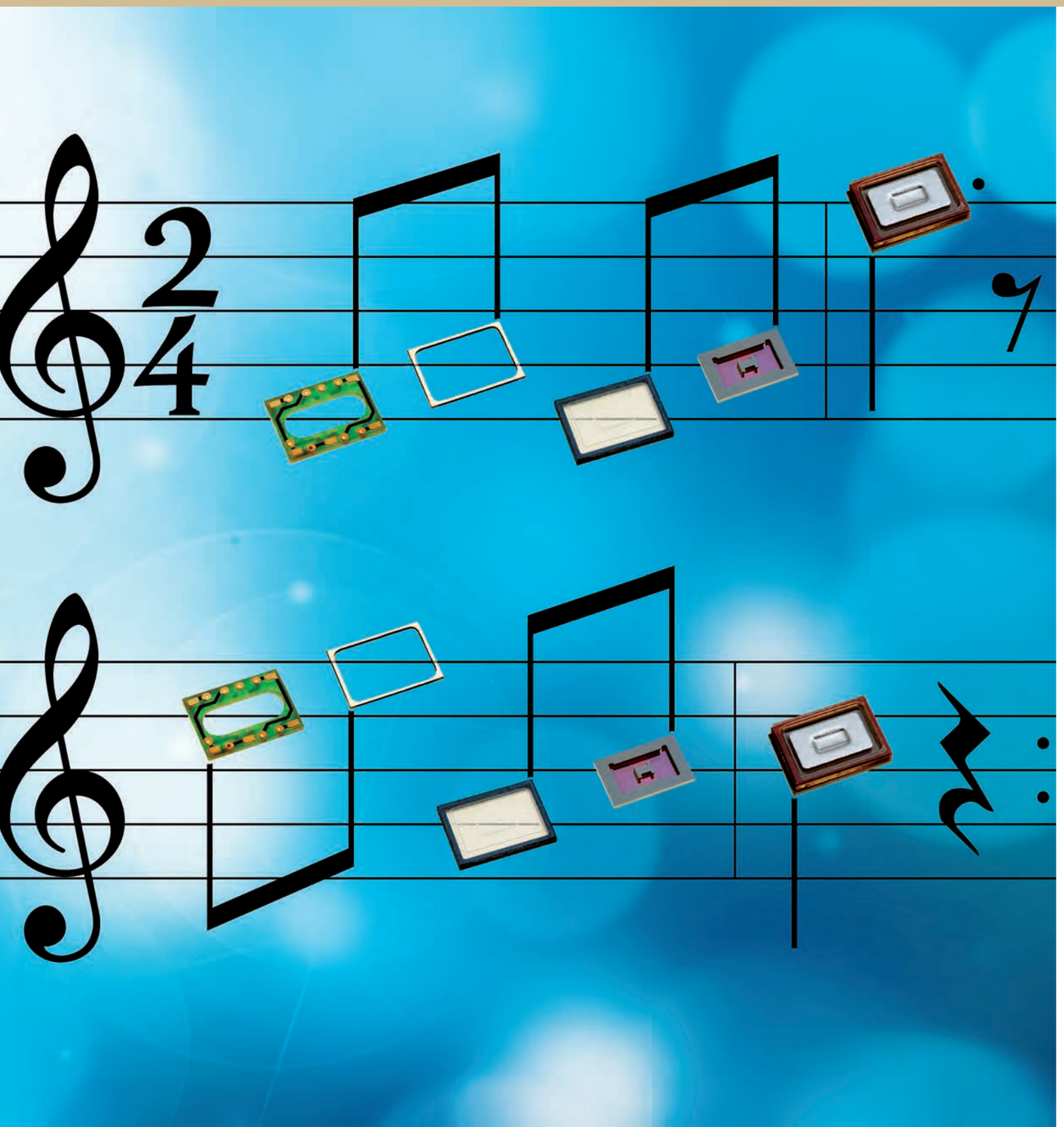
FRAUNHOFER IZM EVENTS



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EVENTS & WORKSHOPS

Launching the Microbattery Prototyping Line
Many modern applications in medical technology and many other fields depend on power sources for which traditional button cell or other battery types in the market are either too large or impractical to integrate in new devices. The new microbattery prototype production line at Fraunhofer IZM in Berlin was opened as part of its mission to develop solutions for autonomous power supplies for the small and miniature sensors in future technology. The patron behind the project, Dr Robert Hahn, and the Institute's Director, Professor Klaus-Dieter Lang, were proud to inaugurate the new facilities in the presence of invited guests and reporters on March 15, 2016. At more than 10 meters in length, the new facilities for the development and assembly of microbatteries will be used by Fraunhofer IZM and the Technical University of Berlin. A precision screen printer, substrate bonding facilities, and microfluidic electrolyte injection allow the presentation of tiny, custom microbattery designs with extreme precision. A first practical application of the microbatteries made by the Fraunhofer IZM is a new type of hearing aids, developed with the support of the Federal Ministry for Education and Research, which are placed directly on the eardrum and charged by a special infrared in-ear charger. Flexible microbatteries are currently being developed, which will be an excellent option for integration in wearable electronics. The development of innovative chip cards will also be accelerated by the new prototypes leaving the microbattery line.

Promising talent at Fraunhofer IZM
On March 30, Fraunhofer IZM again opened its doors for the Talent Take Off, an event organized by the Fraunhofer Society in collaboration with FemTec to offer high school students in years 10 to 13 from all over Germany a look behind the scenes at a scientific organization.

After an introduction to the work of the Institute, the visitors had a chance to show their creative sides. For the »Eggs in Flight« game, the students had to develop a concept for landing an egg safely from a height of four meters, without breaking it – packaging done differently! The first trials were very successful indeed. While the results of the game were being adjudicated, the visitors were taken on a tour of the labs and cleanroom of the Institute.

To end the event, the most successful »Egg Pilots« were honored, before the potential scientists of the future had a chance to discuss possible degrees and apprenticeships in microelectronics with real-life IZM staff.

Fraunhofer on the run!
At the Berlin Company Run, the Fraunhofer Institutes of Berlin and Brandenburg again showed off their stamina and dedication. 130 runners from Fokus, IPK, and IZM joined in force on May 27, 2016. With »Research on the Go« as their motto, 48 runners from Fraunhofer IZM and two skaters took to the 5.5 km course. Arsen de Mont had the fastest time and completed the course in just 00:20:40 minutes, followed by Christian Ehrhardt at 00:21:03 minutes. The athletic exertion was followed by something more comfortable: the runners put their sore feet up and celebrated their team achievement with a well-deserved beer and BBQ.

