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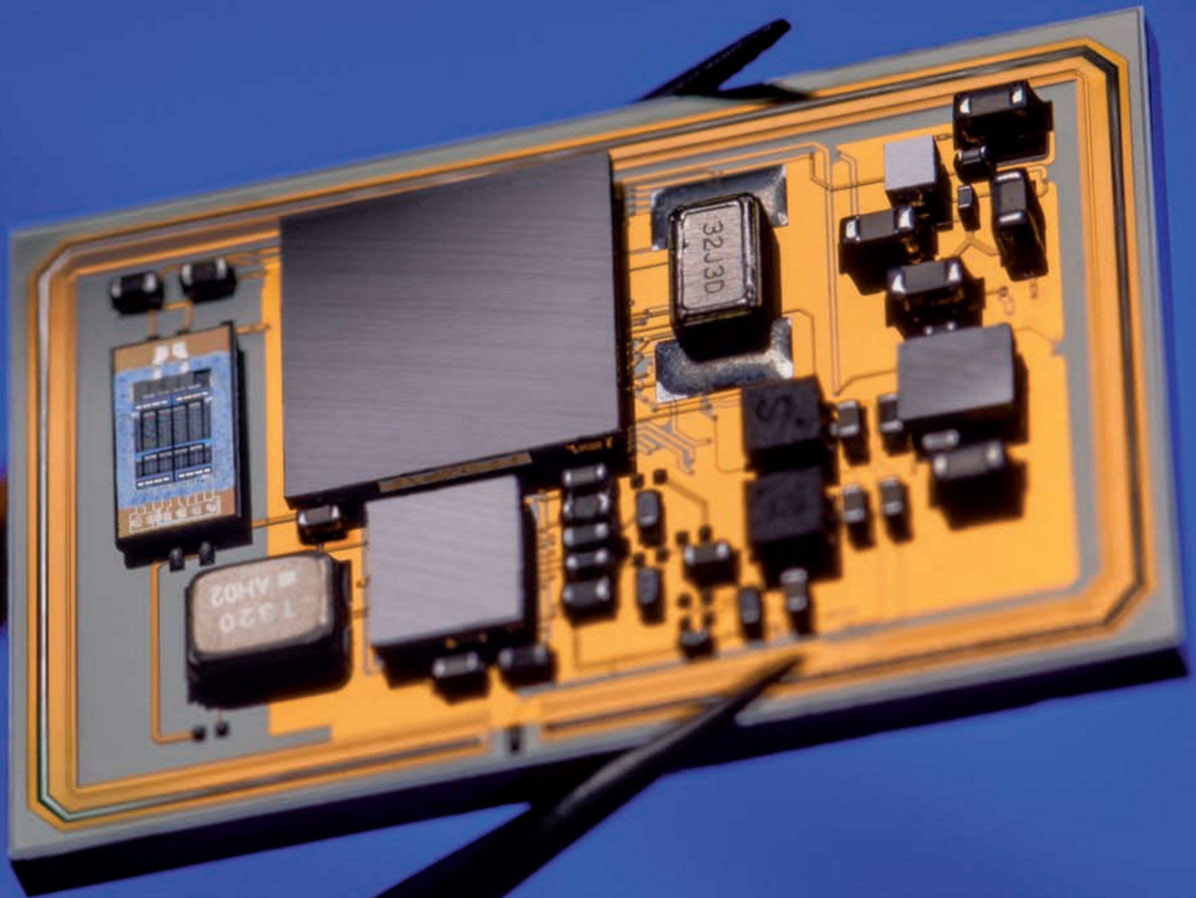
FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM




# ANNUAL REPORT 14/15

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# INTEGRATING HARDWARE AND SOFTWARE FOR THE APPLICATION OF TOMORROW

# PREFACE

A review of 2014 shows that the year was a successful one for Fraunhofer IZM. Despite structural changes and a research landscape with somewhat difficult conditions, we were able to advance the institute's research and strategic position. In summary, the year included a number of important milestones.

Firstly, more intensive cooperation with partners from industry contributed to our outstanding research results. Companies from a diverse range of industry sectors drew on our knowhow in system integration for multifunctional, reliable, miniaturized and energy-efficient solutions. Our system integration technologies were called on in almost all industry application areas – particularly in automotive technology and medical engineering. Close cooperation with German and European companies was the cornerstone of this success. However, projects with the Americas and Asia, particularly, the USA, Japan, Korea and Taiwan also increased.

A timely focus on international key topics also contributed greatly to the positive results. This was evident at Fraunhofer IZM-ASSID in Dresden, which was integrated into the Fraunhofer Model and advanced significantly in 2014. This allowed us to take a leading role in implementing 3D integration and new solutions for wafer-level packaging in industry settings.

Our success in collaborations with project partners was numerous. Outstanding results were achieved in projects such as the further development of 3D structures using TSVs and interposers, the development of high-reliability contacts for vehicles (e.g. »ROBE« – Robust Bonds in Electric Vehicles), the embedding of power modules (e.g. »Very Fast Switching« for the miniaturization of solar converters) or the assembly of functional systems in medical engineering (e.g. »Health Coach« – a sensor system for monitoring a patient's vital signs).

Apart from our solid expertise in advanced assembly and packaging technologies, innovative, creative research and development of application-oriented system integration remained a key focus. We were exceedingly well prepared for a wide range of new challenges arose, particularly in the areas of the Internet of Things and Industry 4.0. A key provision was the new Center for Adaptive System Integration (AdaptSys).

Comprehensive investment and construction measures, financed by the EU, German federal ministry of education and research (BMBF) and the Land Berlin will be completed and go into full operation this year. As part of this, Fraunhofer IZM will have two complete processing lines, suitable for implementation in the industry setting, available for wafer- and panel-level integration. This takes the institute a significant step forwards. We will be able to provide production-oriented technology solutions for high-tech systems – a unique achievement in this area of applied research. For example, using the new large-area panel molder, we will be able to process industry-compatible sizes up to 456 x 610 mm² for a wide range of applications cost-efficiently and at high-quality.

This will allow Fraunhofer IZM to take great strides into the future, in order to continue providing new approaches and techniques that meet international standards for application-oriented, multifunctional and very-high reliability system integration technologies.

At this point, I'd like to thank all our partners from industry and science, the project executing bodies, and federal and Länder ministries for their outstanding cooperation and their trust in our work. However, none of this would have been possible without the dedication and expertise of our institute team – my warmest thanks go to the Fraunhofer IZM staff.

This annual report covers a selection of the previous year's research and development results and highlights areas we intend to focus on in the future.

I hope all our readers enjoy the overview, find inspiration in our latest work and perhaps even seek out further discussion of the technological possibilities with us in person.

Warmest regards,

Prof. Klaus-Dieter Lang

# FRAUNHOFER IZM


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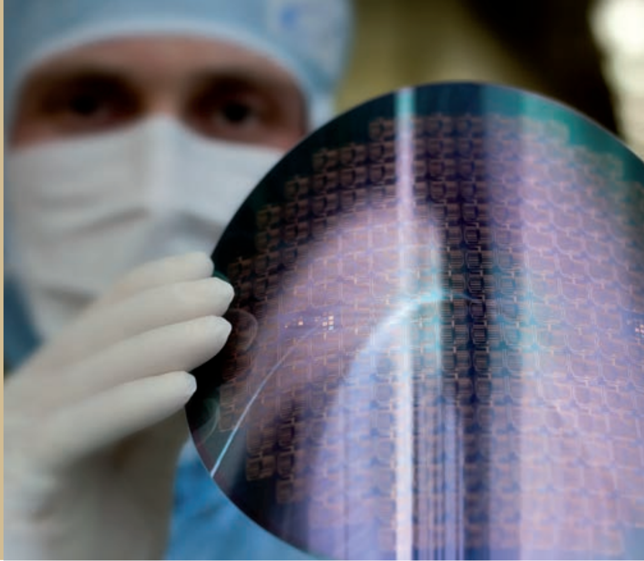
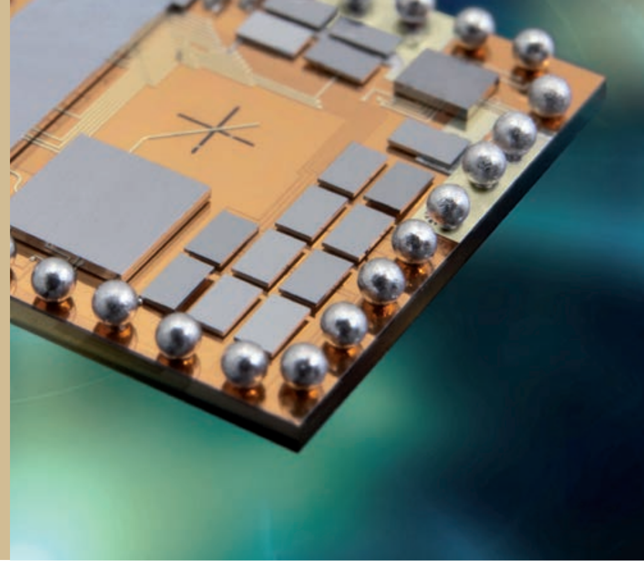




# FRAUNHOFER – A STRONG NETWORK

**The Fraunhofer-Gesellschaft**

Fraunhofer IZM is one of 66 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 almost 24,000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2 billion euros. Of this sum, 1.7 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 Microelectronics**

Fraunhofer has pooled the competences of institutes working in related subject areas in the seven Fraunhofer Groups Information and Communication Technology, Life Sciences, Microelectronics, Light & Surfaces, Materials and Components, Production, and Defence and Security. Fraunhofer IZM is a member of the Fraunhofer Group Microelectronics and is your partner for packaging and smart system integration.

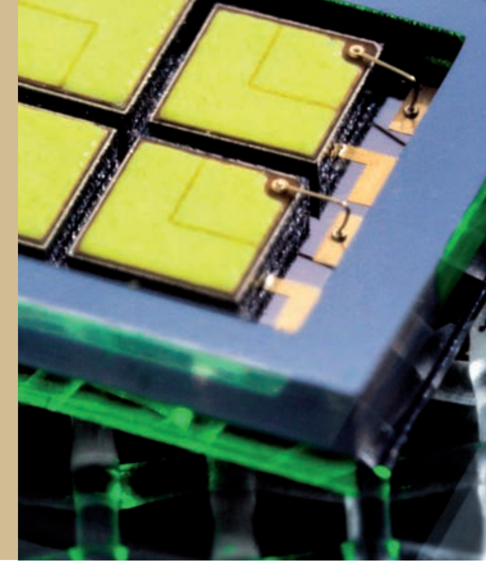
The Fraunhofer Group Microelectronics VµE has been coordinating the activities of Fraunhofer Institutes working in the fields of microelectronics and microintegration since 1996. Its membership consists of eleven institutes as full members and five as associated members, with a total workforce of more than 3,000 and a combined budget of roughly 345 million euros. The purpose of the Fraunhofer VµE is to scout for new trends in microelectronics technologies and applications and to integrate them in the strategic planning of the member institutes.

The group pools the core competences of its member institutes in the following cross-sectional fields of competence: design for smart systems, semiconductor-based technologies, system integration technologies, power electronics and energy supply, sensors and RF and communication technologies. The application-orientated business areas are:

- Ambient Assisted Living, Health & Well-being
- Energy Efficient Systems
- Mobility & Urbanization
- Smart Living

www.mikroelektronik.fraunhofer.de/en





# 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.

As of 2015, our customers have a business development team of four 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 350 and saw a turnover of 27.7 million euros in 2014, of which 82.1 percent was derived from contract research. It has three branches in Germany. Apart from its headquarters just north of Berlin Mitte, it also maintains sites in Dresden and Munich, both strategically important centers for electronics development and manufacturing.

Resarch | Design & Concept | Feasibility | Technology | Process | Prototyping | Reliability Evaluation | Qualification & Test

# 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.

# 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 project. 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. Under the stewardship of Professor Herbert Reichl, the institute was one of the world's first 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. 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 at high integration densities to increase flexibility and yield while reducing costs. 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 microsystem technology. Key areas of research include:

- Materials and processes for integration technologies on wafer, chip and substrate level
- Nano interconnect technologies
- Polytronic microsystems
- Reliability from nano structures up to the system
- Sustainable technologies
- System design and modeling

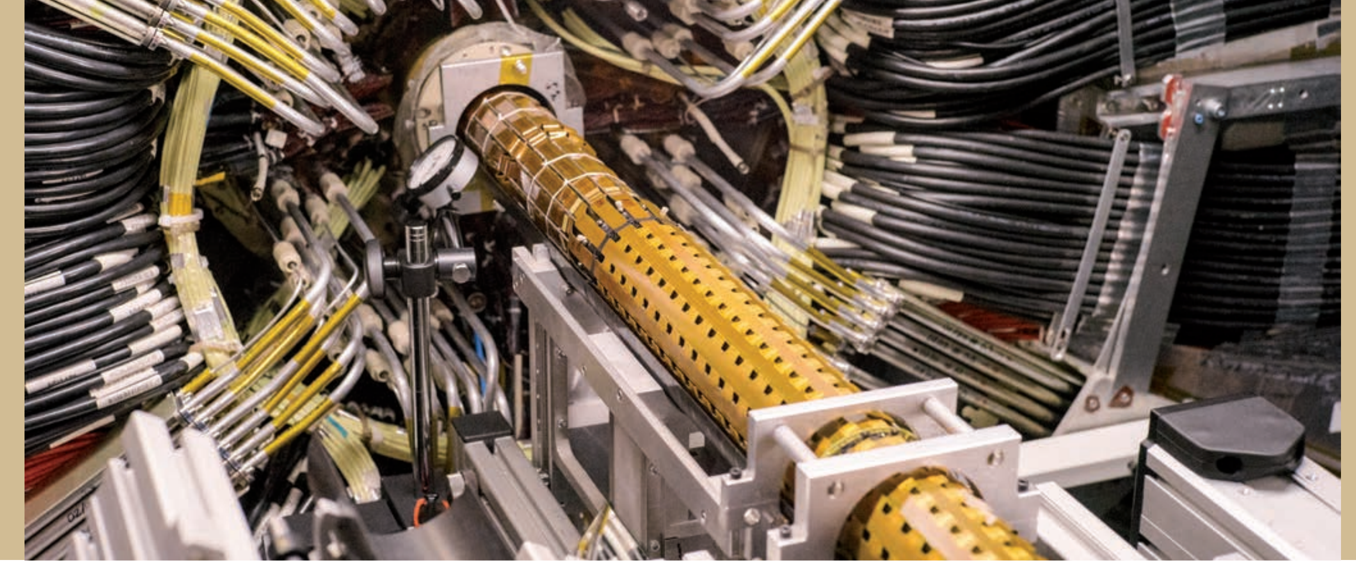
Fraunhofer IZM also supports teaching at Technische Universität Berlin by offering students additional seminars and the opportunity to participate in national and international research projects.

**Cooperation with TU Berlin in German Research Foundation projects**
Working with universities on basic research projects advances and deepens Fraunhofer IZM's skills and know-how. One example is our collaboration with Prof. Dr. Christian Schuster of the Hamburg University of Technology in the project »Electrical modeling and design of through silicon vias for integrated systems«, funded by the German Research Foundation (DFG). Together we are developing fast computation methods for calculating signal transmission using TSVs. The results help establish TSV as a technology in contract research for industry.