1 *Fraunhofer IZM's new microbattery line in operation*

2 *Talent take-off at Fraunhofer IZM: An egg survived a fall from 4 meters – a clear indicator that the packaging is good!*

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Smarter World Tour: IoT-Truck visits Fraunhofer IZM
On June 15, 2016, the Bavarian EBV Elektronik, a long-standing partner of the Fraunhofer Society, brought the "IoT Truck" of the Dutch semiconductor producer NXP to the Fraunhofer IZM premises in Berlin. The eye-capturing truck – futuristic inside and out – showcased more than 150 IoT solutions for smart homes, smart living, smart cities, and many other areas of application.

The »Discovery Workshop« hosted at Fraunhofer IZM on the same day was given over to all things Internet of Things: A stimulating range of lectures and presentations by speakers from Fraunhofer IZM, EBV Elektronik, NXP, and other electronics enterprises gave the 70 invited guests a chance to get up to date with current trends in the Internet of Things. The breaks in between presentations saw the guests as well as many other attendees, students, Fraunhofer employees, and chance visitors, returning to the truck for an up-close-and-personal experience of the many IoT applications in practice.

2nd Summer School on Optical Interconnects
The University of St. Andrews hosted its »Summer School on Optical Interconnects« from August 1-4, 2016, enabling students to learn about and share new developments in optical interconnects on all hierarchical levels of data centers in the unique atmosphere of Scotland's historical university. Joining big-name brands like Seagate Technology, Fraunhofer IZM helped organize the summer school for over 60 motivated attendees. Over the four days, doctorate students, young engineers, and promising researchers had an opportunity to attend 26 presentations by renowned international speakers in eight dedicated sessions. Alongside Fraunhofer IZM, Seagate, Huawei, IBM, the University of Cambridge, and the Technical University of Eindhoven sent speakers to the event, kick-starting a lively debate about recent developments and novel technologies in the field of optical interconnects.

The place to be every four years: Electronics Goes Green
From September 7-9, 2016, Electronics Goes Green, the world's largest conference dedicated to sustainability in electronics, organized by Fraunhofer IZM together with TU Berlin, took place in Berlin. More than 160 presentations and workshops brought researchers, environmentalists, and engineers from all four corners of the globe to Berlin, where they spent their time debating green electronics, recycling, and the need to close the loop for a true circular economy.

The idea of the circular economy featured prominently in no less than half of the sessions. In addition to the potential extension and improvement of the recycling of electronics and the need to manage the flows of waste on a global scale, several sessions addressed new business models and ways to improve the repairability of electronics. Modular construction is gaining ground even for highly integrated devices like smartphones and tablet computers.

Electronics Goes Green can be considered a fine-tuned mood barometer for the industry and a hotbed for new projects and partnerships. IZM-scientists contributed their know-how to numerous sessions, presented their research results and hosted panel discussions.

Seminar »Polymers in Microelectronics«: From adhesion to reliability in the aging process
Microelectronic applications rely on a wide range of materials to function. Polymers, be they filled or unfilled, in particular suffer from certain intrinsic traits that affect their durability. On October 13, 2016, the Fraunhofer IZM in Weßling-Oberpfaffenhofen invited 20 professionals working in the field of packaging and interconnection technology in power electronics for a workshop on polymer aging. The many presentations given by speakers from Fraunhofer IZM in Berlin and Oberpfaffenhofen covered the basics of polymer bonding, the issue of reliability in humidity, and the effect of time and

Events with Fraunhofer IZM participation in 2016	
European 3D TSV Summit	January 2016, Grenoble
EIPC-Workshop »Metallization & Surface Finishes«	February 2016, Berlin
Opening Microbattery-Line	March 2016, Berlin
IoT-Workshop as part of »Smarter World Tour«	June 2016, Berlin
Symposium »Manufacturing Technologies for Fan-out Panel Level Packaging«	June 2016, Berlin
2nd Summer School in Optical Interconnects	August 2016, St. Andrews
Electronics Goes Green 2016	September 2016, Berlin
OpTecBB Summerschool »Intelligent Systems for Autonomous Driving«	September 2016, Berlin
4th Optical Interconnect in Data Centers Symposium	September 2016, Düsseldorf
Workshop MATFLEXEND	September 2016, Vienna
Workshop »Polymers in Microelectronics - From Adhesion to Reliability in the Aging Process«	October 2016, Oberpfaffenhofen
Exhibition and Workshop »New Sensor Systems for Future UAV-Applications«	October 2016, Berlin
Symposium »Anticipating the Future«	November 2016, Berlin
Workshop »COB-SMT Combined Assembly, Practical Guidelines«	December 2016, Oberpfaffenhofen
Panel Discussion »Think Different – Inverting the Pyramid for the Care of Patients with Dementia«	December 2016, Berlin

1-2 *Unstoppable – IZM colleagues at the Berliner Corporate Run B2Run*

3 *On his Smarter World Tour, the IoT Truck Station stops at Fraunhofer IZM*

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temperature exposure. The talks also discussed the potential and limitations of simulations in this field of production technology. In addition to sharing expertise on the right selection of polymers for microelectronic applications, the event left more than enough room for debates and a tour of the facilities at Weßling-Oberpfaffenhofen.

Drone Berlin 2016 – Workshop »New Sensor Systems for Future UAV-Applications«
On October 14-15, Berlin's Adlershof con.vent. teamed up with Fraunhofer IZM for an exhibition and workshop on "New Sensor Systems for Future UAV Applications", bringing together leading experts in the field of unmanned aircraft. The lively discussion covered a wide range of innovative applications. A demonstration and presentation by the Fraunhofer IZM showcased innovative minia-ture sensor technology, cutting-edge power supply and operating concepts, and novel sensor fusion ideas.

Workshop »COB-SMT Combined Assemblies: Practical Guidelines«
Chip-on-board technology (COB) is used to mount unenclosed chips, so-called bare dies, in virtually all cases in combination with the SMD (surface-mount device) integration of passive components. On 17 November 2016, the IZM in Weßling-Oberpfaffenhofen opened its doors for a workshop that covered all relevant aspects of this type of combined assembly. The speakers, including Professor Martin Schneider-Ramelow, Dr. Frank Ansorge, and Karl-Friedrich Becker, covered the critical aspects in their contributions, ranging from PCB surfaces and die attach approaches to wire bonding and encapsulation technologies.

The workshop also looked into the materials' side of the technology and the available methods for testing and quality assurance. More than 30 participants used the opportunity to meet and share ideas with likeminded peers in between the presentations. The event was a great success and will be repeated in 2017 – as expertise in COB-SMT combinations and practical know-how about the problems and challenges in the field will remain relevant topics in effective electronics design and production.

AMA Seminar on »Autonomous Wireless Sensors«
2016 again featured the training seminar on autonomous wireless sensors, hosted by Fraunhofer IZM in partnership with the AMA Association for Sensors and Measurement. Under the motto »What are autonomous wireless sensors, and which applications are promising?«, the seminar touched on current trends and applications for wireless sensor networks.

4th Optical Interconnect in Data Centers Symposium
The 4th Optical Interconnect in Data Centers Symposium was another popular highlight of the European Conference on Optical Communication (ECOC). The event focused on powerful, economical, and energy-efficient optical interconnects across data center hierarchies, with particular emphasis on on-board, board-to-board, and rack-to-rack technologies.

High profile speakers from Facebook, IBM, Huawei, Furukawa, UCL and others addressed over 150 visi-tors from around the world in four separate sessions. A separate roundtable discussion invited the attendees to share their experiences, and the team around Tolga Tekin was available for visitors to the PhoxTroT booth.

Exhibiting the work of Fraunhofer IZM
With more than a dozen expos in Germany and abroad, 2016 was again a very busy exhibition year for the Fraunhofer IZM. New IZM innovations were showcased in the United States not once, but twice: San Francisco's Photonics West in February introduced current trends in optical interconnects, while the ECTC in June was given over to the Panel Level Packaging process developed at the Institute.

Fraunhofer IZM at the SMT in Nürnberg
The booth of Fraunhofer IZM at the SMT in Nürnberg was again dominated by a highlight exhibit: a 610 x 457 mm² panel made at the Institute. In addition to hosting its own booth and the joint opto-electronics exhibit, Fraunhofer IZM organized the "Future Packaging" line for a seventh time under this year's motto of "Living in the Internet". With 17 equipment suppliers as partner and 18 co-exhibitors, the expo attracted record numbers of visitors.

Fraunhofer IZM at trade shows 2016	
SPIE Photonics West	February 2016, San Francisco, USA
Smart Systems Integration	March 2016, Munich
SMT Hybrid Packaging	April 2016, Nürnberg
Sensor + Test	May 2016, Nürnberg
PCIM Europe	May 2016, Nürnberg
ECTC	May - June 2016, Las Vegas, USA
micro photonics	October 2016, Berlin
DRONE	October 2016, Berlin
SEMICON Europa	October 2016, Grenoble, France
electronica	November 2016, Munich
Compamed	November 2016, Düsseldorf

1 *Award ceremony for the Green Electronics Council Catalyst Award at Electronics Goes Green 2016*

2 *Fraunhofer IZM's Christine Kallmayer at a press conference held as part of Compamed in Düsseldorf*

WORKSHOPS 2017

Workshops at Fraunhofer IZM
In the framework of the Berlin Center for Digital Transformation Fraunhofer IZM's Transfer Center Hardware for Cyber-Physical Systems (CPS) is offering workshops in the following formats. Please note that the majority of courses are held in German.

TUTORIAL
Join our tutorials for in-depth knowledge on various topics relating to the packaging and interconnection of electronic systems.

LAB COURSE
In small groups of up to 12 participants you can experience Fraunhofer IZM's technological know-how and get some hands-on experience with the institute's state-of-the-art equipment.

INDUSTRY WORKING GROUP
In these working groups organized by Fraunhofer IZM challenges concerning industrial application and research are being discussed with partners from industry.

TECHNOLOGY DAY
These one-day events are designed to give you an overview of our institute's core competencies and ways of cooperating with Fraunhofer IZM.

INDIVIDUAL CUSTOMER EVENTS
Book a tailor-made training for your company, either at Fraunhofer IZM or at your premises. The exact content will be discussed together.

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System Design

April 28, 2017
Characterization of Dielectric Materials (Tutorial)
www.izm.fraunhofer.de/t_4

May 3-4, 2017
EMC in Power Electronics (Tutorial)
www.izm.fraunhofer.de/t_8

May 10, 2017
Reliability and Test of Robust Wireless Sensor Systems (Tutorial)
www.izm.fraunhofer.de/t_7

September 19, 2017
Sensors for Radio Detection of the Surroundings (Tutorial)
www.izm.fraunhofer.de/t_2

September 20, 2017
Sensors for Radio Detection of the Surroundings (Lab Course)
www.izm.fraunhofer.de/lc_3

November 6-7, 2017
EMC-compatible Design of Power Electronic Systems (Lab Course)
www.izm.fraunhofer.de/lc_9

November 28, 2017
Autonomous Wireless Sensors (Tutorial)
www.izm.fraunhofer.de/t_6

Integration Technologies

February 24, 2017
Colloquium »Silicon Microsensors« (Technology Day)
www.izm.fraunhofer.de/tt_10

May 4, 2017
Conformable Electronics (Tutorial)
www.izm.fraunhofer.de/t_13

May 31, 2017
Packaging of Modular Power Electronics (Tutorial)
www.izm.fraunhofer.de/t_16

June 28-30, 2017; December 6-8, 2017
Wirebonding Technology (Tutorial)
www.izm.fraunhofer.de/t_17

July 3-5, 2017
Bare Die Processing and Assembly Using Flip-Chip and Die-Attach Technologies (Lab Course)
www.izm.fraunhofer.de/lc_20

September 6-8, 2017
Chip-on-Board-Technologies (Lab Course)
www.izm.fraunhofer.de/lc_18

September 13, 2017
Custom-made Silicon-based Sensors (Tutorial)
www.izm.fraunhofer.de/t_12

September 21, 2017
»From Package to Application« (Technology Day)

September 22, 2017
Opening »Start-a-Factory«: The Modular Development and Manufacturing Labs at IZM
see pp. 30-31

September 21-22, 2017
PCB Surfaces: Layer Deposition and its Effects on Interconnection Processes (Lab Course)
www.izm.fraunhofer.de/lc_19

September 29, 2017
Low-Cost Packaging-Platform for Photonic Components (Tutorial)
www.izm.fraunhofer.de/t_14

November 2017
Integrated Electronics (Technology Day)
www.izm.fraunhofer.de/tt_15

Materials & Reliability

May 5, 2017; October 11, 2017
System Reliability of Packaging and Interconnection Technologies (Industry Working Group)
www.izm.fraunhofer.de/ia_22

June 1, 2017
Environmental Management in the Electronics Industry (Industy Working Group)
www.izm.fraunhofer.de/ia_23

October 12-13, 2017
Reliability Management (Tutorial)
www.izm.fraunhofer.de/t_21

PROMOTING YOUNG TALENT

The future of our research area depends on an ongoing influx of young talents from the life sciences. Fraunhofer IZM has been supporting up-and-coming researchers and technicians for more than 20 years and has long been reaping the rewards. Our tours and internships are also designed to introduce youngsters to the possibilities of a career in the life sciences, be it as technician or scientist. A particular and welcome development over recent years has been the increasing number of girls and young women participating.

Professional orientation of students
As part of a school and professional orientation project day, 8 high school students majoring in physics at the Lise Meitner Secondary Vocational Center visited the institute. The teenagers were particularly keen to find out the professions for with Fraunhofer IZM provides training and what the associated career paths and opportunities were likely?

Stefan Ast, one of Fraunhofer IZM's Training Officers, gave an overview of the profession microtechnologist and patiently answered all the questions. Then, a tour of the clean room and the various laboratories gave the teenagers an up-close overview of a microtechnologist's areas of work – live and in full color.