**Fraunhofer IZM-ASSID cooperates with the Electronic Packaging Laboratory (IAVT) at TU Dresden**
In July 2014 Fraunhofer IZM-ASSID and TU Dresden (Electronic Packaging Laboratory, IAVT) established a joint Assistant Professorship. The goal of the new position, held by Professor Iuliana Panchenko, is to foster a close link between basic and applied research. Professor Panchenko will set up a new research group at IZM-ASSID and a young researchers group comprising Master's and PhD students at TU Dresden.

The main research foci are new material systems and interconnect technologies for high-density current and heat transport for 3D integration (micro- and nanoscale materials, carbon-based materials, bumpless interconnects), experimental proof of reliability, microstructure analysis and reliability predictions by FEM. Concurrently, the lecture »Materials and Reliability« (course module »Functional materials for Electronics Packaging Technologies«), a lab course and an excursion to IZM-ASSID during the summer term will be offered for fourth-year students.

| Some of Fraunhofer IZM's other university partners |
|---|
| Technical University of Delft, The Netherlands |
| Technical University of Eindhoven, The Netherlands |
| Technical University of Tampere, Finland |
| Bologna University, Italy |
| Cárdiz University, Spain |
| Tokyo University, Japan |
| Twente University, The Netherlands |
| Uppsala University, Sweden |
| University College London, Great Britain |
| |
| Albert Ludwigs University Freiburg |
| Brandenburg University of Technology, Cottbus |
| Christian Albrechts University Kiel |
| Friedrich Alexander University Erlangen-Nürnberg |
| Humboldt University Berlin |
| Rheinische Friedrich Wilhelms University Bonn |
| Technical University Chemnitz |
| Technical University Darmstadt |
| Technical University Dresden |
| Berlin University of the Arts, Communications and Marketing |
| University of Heidelberg |
| University of Potsdam |
| University of Rostock |



# INTERNATIONAL RESEARCH COOPERATIONS

**German-Spanish cooperation on Ambient Assisted Living**
Fraunhofer IZM has been researching Ambient Assisted Living (AAL) and medical engineering together with Spanish research and development partners for several years now. Several EU projects have already been initiated with Universidad de Cadiz, focusing on AAL and the link between the health care sector and gentle tourism.

With the Barcelona Digital Technology Center (BDIGITAL) Fraunhofer IZM developed innovative concepts in patient care as part of the joint project SAPPHO. BDIGITAL also facilitates Fraunhofer IZM's foothold in the economically strong region of Catalonia. In turn, our institute paves the way for the Spanish institute's access to Germany-based SMEs interested in international collaboration.

**Green Economy: Research into highly efficient power electronics based on GaN**
Gallium nitride (GaN) components are suitable for the 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. In the joint project »E²COGaN – Energy efficient converters based on GaN-semiconductors«, seven partners from industry and research are investigating materials and circuitry that could be used as a basis for energy-efficient and cost-effective GaN power electronics. Alongside the three partners from industry – Audi AG, Robert Bosch GmbH und AZZURRO Semiconductors AG – the University of Kassel and the Fraunhofer institutes IMS and IISB are participating in the project. In this project, Fraunhofer IZM is developing technologies for wafer-level packaging and module integration. E²COGaN has funding of around 3.6 million Euros over three years from the Federal Ministry for Education and Research (BMBF) within the framework of »IKT 2020 – Research for Innovation«. E²COGaN is simultaneously part of the European technology initiative ENIAC, which includes 24 partners from ten European countries. This collaboration strengthens Europe's position as a worldwide leader in the field of electronics. Fraunhofer IZM coordinates German participation in the project.

**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 and microintegration of complex signal processors.

Since 2008 Fraunhofer IZM has also been funding a research position at the University of Utah for the analysis of biocompatible packaging technologies and supports a bilateral student exchange. These transatlantic research projects also allow Fraunhofer IZM to support US-American companies in the field of neural prostheses by strengthening their technological portfolio for commercial products.and to improve the patent exploitation, the latter in cooperation with the Technology Commercialization Office (TCO).

**Cooperation with the University of Tokyo extended**
The long-standing cooperation with the University of Tokyo has again been extended. Within this framework, a researcher from the Fraunhofer IZM has for two years now been part of the team around Prof. Tadatomo Suga, who leads the laboratory for microsystem integration and packaging. The aim of collaboration is both scientific exchange and the maintenance of direct cooperation with partners from industry.

**European Center for Power Electronics (ECPE)**
Fraunhofer IZM is a member of the European Center for Power Electronics's (ECPE) competence center and provides support in its areas of expertise, i. e. design, simulation, assembly and packaging, EMC and reliability for power electronics. The institute is also regularly involved in the organization of ECPE tutorials and workshops.
Further information: www.ecpe.org

**Invisibility cloak for hearing aids and implants**
Microsystems are at the heart of portable hearing aids and implants. In the EU WiserBAN project, researchers from TU Berlin and Fraunhofer IZM are developing a new microsystem designed to make hearing aids so small, so that they can be concealed out of sight within the ear. The technology is also suitable for implants, pacemakers and insulin pumps. With dimensions of just 4x4x1 mm³, the new microsystem is fifty times smaller than the current models for body area network (BAN) applications – electronics applied directly to the body. To achieve this, the project partners first developed especially small components such as innovative miniature antennas, system-on-chip integrated circuitry and high frequency filters. The job of the researchers was to find a space-saving concept to accommodate all the components involved – 19 in all – in a single module. Besides Fraunhofer IZM and TU Berlin the project partners include the University of Bologna, three renowned research institutes from France, Finland and Switzerland as well as leading companies from the European medical and electronics sectors.

**EU flagship project Human Brain**
Approximately 250 researchers from 23 countries are working together to try achieve an ambitious goal simulating the human brain. A key strategy of the collaboration, which runs under the title Human Brain Project (HBP), is combining the strategies of neuroscience with those of IT. Entire silicon wafers (instead of just single chips) have to be linked using high-density interconnection for HBP's highly complex neuromorphic computers. Fraunhofer IZM's task is developing the technologies needed to attach these interconnection systems on the silicon wafers and between the wafers. The institute's many years of experience in developing 3D packaging technology is a key prerequisite for taking on this design challenge.
Further information: www.humanbrainproject.eu

**Detector modules for the LHC at CERN in Geneva**
The search for the Higgs Boson, also known as the »God particle«, has been actively supported for several years by the Fraunhofer IZM. The ATLAS detector used for this purpose at CERN in Geneva documents particle decay during the collision of high-energy protons. The actual detector modules were designed and produced by the Fraunhofer IZM, and this won the institute researchers the ATLAS Supplier Award. In 2014, the performance of the modules was again significantly enhanced by the insertion of a further pixel detector shell, thus allowing an even better evaluation of the experiments.

**CarrICool – Interposer-based 3D system solutions**
As part of the European project CarrICool, we are developing processes and technologies for the robust manufacture of modular and scalable interposers, using the smart implementation of sophisticated More-than-Moore components. The new techniques are also advancing System-on-Chip (SoC) and System-in-Package (SiP) evolution. These new packaging solutions are crucial to improving 3D and beyond-CMOS device integration density. Furthermore, they meet new system demands in terms of energy efficiency, reliability, and computational performance – key metrics in the many-core, exascale and post-CMOS era. Six European countries are represented among the nine participating research and industry partners. The three-year project, initiated in January 2014, is funded by the European Union with approximately four million euros.

# BUSINESS UNITS & COOPERATION

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## The Business Development Team at the Fraunhofer IZM

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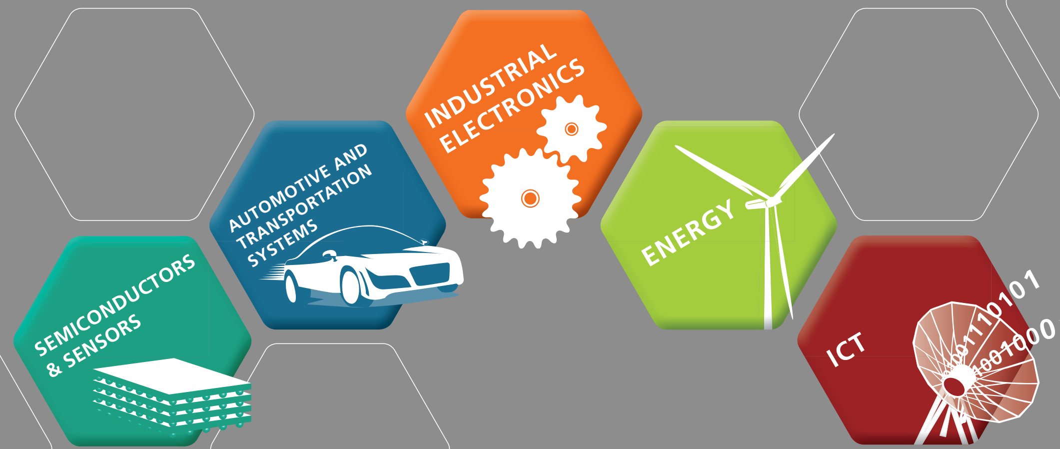


# INVEST IN CUSTOMIZED INTEGRATION TECHNOLOGIES

The trend in packaging and interconnection technology is currently undergoing changes - today, the materials used, the required reliability, the design and the technology employed to assemble and integrate a system are increasingly determined by the application.

**Mission**

Fraunhofer IZM's Application Center Smart System Integration links your ideas for new products with Fraunhofer IZM's technological portfolio. We offer feasibility studies, expert know-how, technological services, lab cooperations and workshops. Helping you develop your product is our main aim!

Apart from the expertise of our scientists, the application center provides access to Fraunhofer IZM's vast range of patents for technology innovations in electronic system integration, testing, analysis and reliability, as well as samples and prototypes.

**New kid in town?**

You want to upgrade your products but have not yet invested in microsystem technology or only use it to a limited extent? Despite this, you would like to make use of our know-how and technology in system-in-package and system integration?

If your company plans to integrate microsystem technology into your product line for the first time in the near future, you can reap enormous rewards from recent developments in IZM technology.

In addition to providing support at any development stage, we offer customized technological consultancy, e.g. on selecting feasible technologies, feasibility studies, complete technology transfer, and the provision of manufacturing capacities. You will be accommodated with the entire range of services required, from developing your idea, through to successfully marketing the product. Our technology workshops and laboratory facilities are in high demand, too.

**Secure your competitive edge!**

You already have a grasp of electronic packaging, but cannot stay abreast of national and international technology breakthroughs? You want to keep up-to-date on all the latest technology trends? You need help advancing your products, extending the range of suitable applications, increasing functionality or improving reliability?

Companies with experience in electronic integration also rely on our know-how and expertise. Ongoing product optimization and redesign is crucial in today's fast-changing market, and electronics is increasing becoming a key factor, but keeping up with the latest technological developments is beyond most companies.



# FRAUNHOFER IZM APPLICATION CENTER

Fraunhofer IZM can help them to take their product to the next level. Be it extending functionality, increasing miniaturization, improving reliability, reducing production costs – our mission is helping you reach your goal.

**Workshops on packaging technologies and trends in system integration**

Whether it is embedding in power electronics, photonic packaging or the use of laser technologies in electronics manufacturing – if you need assistance with choosing the right technology, one of our regularly held workshops might be a good choice for you. We arrange technical discussions with our staff members and specialists. Our experts will discuss with you the pros and cons of your options, illustrate processes and devices and give you hands-on experience.

**Company-specific workshops**

Whether you are on the look-out for upcoming trends and technologies that could be relevant for your company or plan to put your own latest technology to the test, we can organize a customized workshop that offers access to our services and facilities.

We provide access to our specialists who can discuss the entire bandwidth of technological advancement in electronic packaging, taking into consideration the current state of your company's technological infrastructure. When you need a partner to assist you in taking your product line to the next level, you can rely on us.

**Workshops on application-specific topics**

We also initiate application-specific workshops to discuss product and market developments with individual partners or groups of partners, as the case may be. Our customers benefit from our broad application experience and our interdisciplinary technological know-how.

You have an interesting topic that should be discussed on a broad basis? Contact us! We organize workshops with competent partners, generate value added chains, discuss possible solutions and integrate other expert know-how for a continuous supply chain.

**Contact:**

Dr. Maik Hampicke, maik.hampicke@izm.fraunhofer.de
Phone +49 30 46403-683

AUTOMOTIVE AND TRANSPORTATION SYSTEMS

# 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.

### From idea to prototype in only five months

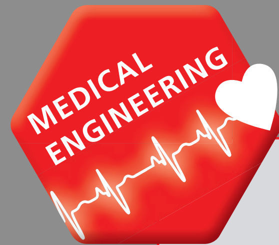
Together with Novero Dabendorf, Freescale Semiconductor Germany and Elektrisola, we have developed a wireless mobile phone charger for Audi. The breakthrough technology uses the Qi interface standard and an antenna coupler. The technology will be integrated into Audi A8 and Audi TT consoles.

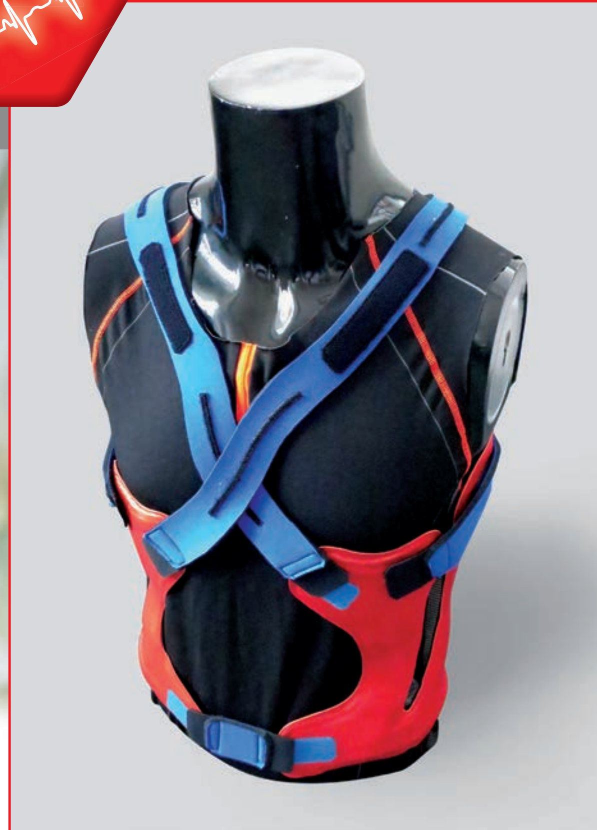
Fraunhofer IZM helped set an impressive pace for the product development – the wireless charger was advanced from concept to working prototype in just five months, with the institute contributing solutions for the electromagnetic compatibility issues, thermal dissipation and customized techniques for integrating discrete HF Litz wire coils into a PCB.

The system design proved a major challenge. More efficient components had to be found, which could facilitate an optimal balance between shielding (so that passengers as well as other electronic systems would not be exposed to unwanted magnetic fields) and charging efficiency. However, Fraunhofer IZM ensured all bases were covered and every milestone was met by deploying a total of three departments simultaneously to the project.

**Services:**
Apart from our specialization in power electronics, we also provide the following services:
- Sensor and actuator technology
- Reliability management and assurance
- Robust design

*Wireless charging device for mobile phones in cars*



# MEDICAL ENGINEERING

### Higher performance and smaller, finer geometries

Today's hearing aids are so small that they can be completely hidden in the ear canal. Pacemakers work better and last longer. Simulators help patients get urinary incontinence under control. Many of the innovations that have improved the lives of patients are the result of advances in microintegration technology. Diagnostics is another area that benefits greatly from such progress. Modern X-ray sensors in dentist practices, microcameras used in endoscopy, high-performance CT sensors or so-called pill cameras, which can simply be swallowed, would not have been possible without miniaturization.