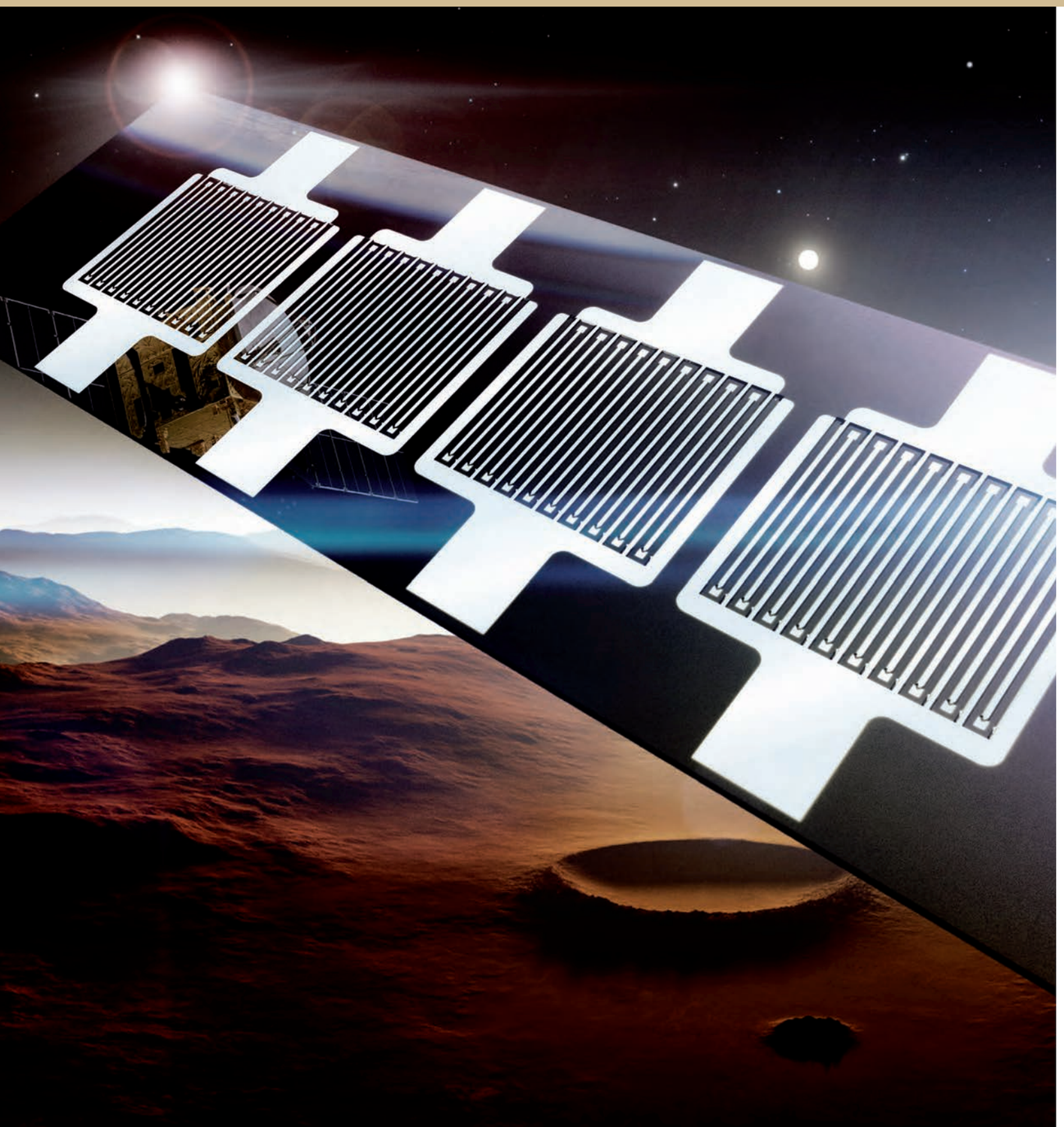
Girls up front – Girls' Day at Fraunhofer IZM
Participating in Girls Day has become a firm tradition at Fraunhofer IZM over the years. The participating staff always look forward to their inquisitive young guests. After a short introduction, the girls were treated to a tour of the institute. From the metallography lab, to right through to the clean room, they had the chance to watch Fraunhofer IZM technologists and technicians at work, and then also try their hand at electronics themselves. The girls each soldered a tea light, worked on and analyzed electronic components and assessed how suitable smart phones and tablets were for recycling refurbishment. It was an exciting day, which all participants, young and old, enjoyed.

»Intelligent sensor systems for autonomous driving«
The six-day summer school on intelligent sensor systems for autonomous driving was organized by OpTecBB with participation by various companies and institutes in Berlin and Brandenburg. On one of the days, the participants, mainly engineering and life science students in their fourth semester of study or later, visited Fraunhofer IZM.

Training achievements at Fraunhofer IZM
Despite the fact that, unusually, 2016 did not include "Best Apprentice" award, the year was still exceptionally successful. In 2016, for the first time, four – more than ever before – microtechnologists trained at Fraunhofer IZM and on completion of their studies as technicians were all kept on by the institutes.

The youngsters getting busy at Fraunhofer IZM' Girls' Day

FRAUNHOFER IZM FACTS & FIGURES



FRAUNHOFER IZM IN FACTS AND FIGURES

Financial Situation
2016 has been a more than satisfactory year for Fraunhofer IZM as a result of the successful launch of several high-profile industry cooperation ventures. Income from work with German and international enterprises and industry association has increased to 14.4 million euros, amounting to an increase of a full 29.7 percent. Fraunhofer IZM has been able to fund 48.8 percent of its costs from its own industry projects.

The revenue of the Fraunhofer IZM grew by 4.8 percent to a total of 29.5 million euros in 2016. The volume of publicly funded projects has remained unchanged at a level of 10.8 million euros.

Fraunhofer IZM has been able to cover 85.5 percent of its operating budget from external income. In total, the Institute was able to invest 25.2 million euros in its current projects.

Investment in Facilities
In 2016, Fraunhofer IZM invested a total of 1.3 million euros of its funds into maintaining or upgrading the Institute's facilities.

These funds were used to substantially expand Fraunhofer IZM's technical resources and increase the efficiency of the existing facilities with carefully selected investments.

Another 0.6 million euros were invested in smaller-scale construction work, including targeted improvements and changes intended to improve the work of Fraunhofer IZM and comply with new health and safety requirements.

HR Development
Its commercial success again allowed Fraunhofer IZM to create new jobs in 2016. The Institute now employs 235 members of staff (up from 227) at its sites in Berlin, Dresden/Moritzburg, and Oberpfaffenhofen. As of January 1, 2017 the Oberpfaffenhofen Training and Analysis Center has become part of the Fraunhofer Research Institution for Microsystems and Solid-State Technologies EMFT.