Fraunhofer IZM has been front and center in this development process for 15 years. Our know-how in microtechnology and innovative integration processes helps manufacturers realize innovative new medical engineering products. With demand for the institute's services shifting from pure technology development to support throughout the development chain (from concept to prototype), the institute has established the new research area Medical Engineering.

Now 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, evaluates biocompatibility and assesses risk according to ISO 14971 standards, which are all 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.

As members of the Fraunhofer Alliance Ambient Assisted Living and the Fraunhofer Network Medical Engineering we benefit from the synergies of overall Fraunhofer know-how.

### Example projects

Fraunhofer IZM participates in government projects and bi- and trilateral cooperations with medical engineering companies and researchers throughout Europe and overseas. For example, in the European project Cajal4EU we have developed a fully integrated diagnosis platform that uses nanoelectronic components. Together with INCITE sensors and diagnosis systems are being integrated into the top of a catheter with a diameter of just 2 mm.

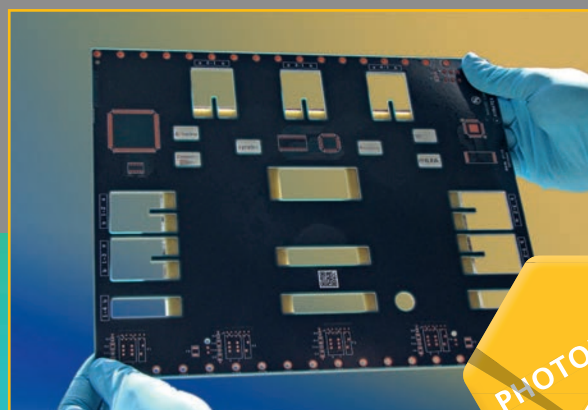
Researchers in the project CAREJack are developing textile-integrated sensors that monitor muscle activity. The overall goal is providing technical aids that facilitate nursing in the day-to-day outpatient setting. Fraunhofer IZM scientists are participating in the development of an upper-body orthosis with a smart assistance system that makes the particularly difficult conditions of everyday nursing care easier.

The ALUBAR project aims at improving the daily work routine of professionals by integrating »augmented reality« features, monitoring physical strain and thus helping to prevent a burn-out. In this project Fraunhofer IZM is responsible for the realization and system integration of eye tracking and stress sensors into spectacle frames.

**Services**

- Packaging technology and reliability analysis for miniaturized medical devices and implants
- Lab-on-substrate technologies for patient-friendly laboratory diagnostics
- Improving the functionality of neuronal interfaces and intelligent prostheses

*The CareJack vest supports the back without restricting freedom of movement (in cooperation with Orthopädietechnik Winkler, Minden)*



# 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. Developments in the area are powered by the constantly increasing demand for greater bandwidth in data and telecommunication, energy efficiency, and versatile optical applications with low-cost sensors.

Novel concepts for lighting and project technology are in great demand for lighting and projection applications. Optoelectronic modules include edge emitters, VCSEL or LEDs, and detectors as well as such passive elements as lenses, optical fibers, filters, and polarisers. Automation has replaced most manual assembly and interconnection technology with standardized methods and procedures. In order to sustain high bandwidths on the level of the substrates, electro-optical circuit boards (EOCB) are being developed with planar polymer and glass waveguides. As packaging and interconnection technology accounts for up to 90 percent of current costs, there is considerable interest in finding ways of improving efficiency and allowing large-scale production with greater cost efficiency.

**Services:**

- Assembly and interconnection technology for electro-optical and micro-optical components
- Simulation, design, and system trials (thermal, mechanical, optical, and HF)
- Photonic and plasmonic system integration on various substrates (ceramics, glass, polymers)
- Qualification, failure, and reliability analyses
- Integration via panel or wafer-level packaging

## Optical components embedded in thin-glass substrates

Fraunhofer IZM has teamed up with leading industry partners like SEAGATE, Conjunct, TerOpta, ILFA, and V-I-Systems for the FP7 EU project »SEPIAnet«, aimed at producing an optical backplane and innovative transceiver for optical data transmission. Embedded in the thin-glass substrates commonly used in display technology, the target application of the new technology would lie in modern data centers, in particular in network data storage. The solution promises products with more versatile and considerably improved performance, reliability, lower costs, and greater energy efficiency. The basic module developed by Fraunhofer IZM consists of optical transmission paths embedded in the circuit boards themselves. Novel large-scale backplane designs with fully integrated glass films were developed that can accommodate the bandwidth requirements of the future by means of embedded optical waveguides. For this purpose, innovative functionalization and structuring solutions were found to match the production technologies established in the industry. The »SEPIAnet« project has been able to show the feasibility of lossless 32 Gbit/s transmission rates via the new backplane design.

**Results:**

- Innovative system designs for a demonstration unit with backplane and daughter boards
- Production of multimodal optical glass panel waveguides with thermal ion exchange, embedded in standard PCB technology
- Integration and automatic assembly of multichannel, pluggable optical interfaces
- Production of thermally stable 1310 nm VCSEL
- Implementation of efficient electro-optical transceivers

*Thin-glass based substrate with integrated multimode optical waveguides*

# INDUSTRIAL ELECTRONICS

### Industrial Electronics – safe and reliable!

The last twelve months of R&D by the Fraunhofer IZM's industrial electronics specialists were given over to one visionary concept: Industry 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. Industry 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

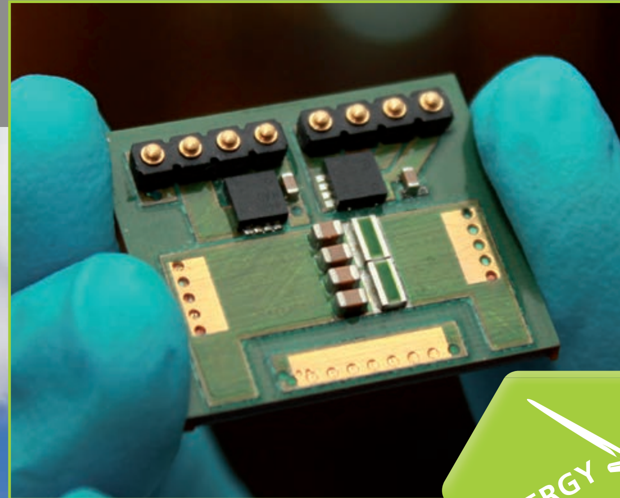
### Autonomous monitoring system for overhead lines

Sensors that monitor the condition of overhead power lines need highly durable and dependable technology to meet the operational reliability requirements of these vital systems. The ASTROSE® sensor system developed in the eponymous project allow the distributed monitoring of high-voltage grids with radio sensor nodes designed for autonomous operation. The sensors track the pitch of the power lines and the movement caused by wind, changes in temperature, or currents in the line. These indicators, which have a major impact on the maximum flow loads in the system, are measured where it matters most: on the lines themselves.

Each sensor node is given a unique ID to pinpoint its exact place in the landscape. The units include the electronic systems, the sensors, two antennas, and one antenna filter. The network formed by the nodes along the route sends the monitoring data to a dedicated feed point, from where it is transmitted to the grid operator's control systems.

In September 2014, 59 autonomous radio sensor nodes began sending their monitoring data from the 12 km section of the route crossing the Harz mountains back to the base station at MITNETZ STROM's transformer station, where the data was received and forwarded to its destination. At the same time, a second radio system is sending a constant stream of monitoring and status data for the sensor nodes to an ASTROSE server. The server records the data and provides the right selection to match the specific application and users' queries, be it for monitoring the state of the autonomous radio sensor network itself, condition monitoring, or later maintenance purposes. With these two separate and dedicated datasets for different recipients, ASTROSE® becomes a vanguard for the purpose-specific data allocation to specific users that Industry 4.0 proponents are calling for.

*Energy autarkic sensor system to monitor the pitch of overhead power lines*



# ENERGY

## The key to reducing 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.

*Very fast switching module with embedded chips*

## Inverter design for fast switching

Silicon-carbide or gallium nitride semiconductors feature high current spikes when switched on or off. This can be exploited to dramatically raise the switching frequency in the inverter circuitry. However, this creates unpreventable parasitic inductances in the demonstrator module, which can cause significant overvoltage during switch-off, consequently possibly damaging the chip, and lead to further oscillations that can drive up switching losses significantly.

Over the past few years, our research activities have focused on the development of packages and their periphery, optimized for the operation of these fast switches. Adapting the control strategy and the passive elements is a central point in successfully bringing fast switching devices into application. Only using all the benefits of fast switches rises the acceptance in the industry despite of the high price. In the module layout, the low side semiconductor is ideally attached face down to the DBC. This reduces the output capacitance to almost zero. Additionally, copper areas for DC+ and DC- on the DCB are designed equally to form equal stray capacitances towards earth. The elimination of those asymmetries reduces EMC disturbances to the environment. With first stage DC-link capacitors placed on the module directly above the chip, DC-link stray inductance is kept as small as possible, a booster for the gate signal, also located on top of the module, reduces the gate inductivity, which was 33nH in a previous project. Additional measures to reduce losses are control strategies like discontinuous current and zero current switching.

**Services:**

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

# SEMICONDUCTORS & SENSORS

### 3D integration & sensor integration on wafer-level

Using 3D integration of components, complex, heterogeneous system-in-packages (SiP solutions) can be developed. The major advantages of 3D system architecture include:

- High miniaturization and improved form factor
- Improved performance and power efficiency thanks to the faster signal speeds and higher bandwidth via shorter and narrower signal paths
- Increased functionality due to heterogeneous integration of components, which are fabricated using various technologies (sensor, memory, ASIC and transceiver)
- System partitioning
- Faster product implementation (also known as 'time to market')
- Fewer costs due parallelization of assembly processes

Fraunhofer IZM's services include a closed process chain – concept and process development, characterization, as well as reliability assessment and prototyping of 3D systems. All processes required throughout the chain for the realization of wafer-level packages, including through silicon via (TSV) formation, are available in our labs.

3D systems that meet the disparate target profiles demanded by various application scenarios, such as image sensors, sensor nodes, eGrains, can be realized and characterized. We work in close cooperation with tool and material suppliers to continuously improve applied technologies.

*Hermetic MEMS-package based on CMOS wafer and cap wafer*

### Hermetic sealing of MEMS components on wafer-level

Through silicon-via technologies offer many advantages in the integration of various components, including sensors, ASICs, memories, transceivers, into a stacked architecture that features excellent performance and small form factor. Together with industrial and academic partners, Fraunhofer IZM develops base technologies for the wafer level fabrication of low-cost, miniature, chip-scale packaged (SCP) hybrid microsystems. For this purpose, standard technologies like redistribution, TSV formation and wafer-to-wafer bonding are combined to produce versatile approaches for hermetic wafer-level packaging of MEMS components.

Some of these new developments were funded by a collaborative project Go4Time, which was part of the EU's 7th FRP. The overall goal of the project was the development of manufacturing concepts for highly stable, generic, low-cost timing devices suitable for power aware, long autonomy and portable telecommunication systems such as mobile phones. One milestone in this project was the wafer-level fabrication of a MEMS package consisting of an active CMOS wafer with vertical copper-filled TSVs and bonded cap wafers for hermetic sealing of resonator components.

**Services:**

- 3D design
- Process development and evaluation
- TSV formation for customized CMOS wafers (via-middle, via-last)
- Backside contacts (BS via-last) for image sensors
- Silicon and glass interposers
- 3D assembly (die-to-wafer, wafer-to-wafer)
- 3D integration of optical interconnects
- Hybrid 3D pixel detector modules
- Hermetic MEMS packaging using TSVs
- Material and equipment evaluation and qualification
- Prototyping and pilot line

# FRAUNHOFER IZM LABS & SERVICES

**Wafer-Level Packaging Line**

Our wafer-level packaging line in Berlin boasts a 800 m² clean room (classes 10 to 1000), with wafer processing of different materials (Silicon, III-V semiconductors, ceramic, glass) and sizes (4'', 6'' and 8''). For some applications prototyping equipment is also available on 300 mm.

- Thin-film deposition (sputter and evaporation)
- Photolithography (including photo varnishes, polymers and spray coating)
- Galvanic bumping, circuit tracks and through-via filling (Cu, Ni, Au, AuSn, SnAg, PbSn)
- Wet-chemical processes (etching, cleaning)
- Wafer bonding (support wafer, thin-wafer handling)
- Silicon plasma etching (through vias, cavities)

**Contact:**

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Phone +49 30 46403-124

**All Silicon System Integration Dresden - ASSID**

The Fraunhofer IZM-ASSID Center in Dresden is equipped with a 300 mm wafer process line and provides the following services:

- Application-oriented Cu-TSV interposer technology
- Cu-TSV-integration (via-middle-, via-last-, backside-via-prozess)
- Wafer-level system-in-package (development & prototyping)
- High-density thin-film-multilayer (RDL)
- Wafer thinning und thin wafer handling
- Wafer level bumping (ECD)
- Wafer-level assembly, wafer dicing (Stealth-laser)
- Wafer-level solder ball attach (100-500 µm)
- Integration of active elements (IC), thin chip integration
- Customer-specific prototyping

**Contact:**

M. Jürgen Wolf, juergen.wolf@izm.fraunhofer.de
Phone +49 351 795572-12

**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.

**Contact:**

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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.

**Contact:**

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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.

**Contact:**

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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.

**Contact:**

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Phone +49 30 46403-167

**Training Center for Interconnection Technology (ZVE)**

The ZVE is ESA approved and IPC certified (IPC A 610) and operates as a training and service center for assembly and connection technology. The training program includes courses and seminars on lead and lead-free manual, reflow or wave soldering, SMT component repair and lead-free connection technology. Other ZVE services include process qualification and consultation on quality-assurance for electronic component manufacture.

**Contact:**

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Phone +49 8153 9097-500

**Further laboratories include:**

- Flip Chip Line
- Die and Wire Bonding Center
- Micromechatronic Center
- Thermo-mechanical Reliability Lab
- Photonics Lab
- Advanced System Engineering Lab

# HIGHLIGHT INNOVATION CENTER ADAPTSYS

On September 1, 2015, the new research and development center »AdaptSys – Multifunctional Microelectronics for Innovative Micro- and Nano-Integration Technology in the Development of Application-Oriented Systems« will open its doors at Fraunhofer IZM in Berlin. The center is being funded by the European Union, the Land Berlin, the BMBF and the Fraunhofer-Gesellschaft and will foster the development of highly complex electronic systems for different areas of application. Furthermore, system integration technologies can be evaluated down to the nanometer scale and their reliability can be tested using new test and qualification processes.

AdaptSys will focus on four main topics:

- Nano-scale process and material development
- Researching, developing and qualifying innovative system integration techniques adapted to the needs of individual applications
- Supporting the industries that employ these technologies with product development
- Failure analysis, quality and reliability assurance, lifetime prediction models and condition monitoring

## SYSTEM INTEGRATION

**Substrate Line**
In the substrate area panel-size substrates with a size of 460x610 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

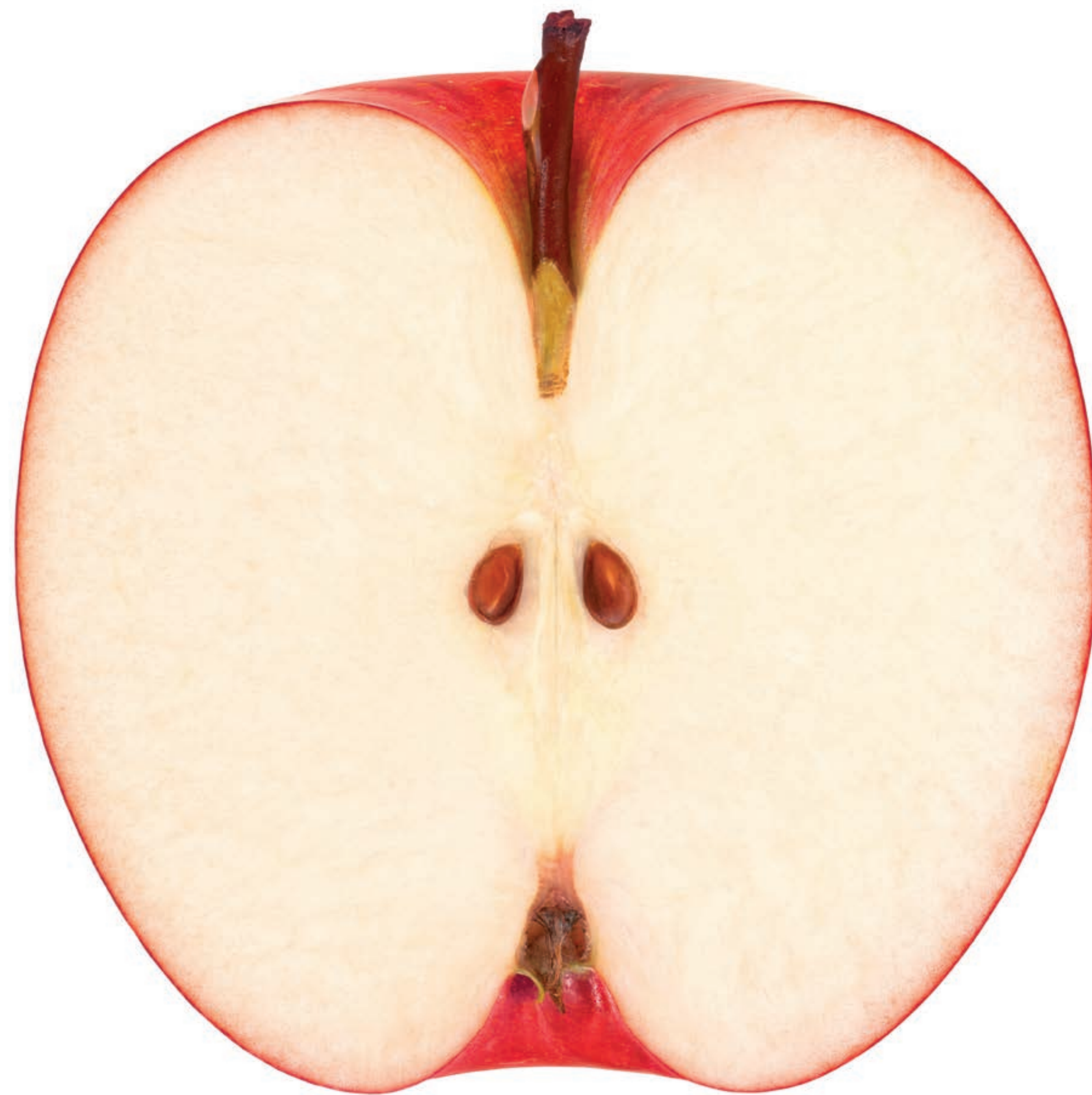
## DESIGN

**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)

**Contact AdaptSys:**
Rolf Aschenbrenner, rolf.aschenbrenner@izm.fraunhofer.de
Phone: +49 30 46403-164

# FRAUNHOFER IZM CORE COMPETENCIES

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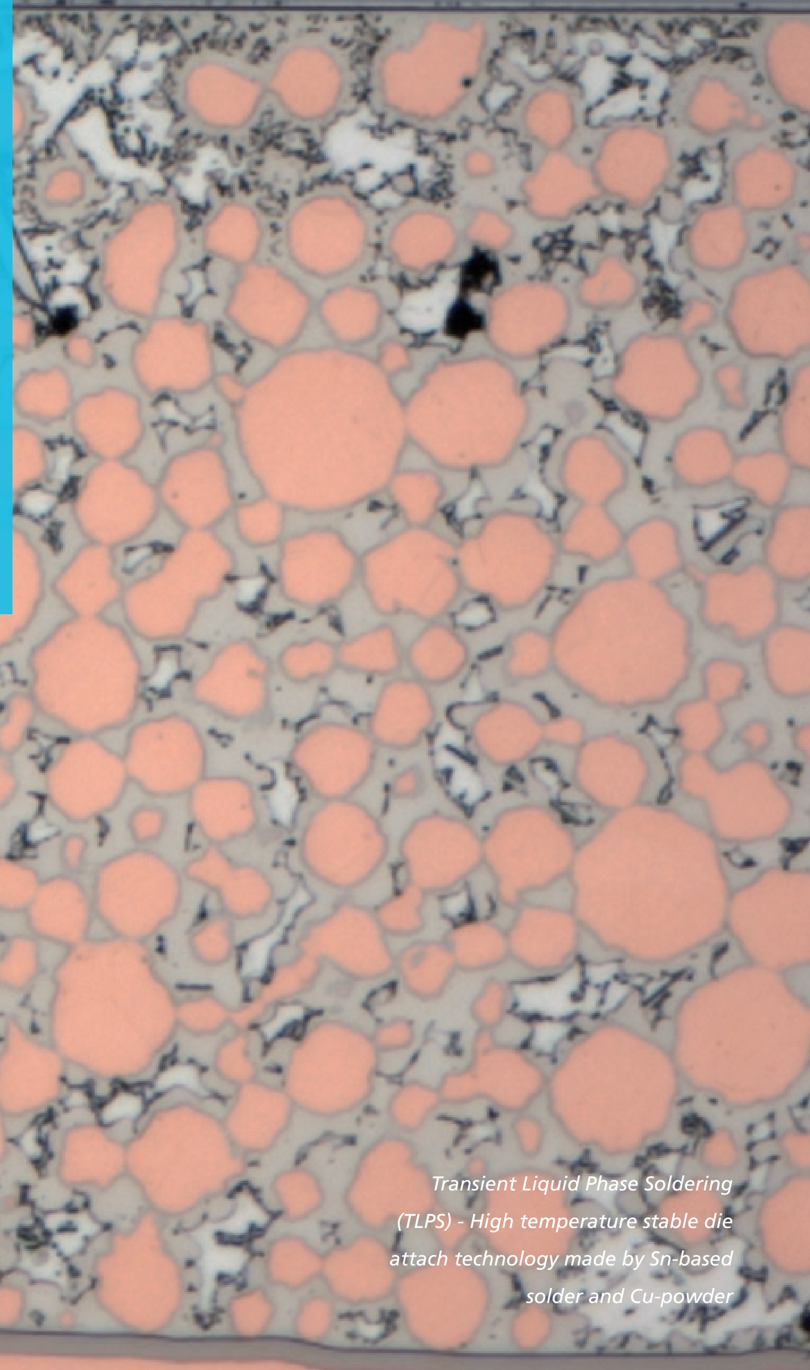
# RESEARCH CLUSTER INTEGRATION ON SUBSTRATE LEVEL

## 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.*




*Transient Liquid Phase Soldering (TLPS) - High temperature stable die attach technology made by Sn-based solder and Cu-powder*

## HIGHLIGHT 2014

**Transient liquid phase soldering – an interconnection technology for high operating temperatures**

Electronic assemblies in many different applications, such as automotive, photovoltaics, or offshore technology need to withstand high operating temperatures.

Along with the components and substrate materials, the interconnections also have to withstand temperatures of 150 °C or even higher without diminished reliability. Led-free soft solder systems that have been used in the past cannot be used in this temperature range, as they fail too quickly due to thermal-mechanical fatigue.

Scientists at Fraunhofer IZM together with project partners from the BMBF joint project »HotPowCon« have developed a new interconnection technology referred to as transient liquid phase soldering (TLPS) that increases the remelting temperature of the joint remarkably. In this approach, a solder sphere with a melting temperature of 220 °C reacts with Cu powder of a much higher melting temperature, forming a joint that comprises the intermetallic phases $Cu_6Sn5$ und $Cu_3Sn$ ($Tm > 400$ °C).

This new type of joint has high creep resistance and a thermal conductivity matching that of conventional solder joints. Tests have shown that higher life times can be achieved using this technology. Transient liquid phase soldering may prove a replacement for high lead-containing PbSn solder alloys used for first-level die attach for optoelectronic components.

*Contact:*
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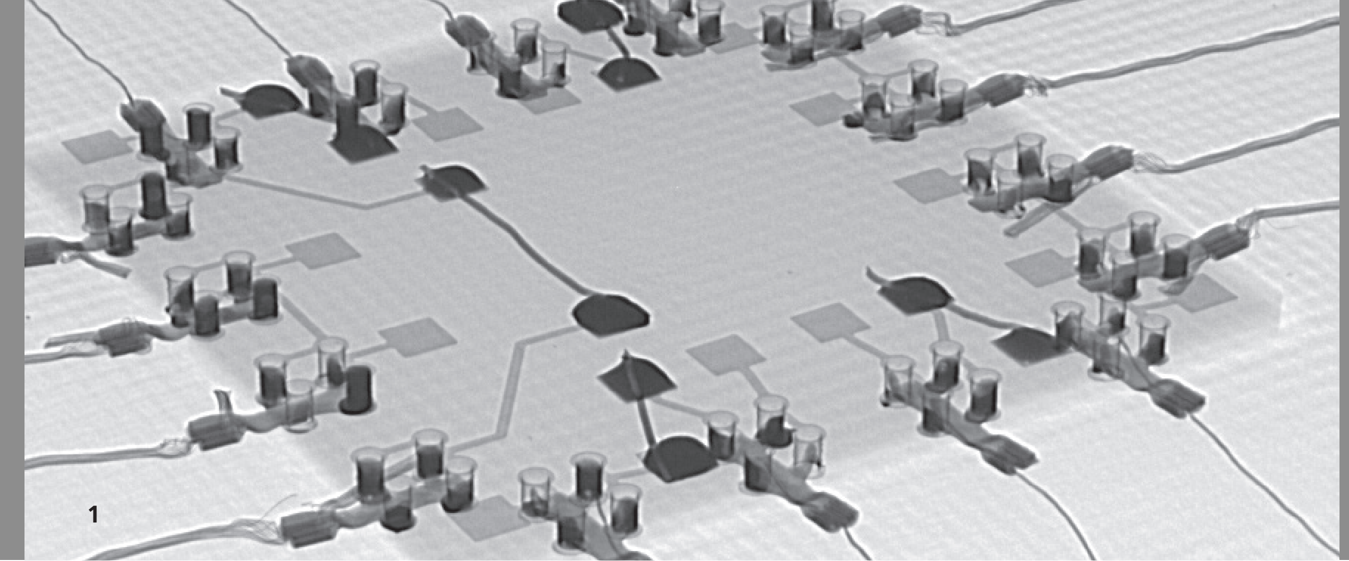

# SYSTEM INTEGRATION & INTERCONNECTION TECHNOLOGIES

**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

**New approaches for the integration of electronics into textiles**

Large-area smart textiles (also known as e-textiles or smart fabric) is the focus of the collaborative EU 7FP project PASTA (Integrating Platform for Advanced Smart Textile Applications). A key goal is translating research results at prototype level into industrial manufacture for a wide range of new products in sport and leisure wear, safety and monitoring, and health care and medical engineering.

PASTA advances innovation in smart textiles by introducing cutting edge packaging technology for a more seamless, comfortable and robust integration of electronics into textiles. Development highlights in PASTA include a new approach to integrating bare die in yarn (by means of micromachining), a novel interconnection approach using mechanical crimping and an innovative flexible interposer for use as compensating layer between rigid components and the flexible textile.

Fraunhofer IZM's task within the research and development consortium was developing a new process for the integration of electronics into technical textiles using crimping. The advantages of crimping include that it can be performed at room temperature and that it can penetrate insulation layers without an additional processing step.

As one of in total four applications, the Fraunhofer IZM researchers and the company Ettlin are developing a new smart textile for non-destructive in-situ monitoring of stress in composite materials. This condition monitoring system estimates remaining lifetime and serves as a warning system for any damage to the materials by tracking accumulated stress and individually set parameters. Both the sensors and bus structures are woven into the textile and a crimping process is used to interconnect the electronic module with the conductive yarn. The technology was demonstrated using prosthetics as application example by integrating the complete sensor textile into an outer layer of a prosthesis.

1 *X-ray image of crimped electronic module in composite*

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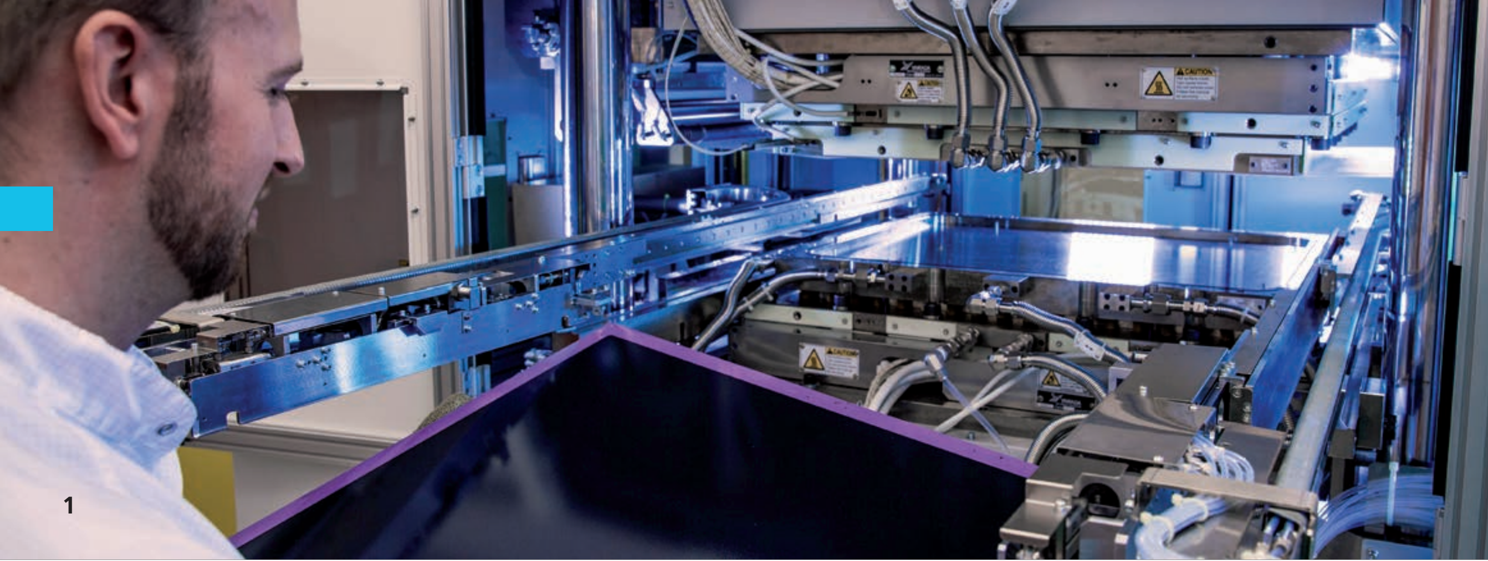
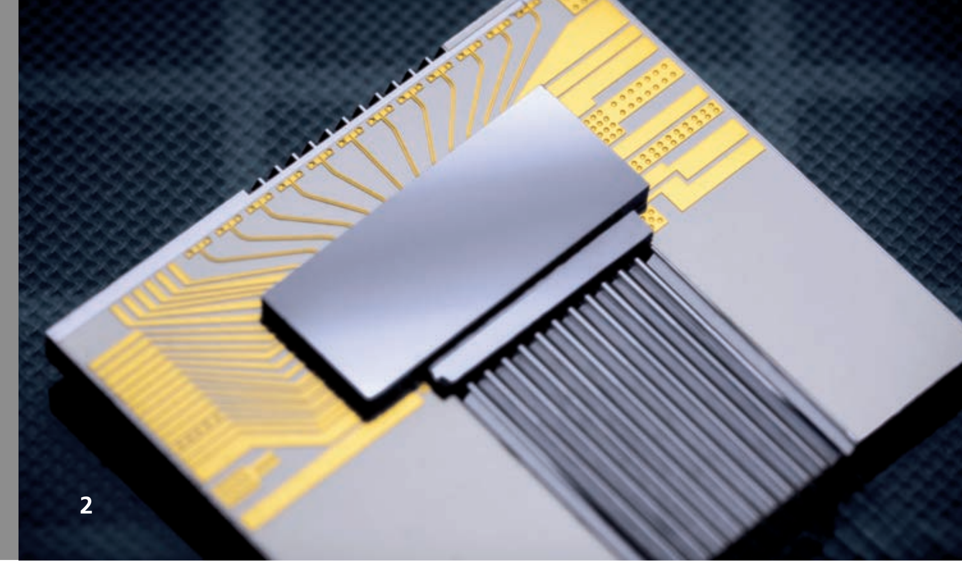