The Institute also offers students an opportunity to combine their studies with applied research work in the offices and lab facilities of the Fraunhofer IZM. By the end of 2016, a total of 132 interns, diploma students, and student assistants passed through the doors of Fraunhofer IZM.

Fraunhofer IZM remains committed to offering apprenticeships to talented young people. In 2016, ten apprentices were being trained at the Institute as microtechnologists, office communications assistants, and office management assistants.

Fraunhofer IZM 2016	
Turnover	29.5 million euros
External revenue	25.2 million euros (85.5 percent of turnover)
Sites	Berlin, Dresden and Oberpfaffenhofen
Number of staff	377 (including 132 student assistants master students, interns and 10 apprentices)

AWARDS

Hotting up high-temperature electronics - Matthias Hutter honored with Fraunhofer IZM Research Award
Solar power systems, wind turbines, hybrid cars: all devices in which direct current is converted into alternating current heat up. The power electronics in the power inverters have to withstand temperatures above 240 degrees Celsius - as does the packaging technology that interconnects the individual components in the modules. As expert in metallic bonding, Fraunhofer IZM's Dr. Matthias Hutter has been exploring new types of bonds that ready electronics for high operating temperatures for over 20 years. The technologies he has helped advance electronic assembly soldering and corresponding failure analysis, transient liquid phase soldering and silver sintering. The 45-year-old's novel insights over the course of his career have been groundbreaking in both research and industry circles. Hutter extended his research and presented an entirely new soldering technology: a special type of tin-copper joint that increases the melting point in power units to above 400 degrees Celsius. Moreover, the unit's lifetime and thus reliability increase the less the maximum temperature is reached. Hutter's technological advance was registered as patent in 2010 - not the first or the last of his contributions to patents. His transient liquid phase soldering technique garnered him particular praise from automotive industry, as it was able to replace lead solder applications. For these achievements Matthias Hutter was presented with Fraunhofer IZM Research Award 2016 on December 16.

Rolf Aschenbrenner receives SEMI Europe Award 2016
Rolf Aschenbrenner, deputy director of the Fraunhofer IZM, has received the European SEMI Award for 2016 for his contribution to 3D integration technologies. He was presented with the award by SEMI Europe president Laith Altimime at the SEMI Industry Strategy Symposium in Munich on March 6, 2017. Aschenbrenner shares the honor with two long-standing cooperation partners of Fraunhofer IZM – Eric Beyne from imec in Belgium and Gilles Poupon from cea-LETI. While Beyne and Poupon pursue a more silicon-based approach to 3D integration, Aschenbrenner is widely recognized for his work in the field of assembly for embedding and panel level packaging technologies.

The three winners were nominated and selected by peers within the international semiconductor community in recognition of their outstanding contributions in the field of 3D Integration.

Rolf Aschenbrenner joined Fraunhofer IZM in 1994. Together with Martin Schneider-Ramelow he heads the institute's department System Integration and Interconnection Technologies and he is the deputy director of the institute. He has served on various committees, and in 2013 he received the IEEE CPMT David Feldman Award.

IMAPS Technical Achievement Award for Ivan Ndip
The 2016 John A. Wagnon Technical Achievement Award was presented to Dr. Ivan Ndip for his outstanding technical contributions in the field of electromagnetic modeling, RF design and optimization of microelectronic components, modules and systems, especially for communication and radar sensor applications.

This prestigious award was handed over to Dr. Ndip by IMAPS President, Susan Trulli, on October 11, 2016 during the award presentation ceremony at the 49th International Symposium on Microelectronics in Pasadena, California, USA.

Dr. Ndip leads the department of RF & Smart Sensor Systems at Fraunhofer IZM. He has authored and co-authored more than 150 scientific publications in referred journals and conference proceedings. He is a recipient of numerous best paper awards at leading international conferences, and the Tiburtius-Prize (Preis der Berliner Hochschulen), awarded yearly for outstanding Ph.D. dissertations in the state of Berlin, Germany. Dr. Ndip has taught professional development courses in the area of RF and high-speed system design to hundreds of practicing engineers worldwide. He also teaches graduate courses in the faculty of Electrical Engineering and Computer Science at the Technische Univeristät Berlin. Dr. Ndip is a Fellow, and Life Member of IMAPS, as well as a Senior Member of IEEE.

Thomas Löher and team win Best Paper Award at 2016 CPMT
Dr. Thomas Löher together with Stefan Karaszkiewicz, Lars Böttcher and Dr. Andreas Ostmann won Best Paper Award at the ICSJ, which was held November 7-9, 2016 in Kyoto. The ICSJ is organized by the "Components, Packaging and Manufacturing Technology Society" (CPMT) and is Japan's annual IEEE CPMT symposium. It is one of the world's leading conferences on packaging technology.

The paper, entitled "Compact power electronic modules realized by PCB embedding technology", presented new technological approaches to embedding power electronic components in PCBs. Löher and his colleagues discussed the specific demands these approaches make on design and components, drawing on real-life experience. They also gave an overview of ongoing challenges and strategies for solving these, as well as current trends in development.

IMAPS honors Martin Schneider-Ramelow with Fellow of the Society Award
For his years of dedication and support in various leadership roles Martin Schneider-Ramelow was honored as a Fellow of the International Microelectronics Assembly and Packaging Society (IMAPS) during the 49th International Symposium on Microelectronics that took place in Pasadena, USA, from Oct. 10-14, 2016. The Fellow of the Society Award is the highest distinction IMAPS can bestow on a member.

Prof. Schneider-Ramelow has made significant scientific contributions in the field of microelectronic packaging, particularly with regard to the quality and reliability of wire bonds. Together with Rolf Aschenbrenner he leads the department System Integration and Interconnection

1 *Award recipient Dr. Matthias Hutter (center) with the Chair of the Award Committee Prof. Martin Schneider-Ramelow (left) and Institute Director Prof. Klaus-Dieter Lang (right)*

2 *SEMI Europe President Laith Altimime presents Rolf Aschenbrenner with the SEMI Europe Award*

3 *Thomas Löher receives the Best Paper Award at the CPMT symposium in Kyoto*

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Technologies (SIIT) at Fraunhofer IZM Berlin. He is also a lecturer at the Technical University Berlin, where he currently teaches graduates courses on Basic Materials and Physical-chemical Principles of System Integration. He has authored and co-authored numerous scientific papers and is a member of the program committees, of many international conferences. In 2015, for example, he was the General Chair of the European Microelectronic Packaging Conference in Friedrichshafen.

Klaus-Dieter Lang receives the DVS Ring of Honor

In recognition of his exceptional technical and scientific contributions and his unfailing commitment to the association's work, Professor Klaus-Dieter Lang, Director of the Fraunhofer IZM, has been awarded the Ring of Honor for the German Welding Society »Deutschen Verbands für Schweißtechnik und verwandte Verfahren e.V.«. The long-standing member of the executive council of the DVS received the ring from the hands of the DVS President Professor Heinrich Flegel as part of the »Consolidated Welding Technology Conference« on September 19, 2016 in Leipzig.