## Panel level packaging

A new and extremely promising microelectronic packaging technology is fan-out wafer level packaging (FOWLP). Currently we are using this technology to encapsulate reconfigured wafers sized up to 12" (300 mm) by means of injection molding. In the near future, we plan to extend this approach to the even larger sizes typical in industrial settings, which will increase throughput significantly and consequently cost. In the long-term, advancement of the wafer-level approach to encapsulation will result in a reconfigured wafer with a diameter of 450 mm. An alternative approach in injection molding would be abandoning FOWLP for fan-out level packaging (FOPLP). In this technology, substrates can be sized up to 457 x 610 mm² (18" x 24") or even more.

Lamination is traditionally used for component embedding in the PCB's build-up layers, such as in the manufacture of multilayer PCBs. In contrast, in FOWLP and FOPLP the reconfigured components are encapsulated by liquid or granular material using injection molding at high pressure and high temperature. It may be possible to combine the two approaches in the future, by laminating the components into a foil-like injection molding mass.

Laser direct imaging (LDI) is a promising alternative to conventional photolithography. It is likely to reduce cost significantly (because masks are not needed) and it is highly flexible (easy customization of processing parameters). With the availability of LDI systems for large substrates, including 450 mm wafers, a higher throughput and thereby cost reduction is possible. Conventional PCB component embedding already allows the processing of substrates sized up to 610 x 457 mm² (24"x18"). New processes pave the way for redistribution layers (RDLs) suitable for large reconfigured wafers and panels and will replace conventional redistribution in thin-film technology.

To manufacture RDLs using PCB technology, a composite of a dielectric layer and a thin copper layer (prepreg or resin coated copper) is firstly laminated onto the reconfigured wafer or panel. Subsequently, micro-vias are drilled through the dielectric layer to the electrical contacts of the components and electrically connected to the outer copper layer using galvanic copper deposition. In the final step, the copper traces are etched using photolithography. Current LDI systems allow imaging of structures up to 20 µm (copper trace width and offset), however resolutions of 10 µm can be expected in the near future. Fraunhofer IZM has characterized the process for FOPLP for panel sizes of up to 610 x 457 mm².

Combining component embedding in PCB with encapsulation by injection molding offers a number of interesting possibilities. For example, injection molding can be used to embed components in multilayer PCBs, while injection molding materials in the form of films can be used to encapsulate components on pre-processed redistribution layers (PCB) by means of lamination. As substrate sizes for such approaches can be as large as 515x610 mm², highly integrated packages can be produced at low cost. Such approaches have already been successfully tested using an LGA package with two integrated chips, a stackable BGA package, a sensor-ASIC package and a CMOS sensor that was integrated into a microfluidic cell.

## New developments in optical technologies

More data than ever have been generated in recent years – via social media, video portals, remote control, the Internet of Things and many other avenues.

Demand for convenient, around-the-clock access to data has also grown considerably, which is why most users prefer cloud storage, not only to ensure accessibility, but also as a safeguard against data loss and downtime. Consequently, data are now stored in gigantic data centers around the world, which together require about 30 billion watts of electricity and incur significant costs.

Approaches based on optical technology offer solutions for the ever growing increase of data and the resulting power and cost factors.

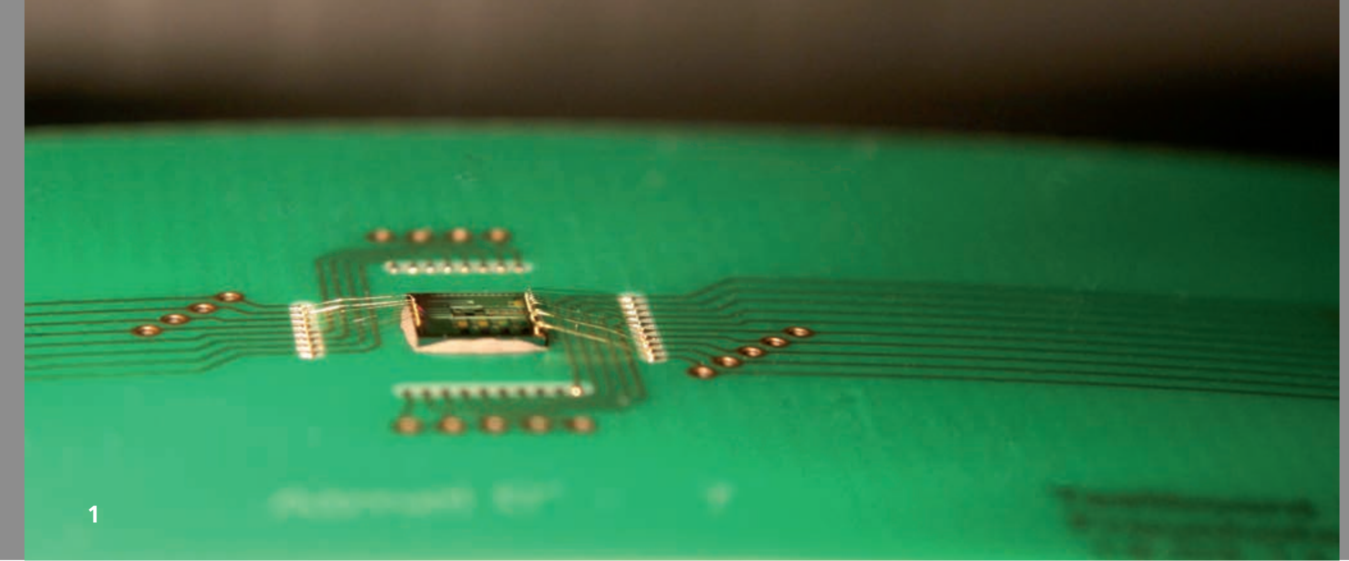
PhoxTroT, one of the largest EU 7$^{th}$ Framework research projects, is tackling this. Led by Fraunhofer IZM, 19 companies and research groups are developing new optical technologies on board, board-to-board and rack-to-rack levels.

The new components and technologies are specifically designed to maximize performance, while keeping power requirements and resulting operating cost at a minimum. Project outcomes to date include 40 Gb/s VCSELs, 40 Gb/s photodiodes, 480 Gb /s transceivers, 16 QAM modulation units, 2 Tb/s routers, Tb/s switches, multi-mode und single-mode electro-optical PCBs and 3D integration of the latter. These new technologies reduce power consumption by 50 percent.

Apart from coordinating the project, Fraunhofer IZM is working on silicon photonic integration and component mounting to facilitate optical interconnection between chip/substrate/board/backplane. These are Fraunhofer IZM's biggest challenges, which we are tackling by focusing on single-mode optical interconnection on board-level for ICT technology.

1 *Process characterization for fan-out panel level packaging*

2 *High-power receiver module for ten 40 GHz channels*



# MICROMECHATRONICS & PCB TECHNOLOGY

**Fraunhofer IZM Oberpfaffenhofen**
Our department »Micromechatronics and PCB Technology« at Fraunhofer IZM's Oberpfaffenhofen branch applies cutting-edge quantification techniques and numerical simulation to analyze and optimize mechatronic packages. We provide consultation on the reliability of electrical systems and interconnection. Moreover, we carry out in-depth qualification and failure analysis of components, assemblies, electrical contacts and electrical systems. Simulation is primarily applied to electronic encapsulation testing and development (transfer molding, injection molding, the role of fiber direction) and to optimize the packaging process.

We advance mechanical-electrical interconnection technology and transfer our insights and know-how to industry in our training courses. Our basic research employs cutting-edge electrical measurement techniques, such as contact resistance, thermography, sealing behavior of contact surfaces and the effect of stress and contaminants on reliability.

Our training courses and workshops cover packaging, soldering, crimping, and repair and acceptance criteria, in particular for certification courses (ESA, IPC, DVS). This year, we will be offering the certification course IPC/WHMA-A-620B »Requirements and Acceptance for Cable and Wire Harness Assemblies« and a practical lab course on cable interconnection techniques.

**Trends**
Groundbreaking advances in electronic system integration can be achieved by fusing form and function. A key innovative technique here is generative manufacturing technology. Electro-mechanical interconnection requires new interconnection, cable and shielding materials.

Multicomponent parts, so-called »smart power mechanics«, require intensive research into the surfaces of the contacts and the electronic systems integrated into the connectors. Determining the geometries actually produced by the manufacturing process are key to understanding the relevant material's local and, where applicable, anisotropic properties. Using numerical simulation, this information can be used to quantify and describe new insights into micro- and nano-electronic development.

**Key development goals:**
- Cost-efficient materials for connectors, cables and shielding in electrical interconnection (e. g. aluminum instead of copper)
- Increased use of crimping, clinching and press-fitting, including for high-current applications
- Numerical simulation using true geometries and material parameters
- Development of generative technologies and ink-jet printing techniques for smart power mechanics
- Improving rework and repair processes
- Advanced training approaches (esp. for areas such as medical engineering, solar technology, crimping, cable harness and blended learning)

# RESEARCH & DEVELOPMENT HIGHLIGHTS

**Vehicle electronics: Moving from cable clutter to backbone architecture**
Tomorrow's vehicle electronics will be lightweight, power efficient and modular. Backbone architecture in the form of an aluminum multi-busbar that can handle power and data paves the way for entirely new possibilities in future vehicle electronics. Systematic investigation has allowed us to develop, test and optimize an innovative vehicle electrical wiring system with smart protection. Development of the new technology was funded by the Bavarian Research Foundation. Project partners included the BMW Group Forschung und Technik GmbH (BMW Group Research and Technology), Dräxlmaier, TU Munich.

**Solvent-free soldering**
Solvents remain a necessary evil in in soft soldering. Although indispensible in the soldering process, they have many negative effects. For example, contamination of soldered surfaces can hamper subsequent bonding and adhesion of sensors and impair coating and encapsulation processes. Humidity can cause moisture to form on the surface of the flux residue, leading to component or interconnection failure. Fraunhofer IZM tackled this problem in collaboration with industry, including Reinhausen Plasma, SEHO Systems, Zollner, the flux and surface specialists Emil OTTO, Osram and Siemens. A solution was developed, in which wet-chemical flux activation is replaced by plasma-assisted deposition of adipic acid or powdered flux. The new process is completely VOC-free, i.e. no solvents are released into the atmosphere. Handling and storage of solder fluxes, which are currently categorized as hazardous material, will become simpler (funded by the development initiative »Mikrosystemtechnik Bayern«)

**Impact of mechanical stress on battery monitoring in electric transportation**
Accurately determining charge is key to making best use of cutting-edge lithium-ion batteries in electric vehicles. The parameter is indispensible in estimating reach precisely, optimizing battery charging and discharging and preventing overheating and hazardous charge depletion. However, mechanical stress can negatively impact the BMS chip, leading to flawed assessments. To redress this issue, we developed a process for precisely characterizing the mechanical stress on a sample BMS chip supplied by the company Atmel. The new process can quantify the correlation between mechanical stress and electrical impairment, paving the way for optimizing the electrical chip design (sponsored by the BMBF as part of the project IKEBA).

1 *Chip for battery monitoring system in the bending fixture of a confocal microscope*

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# 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.*

*Installation of ATLAS IBL detector at CERN*

# HIGHLIGHT 2014

**ATLAS detector upgrade**

After the observation of the Higgs-Boson at the Large Hadron Collider (LHC) at CERN in 2012 the accelerator as well as ATLAS and CMS detectors will be upgraded for the next period of data acquisition. Following this phase proton-proton collisions with a center energy of 14 TeV are possible at a higher interaction rate. To increase the detection accuracy of the particle tracks a fourth pixel detector layer has been inserted into the center of the ATLAS detector – the so called Insertable B-Layer (IBL). This part of the detector is installed closest to the collision point of the protons; therefore the electronic readout chips have to fulfill their functionality at the highest radiation level inside the detector. A new generation of readout chips, the ATLAS frontend-I 4B (FE-I4B) chip, was developed and used for pixel detector module production due to these requirements. With a size of 2x2 cm² the ATLAS FE-I4B chip is the biggest readout chip that has been used in a pixel detector at CERN so far. One or more of these electronic readout chips which are flip-chip bonded onto a particle sensing silicon chip built a hybrid module, the basic modules of a pixel detector. The ATLAS IBL detector is assembled of 168 double and 112 single readout chip modules in total which were all fabricated at Fraunhofer IZM.

The fabrication process included the bump deposition on readout chip wafer, the deposition of solderable metallization on sensor wafer, readout chip wafer thinning and flip chip assembly. On the final module every pixel of the sensor with the size of 50 x 250 µm² is connected to the electronic readout cell by one micro solder bump – these are 26,880 bump connections per chip. To fulfill the target of minimum material budget for the whole detector sensors with a thickness of only 20 µm and 230 µm were used and the readout chip wafers were thinned to a final thickness of 150 µm. Under these requirements and in order to produce modules with a maximum pixel yield cutting-edge assembly technologies were applied. One example is the temporary glass chip carrier technology that enables the reflow soldering of large readout chips onto sensor tiles without warping. A glass chip glued onto the thinned readout chip backside in a wafer level process prevents the chip from bending at reflow temperature. Finally the glass chip is released by laser exposure after flip-chip assembly on module level. The further assembly steps to form the IBL detector were performed at different partners of the ATLAS pixel collaboration: the Bonn University, INFN Genoa and CERN.

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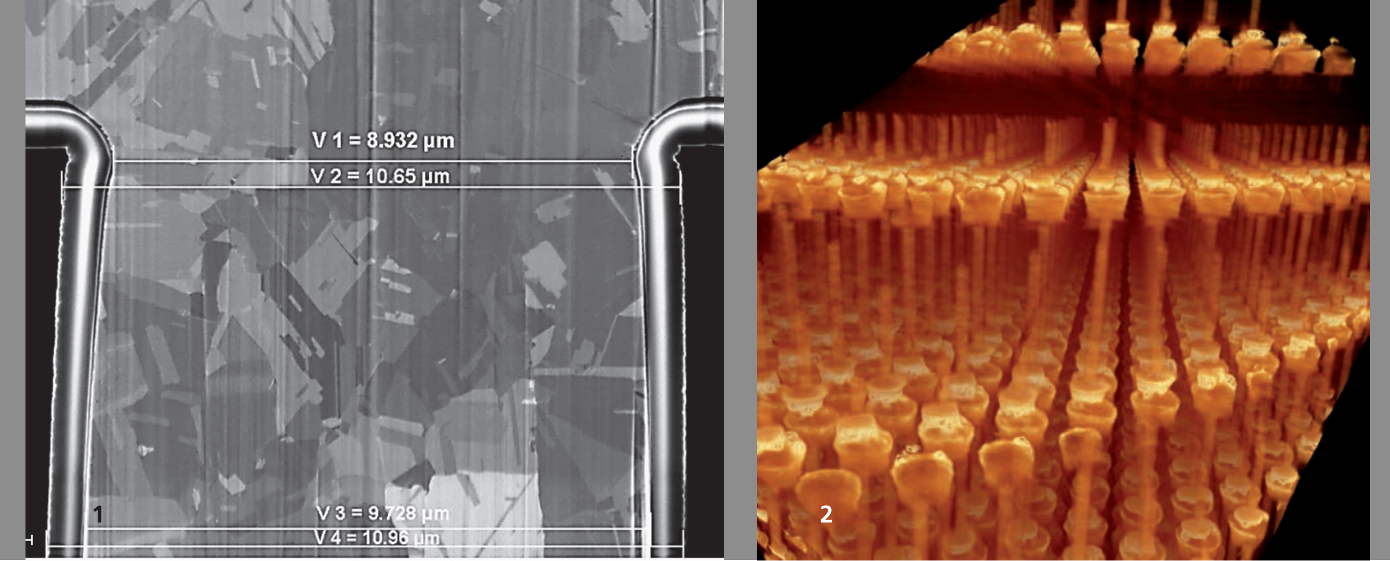


# WAFER LEVEL SYSTEM INTEGRATION – ALL SILICON SYSTEM INTEGRATION ASSID

**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 which are exclusively related to wafer processing.

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 the center ASSID is particularly tailored to realize production-related and industry-compatible development and processing.

The focus of the scientific work is on:

- Wafer level packaging and CSP
- 3D integration technologies
- Silicon interposer
- High-density redistribution
- Ultra-fine pitch interconnect formation and micro-bumping
- Pre-assembly (thinning, dicing, singulation)
- Die to wafer (D2W) assembly
- 3D wafer level stacking

R&D services for customers include process development, material evaluation and qualification, prototyping, low-volume manufacturing as well as process transfer. Newly developed technologies are 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 (WL-SiP) 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) for 3D systems
- Backside via-last technologies
- 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

**TSV (Through Silicon Via) integration**

For the various via approaches in the field of TSV integration significant progress could be achieved, which enables manufacturing-compatible 3D integration.

Particularly an optimization of the dry etch processes (DRIE) resulted in desired TSV profiles which support an optimal subsequent filling of the TSVs (e. g. PVD and ECD). This not only enables faster and more robust processing but also helps to improve the reliability.

As a result, TSVs with diameters of 10 µm, 5 µm and 3 µm and aspect ratios of 10 could be realized. Those exhibit a slightly positive TSV profile and zero undercutting while maintaining very smooth side walls (scallops 0..20 nm). With the goal to realize TSV arrays with smaller pitches on thicker wafers R&D activities focus on larger TSV aspect ratios. Here, aspect ratios of up to 20 were realized for TSV diameters of 10 µm and 5 µm. The TSV depth variation is below 1.5 percent on a 300 mm wafer.

Furthermore, considerable improvement has been achieved with regard to TSV reveal processing on the wafer backside. An optimized process flow using e.g. recess etch, planarization and polymer based isolation allows a TSV reveal compensating any wafer non-uniformities while ensuring reliable electrical isolation. This challenge is mastered on temporary bonded wafers with strict limitations in process temperature utilizing polymer CMP. The combination of planarization and polyimide deposition is a self-aligning process without the need of lithography and therefore scalable to any TSV dimension.

**Test structures for metal characterization**

In a joint project with Technical University Hamburg funded by the German Research Foundation (DFG), test structures with Cu-RDL and TSVs were successfully realized on 300 mm silicon wafers. These test structures serve especially for material characterization up to frequencies of 100 GHz. Based on this design, different isolation materials and layer combinations can be realized. As a result, decision certainty for customer-specific applications with respect to electrical performance can be increased. Elements can be realized with and without TSVs. For isolation materials, thermal and CVD oxides and polymers (PBO, WPR, BCB) are used. Electrical measurements (e.g. leakage and CV measurement) demonstrated that process results significantly depend on materials/group of materials.

*1 FIB cross section, detail of Cu-TSV 10 µm/100 µm*

*2 Nano X-ray tomography of Cu TSV chip stack (in cooperation with members and partners of Dresden Fraunhofer Cluster Nanoanalysis)*

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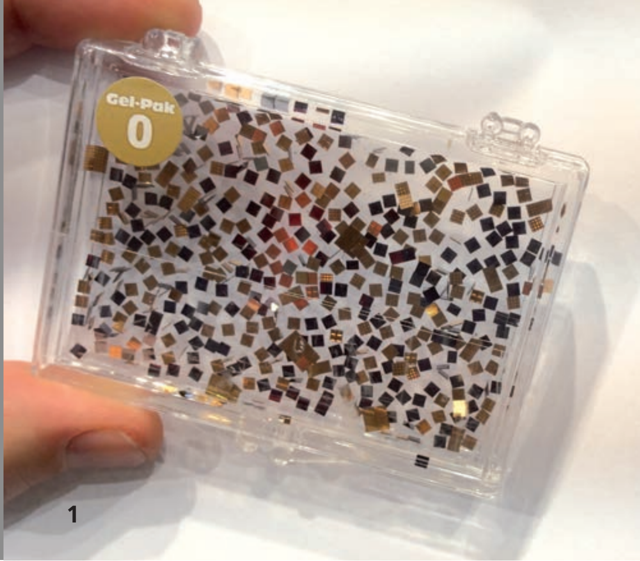
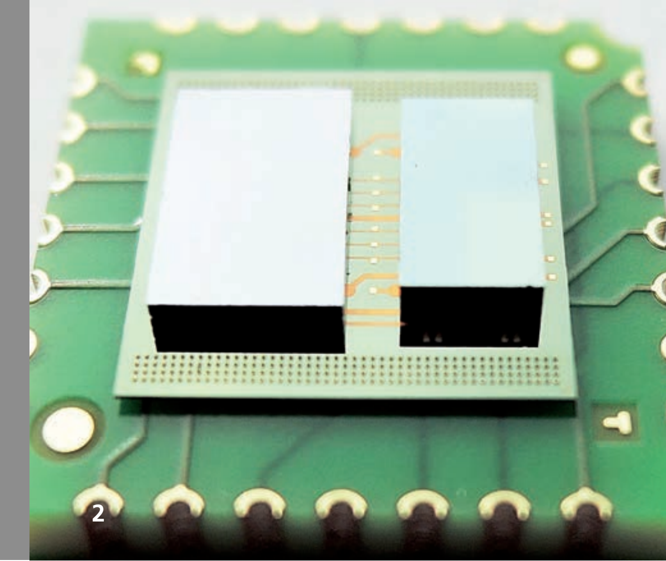
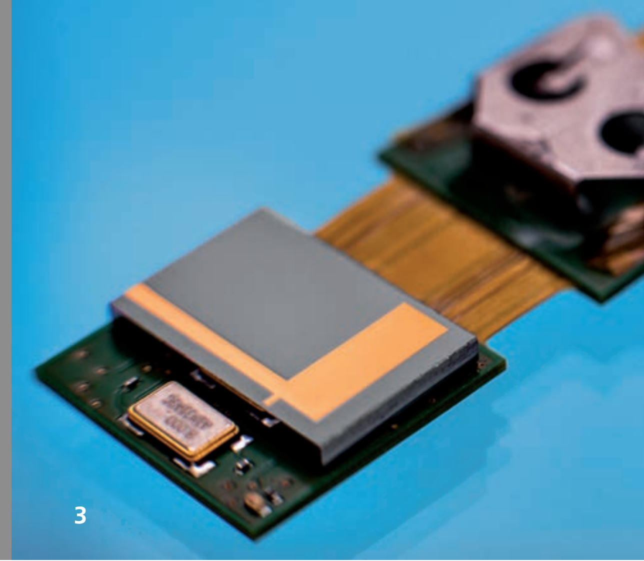
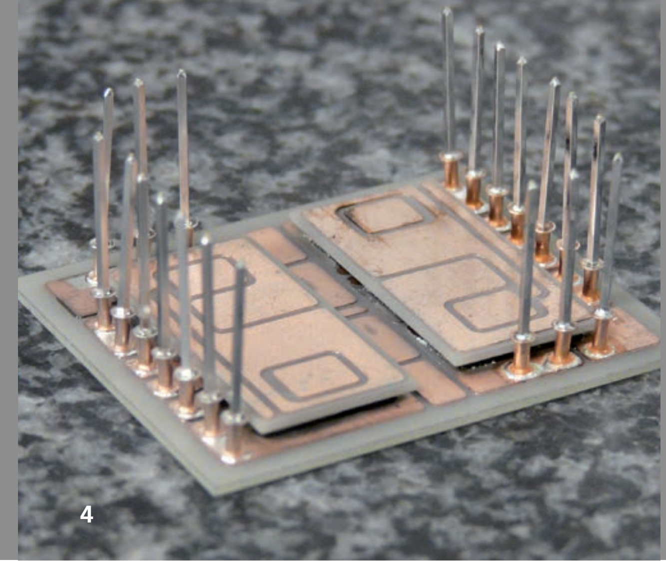





**Ultra-thin, high density integrated capacitors**
In close cooperation with Fraunhofer IPMS and ALD Lab Dresden, ultra-compact capacitors for direct integrated circuit packaging have been developed. Using technologies available at Fraunhofer IZM-ASSID, numerous customer-specific package integration variations can be realized. Here, special RDL & interposer technologies with novel high-k materials for capacities with $\varepsilon r > 80$ are applied.

**SIMEIT: TSV interposer for sensor an CMOS integration**
Within the project SIMEIT the integration of sensor and ASIC on a Si-interposer was realized and established as a basic technology with improved system performance. A TSV silicon interposer that has been developed at Fraunhofer IZM-ASSID for system evaluations consists of a copper redistribution layer, Ni/Au test pads and micro-bumps (Cu/SnAg) on the top side and polymeric isolation and Cu-landing pads on the bottom side.

For the vertical interconnection of top and bottom side Copper TSV have been inserted. Further specifications are: 10/100µm Cu-TSV, Cu/Polymer-RDL (top), Ni/Au test pads und Cu/SnAg FC-bumps as well as polymer insulation und landing pads (bottom). For TSV processing, newly developed and optimized TSV processes have been applied.

Within the project, the interposer was assembled in cooperation with the project partners and successfully tested. The applied novel technology serves as a prototype for future, form factor optimized generations of sensor packages.

**NANETT: eGrain 3D packaging**
Wireless communication for the connection of devices and assembly groups of complex systems is an important trend that requires the realization of miniaturized sensor nodes (eGrains) containing sensors, controllers and a radio interface.

Within the project NANETT, a new prototype of a so-called eGrain has been developed that consists of a silicon carrier with through silicon vias assembled with active and passive devices and a top cover with an integrated antenna. On the interposer the following components are connected to form a system: an RF transceiver CC2520, a micro controller MSP, an especially developed antenna for 2.4 GHz and passive devices.

A significant challenge posed the development of a highly miniaturized and efficient 2.4 GHz antenna and its integration into the module taking into account the interactions between antenna and the other implemented components.

**SmartPower: double sided cooling**
In power electronics, new components made of GaN and SiC allow a higher switching frequency and in this way enable higher efficiency as well as lower loss.

On the one hand, the modules become increasingly compact due to smaller capacitors. On the other hand they have to be designed with lower -package related inductivities.

Within the European project Smart Power, different module types based on Si-IGBTs and SiC have been realized in cooperation with Thales (also project coordinator), Schneider Electric and Infineon. For the double-sided contact, the chip front side was realized with solderable properties. Fraunhofer IZM added a 80 µm contact structure for flip chip mounting. The established contact height guarantees a sufficient distance to achieve the required breakdown voltage up to 1200 V.

New bonding methods such as sintering, TLPB and TLPS offer a robust connection also at higher junction temperatures. Finally, Fraunhofer IZM realized half and full bridges with very compact dimensions and integrated them with double sided cooling into a modified standard package manufactured by Infineon.