The DVS has been active since 1897 as a technology and science association dedicated to all joining, cutting, and coating technology. With around 19,000 members and more than 340 educational institutes, the association is committed to promoting research, young professionals, technology, standardization, and certification. The DVS Ring of Honor has been awarded since 1954 for outstanding contributions to the science and practice of innovative welding technology.

Fraunhofer Cluster 3D Integration honored with InCites Award

The Fraunhofer cluster 3D Integration headed by the Fraunhofer IZM-ASSID institute has won the coveted »2016 3D InCites Award for Excellence in 3D Packaging Technologies« in the »Research Institute of the Year« category at this year's SEMICON West expo. Beating the other high-profile candidates Leti (France) and IME (Singapore), the cluster and its constituent institutes IZM-ASSID, ENAS, IKTS, IIS/EAS, and IPMS gained international recognition for the exceptional research achievements in the field of wafer-level 3D system integration. Cluster chairman M. Jürgen Wolf received the award on behalf of the cluster on July 12, 2016.

German Industry Innovation Award for flexible ultra-thin glass

Glass, thinner than a human hair, that bends and flexes? What sounds like science fiction has now become reality with the aid of Fraunhofer IZM. Schott AG, one of the world's leading producers of technical glass and long-standing research partner of Fraunhofer IZM, has won the coveted German Industry Innovation Award in the large company category for its new ultra-thin glass. On receiving the award in Darmstadt on April 16, 2016, Dr. Frank Heinricht, Chairman of the Management Board of Schott AG, paid tribute to the close partnerships with national institutes and companies in his acceptance speech – also in recognition of the value of these partnerships for maintaining Germany's position as a leading research and technology nation. The unique material – half as thick as a human hair at only 25 µm – combines stability with flexibility and promises a wide range of applications: Pliant and malleable touchscreens that are near-shatterproof, or improved fingerprint recognition for smartphone encryption with much thinner scanner glass. On top of these visible and touchable applications, the new material paves the way for new technology under the surface, as ultra-thin glass has great potential for traditional semiconductor technology or novel battery solutions.

1 DVS President, Prof. Heinrich Flegel presents Prof. Klaus-Dieter Lang with the DVS Honor Ring

2 M. Jürgen Wolf, Chairman of the Fraunhofer Cluster 3D Integration (left), together with other recipients of the 2016 3D Incites Awards

3 Fraunhofer IZM partner Schott AG is presented with the »Innovation Award of the German Economy«

»LCA to go« certified as 2016 »Werkstatt N« project

The German Council for Sustainable Development, commissioned by the German federal government, has certified the Fraunhofer IZM initiative »LCA to go« as a »Werkstatt N« project. The certification showcases the diversity, energy and creativity of the sustainable development sector by bringing together projects and initiatives with outstanding ideas.

Many hurdles remain on the path to a sustainable society. Often the technology and know-how for delineating and accurately describing problem areas are lacking. A necessary first step towards sustainability is quantifying the environmental impact of products, workflows or entire enterprises in lifecycle assessment. Many SMEs do not have the resources to meet this challenge alone.

Fraunhofer IZM's »LCA to go« has developed web tools for a variety of business sectors, which can be used to perform lifecycle assessments of products or business models in just half a day. Such rapidly won insights form the basis for further optimization and communication with customers and business partners. More than 100 companies have already benefited from »LCA to go«, including Fairphone and MicroPro.

BEST PAPERS, EDITORIALS, DISSERTATIONS

Best Paper

»Best Interactive Paper« at EPTC 2016
The Fraunhofer IZM scientists Kevin Kröhnert, Oswin Ehrmann, Klaus-Dieter Lang, Piotr Mackowiak and Ha-Duong Ngo won the Best Interactive Paper Award 2015 for their paper »HIPIMS in Full Face Erosion Circular Cathode for Semiconductor Applications« at the Electronics Packaging Technology Conference (EPTC). The award was only announced and presented the following year at the EPTC 2016.

»Best Academic Paper« for Tanja Braun at EPTC 2016
A paper by Fraunhofer IZM scientist Tanja Braun »Material and Process Trends Moving From FOWLP to FOPLP« was also singled out for recognition at EPTC 2016. The work deals with the trend from wafer to panel sizes in fan-out processes, which Fraunhofer IZM has played a crucial role in advancing. Braun's co-authors were Fraunhofer IZM's Steve Voges, Michael Töpper, Martin Wilke, Uwe Maaß, Max Huhn, Karl-F. Becker, Stefan Raatz, J.-U. Kim, Rolf Aschenbrenner and Klaus-Dieter Lang, along with three colleagues from the US-based company Electronic Materials.

Karsten Schischke receives Best Paper Award
A paper by Fraunhfoer IZM scientist Karsten Schischke and colleagues from the association reUse entitled »Re-use: Achieving Sustainable Smart Mobile Devices Lifecycles Through Advanced Re-design, Reliability, and Re-use and Remanufacturing Technology« won Best Award at the 8th International Scientific Conference »Management of Technology (MOTSP) – Step to Sustainable Production«, 2016, in Poreč, Croatia.

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Editorials

PLUS Journal (Eugen G. Leuze Verlag)
Lang, K.-D. (Member of the Editorial Board)

International Journal of Microelectronics and Electronic Packaging
Ndip, I. (Associate Editor)

Smart Systems Integration 2016 Conference Proceedings
Lang, K.-D. (Co-Editor)

Electronics Goes Green 2016 Conference Proceedings
Lang, K.-D. (Co-Editor)
Nissen, N. (Co-Editor)
Chancerel, P. (Co-Editor)

Dissertations

Ehrhardt, C.
Transient Liquid Phase Soldering as Interconnection Technology for Power Semiconductors in High Temperature Applications

Schörle, S.
System-oriented Impedance Simulation of a High-voltage Board Network using the Example of an Automobile

Wilke, M.
Plasma Etching for the Generation of Silicon Through-Vias with Controlled Horizontal Angle for Three-dimensional Integration in Wafer Level Packaging

LECTURES

Technische Universität Berlin

Dr. B. Curran
- Design, Simulation and Reliability of Microsystems
- Electromagnetics for Design and Integration of Microsystems

Dr. R. Hahn
- Miniaturized Energy Supply / Energy Harvesting

Dr. J. Jaeschke
- FEM-Simulation of Micro Sensors and Actuators
- Reliability of Microsystems
- Technologies and Basic Materials for Microsystem Technology

Prof. K.-D. Lang
- Assembly Technologies für Microelectronics and MST
- Assembly of Multifunctional Electronic Systems
- Seminar Packaging and Assembly Technologies for Microelectronics