*1 Ultra-compact capacitor ($\varepsilon$ r >80) for direct integrated circuit packaging*

*2 SiP with ASIC and MEMS on Si TSV interposer (100 µm)*

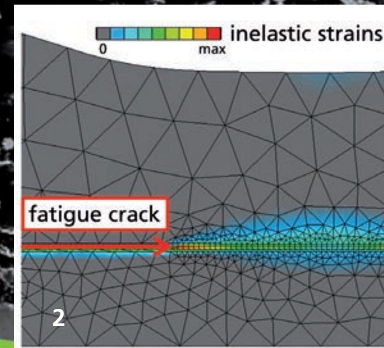
*3 Si TSV interposer, application with active and passive devices as well as integrated antenna*

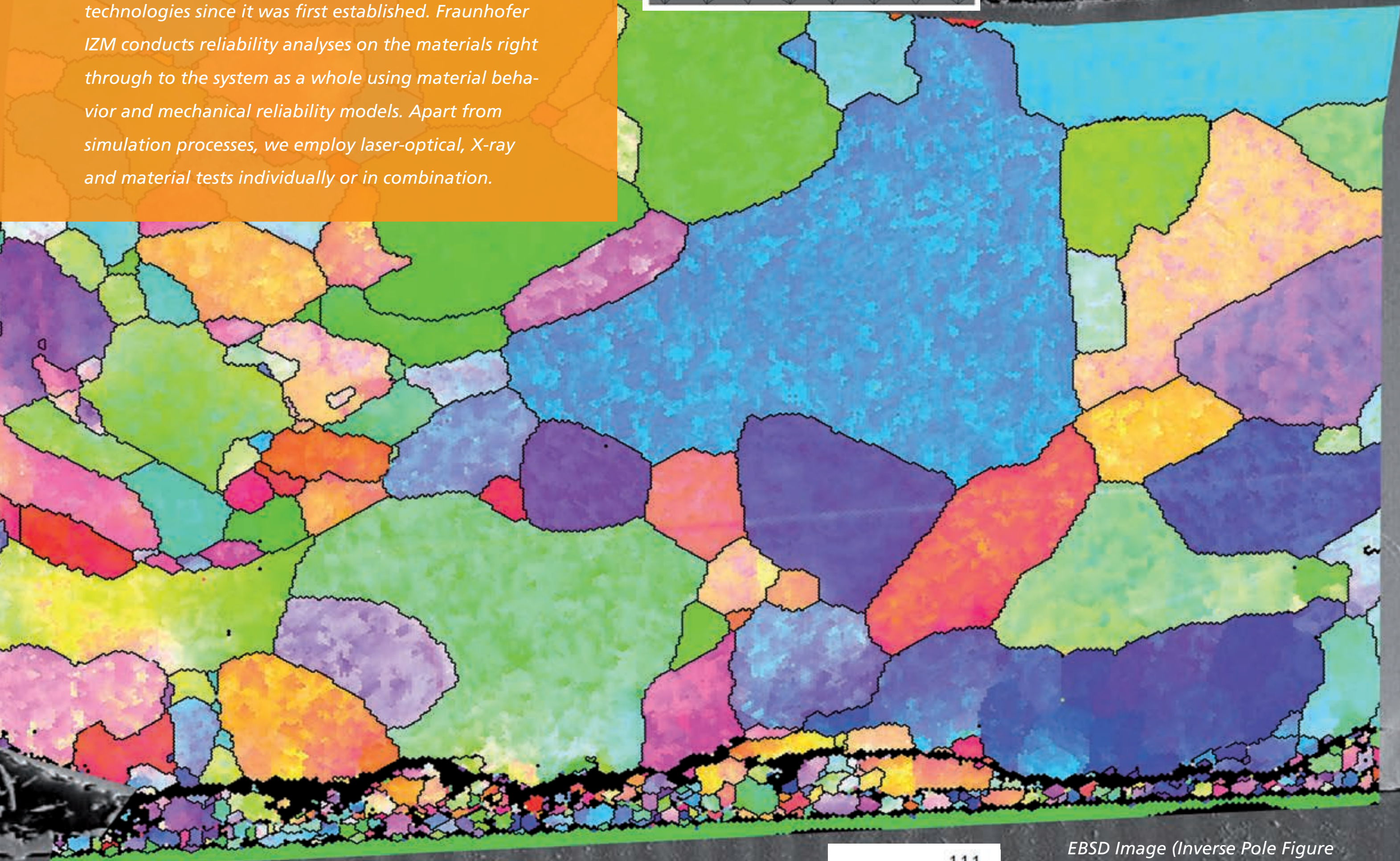
*4 Power electronic inverter for electro mobility applications with double sided cooling for improved heat-dissipation in power electronic systems*

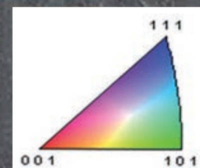
# RESEARCH CLUSTER MATERIALS & RELIABILITY

## MATERIALS & RELIABILITY 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.*




*EBSD Image (Inverse Pole Figure Map, Fig. 1) and numerically calculated strain distribution in an Al-Wirebond (Fig.2) after active power cycling testing*

# HIGHLIGHT 2014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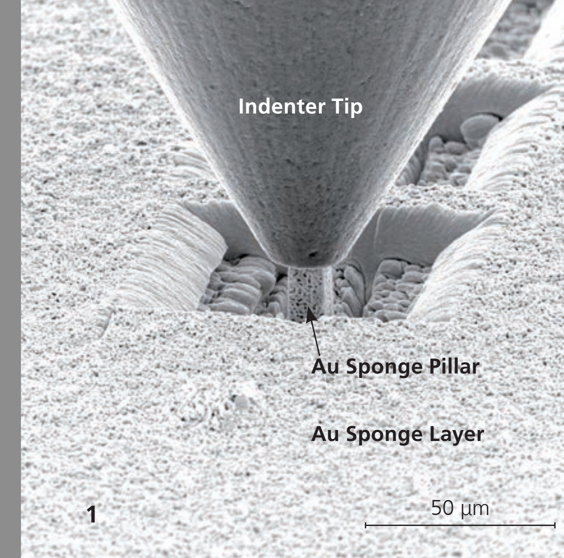
**EBSD investigation of wire bonds**

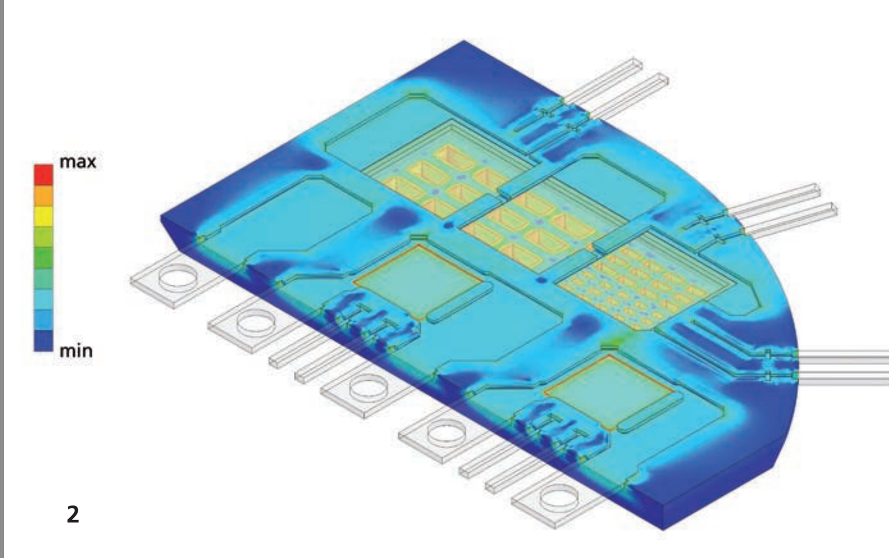
Assessing and predicting the reliability of wire bonds, particularly in power electronics, requires comprehensive know-how of the materials involved A key current goal of the Fraunhofer IZM department Environmental and Reliability Engineering is improving the lifetime of wire bonds for tomorrow's electric vehicle designs.

The German Federal Ministry of Education and Research (BMBF)-funded project »RoBE« (Robust Bonds in Electric Vehicles) tackled this challenge by testing modified wire bonding materials using adapted innovative assembly technologies. The quality of the resulting wire bonds was analyzed and quantified by shear testing and microstructure analysis in initial state and after active power cycling. Using customized lifetime assessment models and the insight gained from the latter experimental data, the bonding process can be optimized.

The project showed a clear correlation between lifetime and microstructure. To characterize the microstructure of individual wire bonds, specifically parameters like texture and grain size, EBSD (electronic backscatter diffraction) analyses were performed in initial state and at defined points during cyclic loading. Data on the texture of individual wire bonds provided insight into their mechanical anisotropic effects. Moreover, data on the texture and grain size, particularly in the bonding area between the wire and contact metallization, facilitated an analysis of microstructure as a factor in shear testing and active power cycling testing.

To predict the lifetime of wire bonds, crack propagation during active power cycling was investigated and a customized lifetime prediction model was developed. Active power cycling identified plastic deformation in the area in front of the crack, which fatigued the material independently of crack growth. This additional deformation was fed into a crack propagation model to predict wire bond lifetime.




# 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**
Electronic systems are being used in more and more diverse application areas. Consequently the task of maximizing reliability while using the least possible resources becomes increasingly complex.

Improving the modeling of how an innovation is used, known as mission profiling, is of central importance here. Mission profiling brings systematic understanding of applicable operating conditions together with cutting-edge technology. In the past, roadmaps set down norms agreed on in broad, consensus-based processes for wide-sweeping areas such as »industry« or »medical engineering«. Today, more detailed and diverse operating conditions have to be considered in order to specify the concrete maximum loads that may occur in the various combinations of application types.

To address this, Fraunhofer IZM has developed the following techniques: Using the application scenarios and the functionality, whose reliability has to be secured as basis, system analyses are carried out and suitable load profiles, known as mission profiles, are developed to ensure optimized planning of reliability testing throughout the supply chain.

Using physics-of-failure approaches, reliability experts can assess various designs and application environments. The resulting data are crucial to making design decisions in a timely fashion and avoiding reliability risks. Both the described application scenarios and the reliability predictions are also important bridges to more precise environmental assessment. Consequently, the interplay between environmental optimization and reliability assurance is potentially an important foundation for improving how we use resources.



# RESEARCH & DEVELOPMENT HIGHLIGHTS

**LCA to go – Lifecycle assessment for SMEs**
Lifecycle assessment of complex products and processes generally requires a great deal of expert know-how, and is an area that is particularly daunting for SMEs. The EU project LCA to Go, coordinated by Fraunhofer IZM, has now developed new, simpler methods and free browser-based software that help PCB manufacturers, sensor producers and end device developers calculate key lifecycle data. At the end of the project, 104 SMEs used the software to calculate their carbon footprint, data that has now been fed into their marketing platforms, environmental management and product development.

**Thermomechanical reliability of packaged power modules**
Power electronic packaging by transfer molding is comparatively simple and allows for high integration density. However, one drawback is lacking thermomechanical reliability, which needs to be addressed at the outset of development by careful selection of materials. Together with ECPE (Engineering Center for Power Electronics), we assessed molding materials for temperatures above 175 °C using a novel approach that combined and correlated material characterization, FEM simulation, modeling and lifetime assessment. This allowed us to identify materials able to withstand high operating temperatures and to assess how thermal aging of the molding material affects thermomechanical reliability.

**Bonding at high temperatures**
At operating temperatures of up to 300 °C, the solders used for bonding fail. Alternative bonding materials with much higher melting points exist, however, little is known about their mechanical properties. We have now developed methods for characterizing these and can present key preliminary results for silver sintering in particular. Against expectations, we found that time-dependent creep was a key mechanism of deformation. This finding has now been included in the reliability assessment of such structures.

*1 SEM image of a pressure test on a pillar from an Au sponge layer*

*2 Simulated thermo-mechanical stress distribution in mold compound of a smart power module demonstrator*

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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.*

*Backbone of future sensor nodes: miniaturized assembly (10 x 15 x 3 mm³) consisting of microcontroller, RF-receiver and integrated antenna*

## HIGHLIGHT 2014

**Embracing the Internet of Things – Design and assembly of highly integrated sensor nodes with self-sufficient power supplies**

On tap, around the clock and around the world – key demands associated with the rising phenomenon that is the Internet of Things. Two different types of sensors will be indispensible in realizing this vision: firstly, highly robust, specialized sensors and, secondly, highly miniaturized, low-cost sensors. The former will be needed for implementation in even the harshest conditions, while the latter will be deployed as a cost-effective tool in projects that have tight profit margins or buildspace.

Several Fraunhofer IZM departments joined forces in the project NANETT to make the dream of a highly integrated sensor node a reality. The institute developed the technology for a wireless sensor node comprising a microcontroller, HF transceiver and integrated antenna, housed in a remarkably compact buildspace (10 x 15 x 3 mm³). The unit forms the core of a sensor node system created by adding sensors. Suitable for use with all types of sensors, easy to use, and highly miniaturized, the sensor node system is a highly flexible tool that can easily be integrated into a wide range of applications.

Our design, simulation and testing techniques have had to keep up with ongoing advancement of integration technologies in terms of system build size, reliability and cost, along with hybrid integration of different functionalities. Consequently, we have developed design techniques and technology flows for the integration of signal and RF traces in 3D silicon stacks using passive Si interposers and RDLs.

Apart from the integration approaches, we have prioritized reducing power consumption. Despite, or perhaps precisely because of increasing miniaturization, power consumption by sensor nodes is steadily outstripping storage capacity. We also developed new approaches to energy-efficient communication in terms of both components and within sensor networks, environmental energy harvesting and efficient power management.

This research was part of the research consortium NANETT (Competence Center for Nanosystem Integration – Application of Nanotechnologies for Energy-Efficient Sensor Systems), which was funded as part of the BMBF program »Research Excellence and Innovation in the New Länder«.

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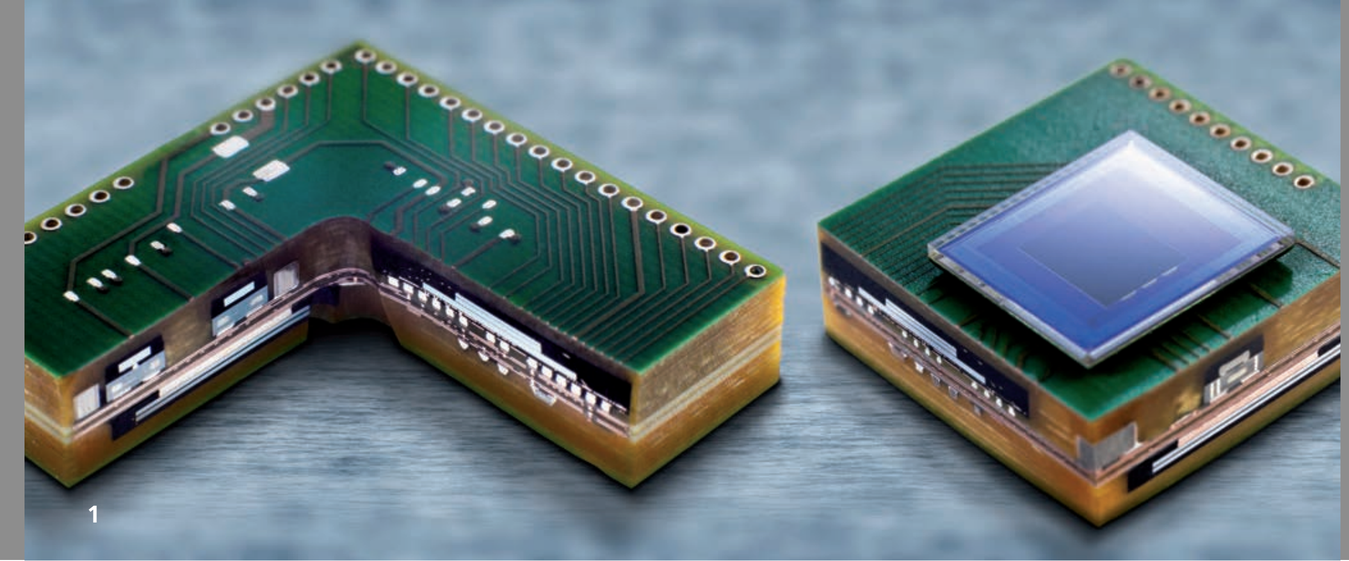

# RF & SMART SENSOR SYSTEMS

**The Department RF and Smart Sensor Systems**
Our department is a key address for technology-oriented system know-how at Fraunhofer IZM. For example, we specialize in autonomous microsystems, from eGrains, to sensor nodes with self-sufficient power supplies, through to cyber-physical systems, all of which have been shaped significantly by the Internet of Things.

We develop and improve methods, models, techniques and tools that optimize microelectronic system design. Our goal is providing an integrated design process that includes the simulation of electrical, magnetic and electromagnetic parameters. The results of simulation studies are fed into function, volume and reliability analyses, improving decision-making in the design process. The department primarily focuses on:

- Design and integration of miniaturized wireless sensor systems
- RF and high-speed system design
- Power supply and management for electronic systems

Today's research and development forms the basis of the services we provide in the future. Our department's commitment to cutting-edge research is also demonstrated by our regular attendance at key academic and industry conferences and our participation in numerous collaborative research projects.