Dr. I. Ndip
- Numeric Computation of Fields
- Electromagnetic Compatibility in Electrical Systems

Prof. H. Ngo, Dr. J. Jaeschke
- Manufacturing Technologies for Semiconductor Sensors

Dr. N. F. Nissen, Dr. A. Middendorf
- Environmentally Compatible Design of Electronic Products

Prof. M. Schneider-Ramelow
- Basic Materials of System Integration

Dr. T. Tekin
- Photonic Packaging
- Antenna Simulation
- Antennas

Aalborg University

Prof. E. Hoene
- Modern Power Semiconductors and their Packaging

HTW, Hochschule für Technik und Wirtschaft Berlin

Dr. H. Walter
- Basic Materials for Microsystem Technologies

Dr. R. Hahn
- Miniaturized Energy Supply Systems

Dr. H. Schröder
- Photonics

Dr. T. Tekin
- Nanotechnology

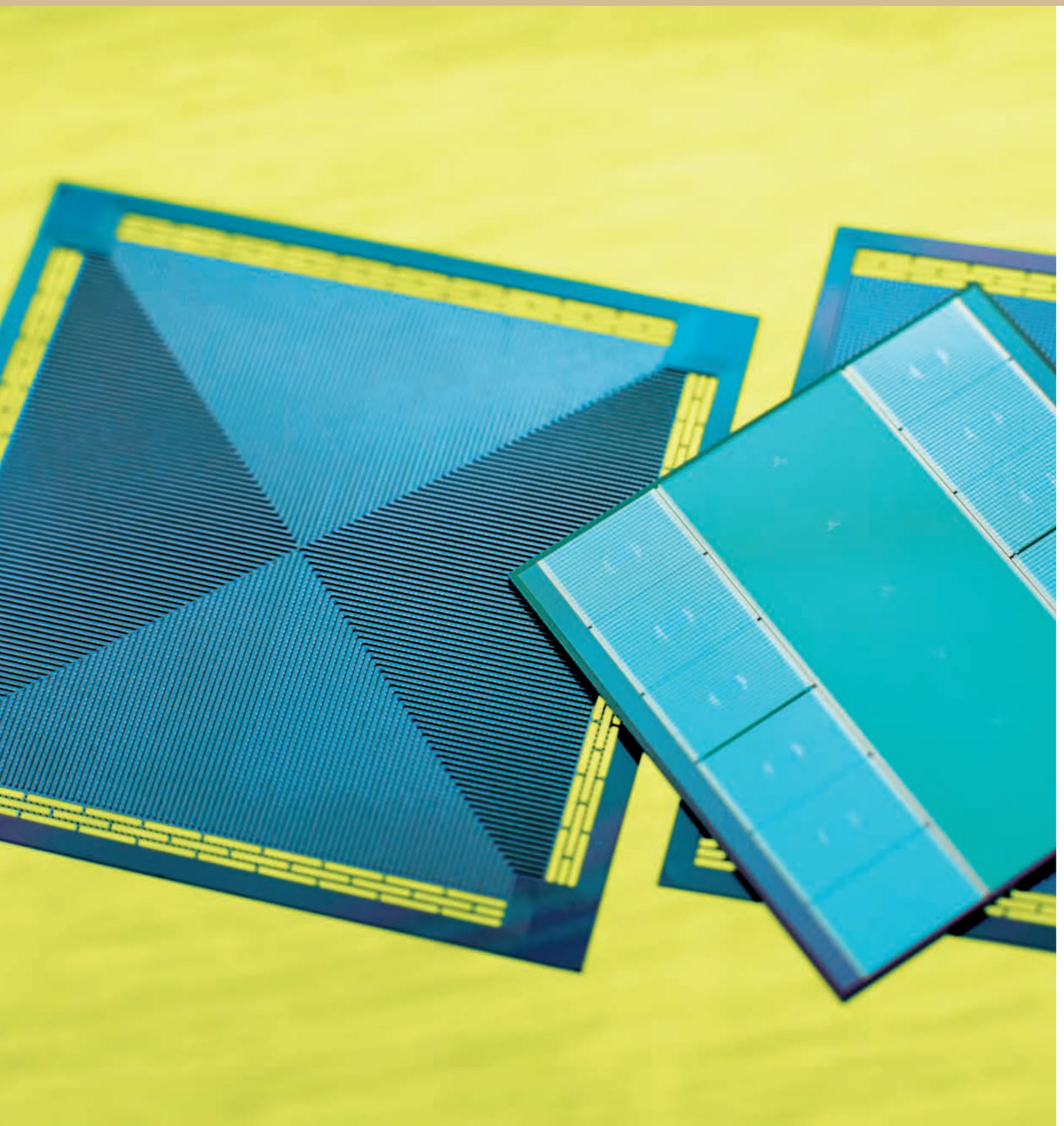
MEMBERSHIPS (SELECTION)

4M Multi Material Micro-Manufacture Association	E. Jung	Representative of Fraunhofer IZM
AMA Fachverband Sensorik, Wissenschaftsrat	Dr. V. Großer	Member
CATRENE – EAS Working Group on Energy Autonomous Systems	Dr. R. Hahn	Member
Cluster Optik Berlin/Brandenburg Photonics for Communication and Sensors	Dr. H. Schröder	Spokesman
DVS - German Welding Society	Prof. K.-D. Lang	Executive Board
DVS - German Welding Society Working Group »Bonding«	Prof. M. Schneider-Ramelow	Chairman
Electronic Components and Technology Conference ECTC	Dr. H. Schröder	Optoelectronics Committee Chair
EOS European Optical Society	Dr. H. Schröder	Member
EURIPIDES Scientific Advisory Board	Prof. K.-D. Lang, M. J. Wolf	Member
European Photonic Industrial Consortium (EPIC)	Dr. H. Schröder	Representative Fraunhofer IZM
European Technology Platform on Smart System Integration (EPoSS)	H. Pötter	Member Executive Committee
IEEE Component, Packaging and Manufacturing Technology Society Technical Committees: Green Electronics Photonics - Communication, Sensing, Lighting IEEE CPMT German Chapter	R. Aschenbrenner Dr. N. F. Nissen Dr. T. Tekin R. Aschenbrenner	Fellow Technical Chair Technical Co-Chair Chair
IMAPS Signal/Power Integrity Committee	Dr. I. Ndip	Chair
IMAPS Executive Council	Dr. I. Ndip	Director
IMAPS Germany	Prof. M. Schneider-Ramelow	President
International Electronics Manufacturing Initiative iNEMI	R. Aschenbrenner	Representative of Fraunhofer IZM
International Technology Roadmap Semiconductors (ITRS)	M. J. Wolf	Chairman Europe
International SSL Alliance (ISA)	Dr. R. Jordan	International Liaison Chair China SSL
IVAM Group Wearables	E. Jung	Technical Chair
Lange Nacht der Wissenschaften e. V. Berlin	H. Pötter	Representative of Fraunhofer
OpTec Berlin Brandenburg	Prof. K.-D. Lang	Executive Board
Photonics21 – Work Group Emerging Lighting, Electronics and Displays	Dr. R. Jordan Dr. H. Schröder	Members
Photonics West Optical Interconnects Conference	Dr. H. Schröder	Chair
SEMI Group Award Committee	Prof. K.-D. Lang	Member
Semiconductor Manufacturing Technology Sematech	M. J. Wolf	Member
Silicon Saxony e. V.	M. J. Wolf	Member
Smart Lighting	Dr. R. Jordan	Steering Committee
SMT/HYBRID/PACKAGING Congress	Prof. K.-D. Lang	Head of Scientific Committee
VDMA, Fachverband Electronics, Micro and Nano Technologies	Dr. V. Großer	Member
Wissenschaftlich-technischer Rat der Fraunhofer-Gesellschaft	Dr. N. F. Nissen	Representative of Fraunhofer IZM
Zentrum für Mikrosystemtechnik Berlin	Prof. K.-D. Lang	Spokesman of the Board

COOPERATION WITH INDUSTRY (SELECTION)

Advanced Semiconductor Engineering Inc.	Kaohsiung (TPE)
AEMtec GmbH	Berlin
AIM Infrarot-Module GmbH	Heilbronn
Airbus Defense & Space	Ulm
Allegro Micro Systems LLC	Worcester (USA)
alpha-board gmbh	Berlin
Altatech	Saint Ismier (FR)
AMO GmbH	St.Peter / Hart (A)
Apple Inc.	Cupertino, Austin (USA)
Applied Materials Inc.	Santa Clara (USA)
Asahi Glass Co., Ltd.	Tokyo (J)
AT&S AG	Leoben (A)
Atotech Deutschland GmbH	Berlin
ATV Technologie GmbH	Vattenstetten
AUDI AG	Ingolstadt
Austriamicrosystems AG	Unterpremstätten (A)
Awaiba GmbH	Nürnberg
Baker Hughes INTEQ GmbH	Celle
Baumer-Hübner GmbH	Berlin
Besi Netherlands B.V.	Duiven (NL)
Blackrock Microsystems LCC	Salt Lake City (USA)
BMW AG	München
Bosch	Renningen, Reutlingen
BrewerScience	Rolla (USA)
Broadcom Ltd.	Regensburg
Brose Fahrzeugteile GmbH & Co. KG	Coburg
Bundesdruckerei GmbH	Berlin
Cascade Microtech GmbH	Thiendorf
COGO Optronics GmbH	Berlin, Boulder (USA)
Coinbau GmbH	Dresden
CONTAG GmbH	Berlin
Continental AG // Continental Automotive GmbH	Regensburg
Converteam SAS	Berlin
Corning Incorporated	Corning (USA)
Daimler AG	Stuttgart
Datacon GmbH	Radfeld (A)
Denso Corp.	Kariya (J)
Disco Corporation	Tokyo (J)
First Sensor AG	Berlin, Dresden
Endress & Hauser GmbH & Co. KG	Maulburg
ESYS GmbH	Berlin
EV Group (EVG)	St. Florian a.I. (A)
Evatec Advanced Technologies AG	Trübbach (CH)
Excelitas Technologies Corp.	Feldkirchen
FiconTEC Service GmbH	Achim
Finisar	D, USA
Fujifilm Electronic Materials	EU, USA
Fujitsu Technology GmbH	Augsburg
Gesellschaft für Maschinendiagnose mbH	Berlin
GLOBALFOUNDRIES INC.	Dresden
HELLA Fahrzeugkomponenten GmbH	Bremen
Heraeus Deutschland GmbH & Co. KG	Hanau
Hitachi Chemical DuPont MicroSystems Ltd.	D, J, USA
Höft & Wessel AG	Hannover
Huawei	CN
IBM Research	Rueschlikon (CH)
Idex	Fornebu (NO)
IMC Messsysteme GmbH	Berlin
IMST GmbH	Kamp-Lintfort
Infineon Technologies AG	D
Invensas	Santa Clara (USA)
Isola USA Corp.	Chandler (USA)
Jenoptik/ESW GmbH	Hamburg-Wedel
John Deere & Company	Mannheim
Leuze electronic GmbH & Co. KG	Owen
Magneti Marelli	I
Maicom Quarz	Posterstein
Mapper Lithography B. V.	Delft (NL)
MDISchott Advanced Processing GmbH	Mainz
MED-EL GmbH	Innsbruck (A)
Micro Systems Engineering Inc.	D, USA
Nexans Power Accessories France	Donchery (FR)
NXP Semiconductors AG	Hamburg, Eindhoven (NL)
OCE	NL
Olympus Deutschland GmbH	Hamburg
ON Semiconductor Belgium BVBA	Oudenaarde (B)
Osram Opto Semiconductors GmbH	Regensburg
Pac Tech Packaging Technologies GmbH	Nauen
PANalytical B.V.	Almelo (NL)
Philips Technology GmbH	Aachen
Ramgraber GmbH	Brunnthal
Robert Bosch GmbH	Reutlingen, Stuttgart
Rohde und Schwarz	Berlin
Samsung	D, ROK
Schaeffler Technologies GmbH & Co. KG	Herzogenaurach
Schleifring GmbH	Kaufbeuren
Schlumberger AG	F, USA
Schneider Electric	F
Schweizer Electronic AG	Schramberg
Semikron GmbH	Nürnberg
Semsysco GmbH	Salzburg (A)
Sensitec GmbH	Lahnau
Siemens AG, Siemens Healthcare	D
SPTS Technologies Ltd.	Newport (UK)
Süss MicroTec AG	Garching, München
Swissbit Germany AG	Berlin
TDK-EPCOS AG	München
Thales Group	F
The Dow Chemical Company	USA
TRUMPF Deutschland GmbH	Ditzlingen (DL)
U-Sound	A
Valeo GmbH	Wemding
Vectron International GmbH	D
Vectura Group plc	Chippenham (GB)
Volkswagen AG	Wolfsburg
Würth Elektronik GmbH & Co. KG	Niedernhall, Rot a.S.
X-Fab Semiconductor Foundries AG	Erfurt
ZF Luftfahrt	Calden

PUBLICATIONS (SELECTION)



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4-Channel Mid-Board-Optical Transceiver. The opto-electrical components are flip-chip mounted on a glass interposer. The glass inteposer is HF-optimized for frequencies up to 40 GHz. The electrical signals are transmitted via through glass vias (TGVs) to a PCB on the backside. Polymer lenses are placed on the glass interposer for the beam shaping of the optical signals which are transmitted through the glass into an electro-optical circuit board (EOCB). (Partners: Amphenol FCI; U-L-M Photonics; Universität-Ulm)