**Trends**
Internet of Things, Industry 4.0, cyber physical systems – these buzz words have come to dominate speculation on the future of technology. The three concepts share a common foundation – they will be made possible by autonomous sensor networks deployed as discrete systems or as part of devices, machines or equipment to gather and transmit data. The overall appraisal of the application environment this prompts shows an increasing role for the design of system concepts and a closer interrelationship between circuit design and technology development. This trend is already firmly established and is continually advanced at Fraunhofer IZM.

Real-time processing, robustness, reach management and increasing data rates are important future issues in the networking of such systems. For this reason, the maximum frequency for RF experiments, including characterization of dielectric material was increased from 110 GHz to 220 GHz, a range that includes 122 GHz and nearby frequencies, which will play key roles in the future.

Hardware-software co-design will also become a necessity, along with new approaches to power supplies for autarkic sensor nodes. Further important research areas will be low power design, multimode energy harvesting and miniaturized voltage transformers.

# RESEARCH & DEVELOPMENT HIGHLIGHTS

The Fraunhofer IZM Department RF & Smart Sensor Systems specializes in developing highly miniaturized sensor nodes for distributed, complex sensor networks.

**Controlling power grids with autarkic sensor systems**
ASTROSE®, a sensor network with self-sufficient power supply, which we developed in collaboration with Fraunhofer ENAS, monitors overhead power lines to improve transmission capacity. The sensor nodes are attached to the power line at intervals of up to 500 m. The measurement data is relayed from sensor to sensor wirelessly and automatically, finally reaching the grid operator's mains control. The system was field-tested using 60 sensor nodes in 2014 and passed with flying colors, despite an extremely harsh operating environment, including high voltage, dirt, wet, cold, heat, and challenging assembly conditions.

**Condition monitoring using wireless sensor technology with self-sufficient power supply**
Identifying component wear-and-tear in time, but only servicing machines when really necessary. The research consortium MoSe has developed a sensor network for railway vehicles that makes this ideal a reality. The project partners developed a design approach customized for wireless sensor nodes. Goal was a system capable of consolidating the measurements and analysis and uploading the condition assessment data to a maintenance cloud. Apart from precise sensor technology, high-performance data processing and wireless communication, power supply was a key factor in the hardware design of the no-maintenance sensor node.

**Modular voltage transformer with flexible input voltage**
We have developed modular transformers with highly flexible input voltage (19V – 265V AC/DC) for application in railway technology. Thanks to the parallel circuit design, the modular inter-leaving converter is capable of almost any output voltage and users can increase the power supply as desired. This makes dedicated voltage transformers for mains and battery voltage redundant.

**Wireless power supply**
Wireless charging is an added convenience for users of mobile devices and also makes new electronic applications possible in areas that lack mains outlets. Litz wire coils are generally used for the necessary transformer coils. However, the project WIPOS explored an alternative – integrating coils into PCBs. The study also investigated the charging technology that would be required. The results have been transferred into design tools and demonstrators, which can now be fed into the design process.

*1 Miniaturized modular camera module: 8-layer HDI-high-speed-design, two layers for plug-in connectors, camera assembly with stacked μVias (Ø 50 μm), 60 μm track width and a board size of 16 x 16 mm²*

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# FRAUNHOFER IZM EVENTS

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1 *Hands-on experience for youngsters at Fraunhofer IZM-ASSID during the Long Night of Science in Dresden*

# EVENTS & WORKSHOPS

**Workshop: Power Embedding**
Which design concepts are indispensible in power electronic embedding? Which materials and processes are needed to ensure efficient, yet reliable applications? These questions and more were answered by Fraunhofer IZM's Power Embedding workshop, held July 2 in Berlin.

Over recent years, the role of packaging technology has grown in line with the rising voltages processed by power electronic circuits and the simultaneous increase in current carrying capacity. In the final instance, a system's electronic functionality will no longer be circumscribed by the properties of silicon, but by the technologies that connect the circuits with the external world. The Fraunhofer IZM approach Power Embedding, originally designed for very high-density microelectronic applications, is an efficient and highly reliable tool for product development. More than 40 experts took up the chance of testing this exciting technology in terms of its design opportunities and the materials and processes it involves.

**Workshop: Laser Technology for Electronic Manufacturing**
How can laser technology be best applied in electronic manufacturing? Fraunhofer IZM and high-profile equipment manufacturers tackled this question in the workshop »Laser Technology for Electronic Manufacturing: New Trends in Wafer Processing, Printed Circuit Boards and Photonic Packaging«, held on July 3, 2014, in Berlin. The workshop highlighted the advantages and future promise of laser technologies, focusing on three main areas:

- Mask-less wafer processing in wafer-level lithography (challenges like limited compatible materials and resolution were also addressed)
- Precise shaping of through vias and interconnection for PCB chip embedding
- High-precision glass processing, including cutting and welding, as well as precision breaking of wave-guide interconnects in planar glass structures for optical components

**Fraunhofer IZM ASSID takes the stage at Dresden's Long Night of Science**
»Join in, gen up, keep going«, was the motto of the 12th Dresden Long Night of Science held on Friday July 4, 2014. As in previous years, the Fraunhofer IZM center All Silicon System Integration Dresden (ASSID) put together a colorful introduction to 3D microintegration for science enthusiasts in Dresden and surrounding areas. The ever-popular clean-room gave visitors insight into the heart of Fraunhofer IZM ASSID, while other tour stops presented microscopy in its myriad forms. The world's tiniest microcamera also featured as a highlight. Apart from the institute tour, visitors were also treated to lectures, a look at a thermography scanner and got to test their science mettle in an ASSID quiz.

During the year, Fraunhofer IZM ASSID also participated in the Young Scientists Program, organized by the network »Dresden – City of Science«, which aims at recruiting high school students in particular for 3D microelectronics.

**Workshop: Photonic Packaging**
Growing ICT bandwidths call for new concepts in photonic system integration. The miniaturization of light sources and a wide range of optical sensors also go hand-in-hand with aspects of cost reduction and reliability. Photonic packaging has a key role here, and covers individual packages, to modules or sub-systems with at least one optoelectronic component or interconnection. The workshop »Photonic Packaging« on September 10-11, 2014, focused on efficient European research strategies and automated packaging techniques for optoelectronic and photonic integration at PCB, package and component levels. Discussion between the participants (OEMs, suppliers and manufacturers) and Fraunhofer IZM experts on the possibilities and individual challenges of tight tolerances, the requirements of photonic systems and the value-added chain was remarkably frank.

**ERSA takes its 2014 hands-on rework tour to Fraunhofer IZM's Center for Interconnection Technologies in Electronics (ZVE)**
The company ERSA held a training course as part of its 2014 Hands-On Rework tour at Fraunhofer IZM's Center for Interconnection Technologies in Electronics (ZVE) in Oberpfaffenhofen at the end of last September. The workshop afforded the participating repair and rework employees and manufacturing process operators insight into reworking. Using practical examples, three different equipment solutions for QFP, BGA and QFN were presented, including a system in use at ZVE, the ERSA IR/PL 550. Afterwards, the participants had the opportunity of trying out the systems themselves. Fraunhofer IZM ZVE's broad training program includes a six-monthly, two-day course in BGA, CSP and QFN inspection and solder repair of SMT components. Certification as trainer/specialist according to IPC-7711/21 is also offered as a five-day training course.

**Fraunhofer IZM and ECPE**
In 2014, Fraunhofer IZM again helped organize and present tutorials and seminars for the European Center for Power Electronics (ECPE) and the Cluster Power Electronics Bavaria. As in the past, a key topic of the diverse events organized by Fraunhofer IZM was electromagnetic compatibility (EMC). One highlight was a lab course, in which the participants learned about EMC via hands-on exercises like measurement, modification of circuits using soldering irons and circuit optimization.

1 Prof. Wolf-Dieter Lukas of the Federal Ministry of Education and Research honors Prof. Klaus-Dieter Lang at the occasion of his 60th birthday

2 As last year's winner, Fraunhofer IZM this summer hosted the largest Fraunhofer Soccer Cup of all times

| Events with Fraunhofer IZM participation 2014 | |
|---|---|
| **OTTI Fachforum: Protective Measures for Climatic Protection of Electronic Assemblies** | March 2014, Regensburg |
| **Symposium: 1. Optical Interconnect in Data Centers** | March 2014, Berlin |
| **ECPE LabCourse: EMC Optimised Design (Parasitics in Power Electronics)** | March/April 2014, Berlin |
| **ECTC Tutorial: Moisture and Media Influence on Microelectronic Package Reliability** | May 2014, Orlando, USA |
| **Workshop: Aging of Laser Diodes and LEDs** | May 2014, Nürnberg |
| **Seminar: Reliability Management** | June 2014, Berlin |
| **14th International Symposium on the Science and Technology of Lighting** | June 2014, Como, I |
| **VDI-Conference: Lifetime and Quality Assurance in Solid State Lighting** | June 2014, Düsseldorf |
| **Seminar: Autarkic Sensor Networks** | July 2014, Berlin |
| **Workshop Lichtforum NRW: LED Packaging for Power and CoB-Systems** | August 2014, Arnsberg |
| **FED-Conference: Quality and Reliability of PCBs and Assemblies** | September 2014, Bamberg |
| **Workshop: Mechanical Interconnection: Crimping according to Industry Standards** | October 2014, Wessling-Oberpfaffenhofen |
| **Workshop: Parasitic Effects in Power Electronics** | November 2014, Berlin |

**Symposium and reception in honor of Prof. Klaus-Dieter Lang's birthday**
Fraunhofer IZM has hosted an informal series of symposia for a number of years that bring its clients and research partners up-to-date on the latest electronic packaging technology. Most recently, the institute welcomed around 300 guests on December 16 to Hotel Scandic at Berlin's Potsdamer Platz, where high-profile experts in research and industry presented cutting-edge trends in a wide range of areas.

Former Fraunhofer IZM Head of Department Prof. Walter Scheel started the day with a history of PCB technology. PCB-Network's Hans Friedrichkeit followed with a discussion of PCBs as possible semi-active integration modules. Former Fraunhofer IZM Director Herbert Reichl speculated on the technical issues that will shape the Internet of Things. Dr. Gerd Teepe from Globalfoundries called for more investment in education and training by presenting convincing statistics on the economic and social impact of microelectronic development. This was followed by two related presentations on security documents. Here, Dr. Dirk Woywod from the Bundesdruckerei GmbH first outlined current challenges in this area, after which Fraunhofer IZM Deputy Director focused on the Fraunhofer IZM's possible role in the solutions to these issues, particularly in terms of 'dual integration', which merges packaging technologies on panel and wafer level.

The second half of the symposium was dedicated to Fraunhofer IZM Director Prof. Klaus-Dieter Lang in honor of his 60th birthday. Two presentations, by Guido Beerman, Permanent Secretary in Berlin's Senate Department for Economics, Technology and Research and Prof. Wolf-Dieter Lukas from the German Federal Ministry of Research and Education (BMBF) emphasized the symbiosis of research funding and innovation. President of the Technische Universität Berlin, Prof. Christian Thomsen, Fraunhofer Gesellschaft Executive Board Member Prof. Alfred Gossner and Chairman of the Fraunhofer Group for Microelectronics Prof. Hubert Lakner outlined Prof. Lang's contribution to his field.

The event also made room for up-and-coming talent. The 2014 Fraunhofer IZM Research Award was presented to Dr.-Ing. Tanja Braun for her outstanding research on the characterization, processing and reliability assessment of microelectronic encapsulation materials. The symposium closed with a reception at the Berlin event space Wasserwerk.

**Fraunhofer IZM's sporty side**
Both fitness and networking were on the agenda when Fraunhofer IZM employees signed up for 2014's TEAM Relay and the Berlin Corporate Marathon.

The institute fielded 30 runners in the 15th Berlin Wasserbetriebe TEAM Relay. One team in the over 5000 participants placed the 108th, covering the 5x5 km stretch in 1:48:21. The Berlin Corporate Marathon also proved that the Fraunhofer-Gesellschaft is not just made up of lab geeks. Across all Berlin Fraunhofer institutes, 365 staff, including 40 from Fraunhofer IZM, took up the challenge of running the 6 km on May 28, 2014.

**2014 Fraunhofer Soccer Championship**
Brazil was not 2014's only address for exciting soccer: The Fraunhofer Annual Soccer Cup proved a nail-biter. As per tradition, the event was organized by the previous year's champions, which last year happened to be Fraunhofer IZM. The showdown was the biggest Fraunhofer tournament ever. More than 400 players and 36 teams congregated in Berlin for a jaw-dropping finale. The championship was decided by a penalty shoot-out, with Bremen's Fraunhofer IFAM beating Pfinztal's Fraunhofer ICT 2:0.

**Cycling for the environment**
Soccer was not the only sport on the agenda last July. Fraunhofer IZM colleagues from Oberpfaffenhofen's MMZ also burnt rubber for the environment as part of the Starnberger Cycling City event. Over three weeks the center's staff ate up more than 2100 of road, equal to 333 kg $Co_2$.

# FRAUNHOFER IZM AT TRADE SHOWS

Showcasing innovations remains a central component of our work: Fraunhofer IZM displayed its newest developments over a dozen times in 2014 at various trade fairs in Germany, Europe and around the world.

Right at the start of the trade fair year in January, the scientists from the Fraunhofer IZM ASSID set off for Grenoble. There, under the umbrella of SEMI Europe, the »European 3D-TSV Summit« took place. The conference and associated trade fair, which was substantially co-organised by the Fraunhofer IZM ASSID, focussed primarily on 3D-TSV technologies, showcasing both the business and the technology perspectives.

Following a guest appearance at Photonics West in San Francisco (USA) in February, where new developments in the field of optical technology were showcased, the Fraunhofer IZM then set off in March to Vienna for the Smart Systems Integration trade fair. This conference is part of the EpoSS activities (the European Technology Platform on Smart Systems Integration). This year again, researchers from the Fraunhofer IZM contributed to the conference programme and showcased the activities of the institute in the field of electronic packaging at the associated trade fair.

A highlight of the spring trade fairs was once again the SMT in Nürnberg. This year an exceptional number of visitors gathered information at the Fraunhofer IZM trade fair stand about the current trends in packaging and interconnection technology from the IZM laboratories. A particular magnet for the public was a miniature intelligent camera, only 3x3 in size, which far outstrips comparable devices from other manufacturers. A textile display also attracted visitors: 64 flexible and colourful SmartPixels, consisting of individually configurable RGB light sources, astounded onlookers by illuminating a jacket.

International experts for power electronics and drive technology met in May at Power Conversion Intelligent Motion (PCIM) in Nürnberg, the largest European trade fair in this field. There, Fraunhofer IZM presented its entire spectrum of services for power electronics. Highlights at the IZM stand were a low-inductive power module with embedded chips, minimising parasitic effects and thus enabling a significant current increase, and a newly developed current sensor, which is able to measure particularly high-frequency current.

**Industry 4.0 live at SMT**

Already for the fifth time, Fraunhofer IZM's Application Centre organized the presence of the Future Packaging production line at the SMT Hybrid Packaging trade fair in May 2014.

Alongside the live-action production line, the many interested visitors could experience the successful interplay of research and industry at the shared stand. Included in the broad spectrum of exhibitors were scientific institutes, machinery producers and component suppliers. The primary theme of the stand and production line in this year was »Industry 4.0 – With New Technologies on the Path to Lot Size 1«. A further exhibition focus was products and services for the manufacturing environment.

*1 At the Laser Optics Berlin Fraunhofer IZM's director Prof. Klaus-Dieter Lang shows recent IZM developments to Guido Beerman, Permanent Secretary in Berlin's Senate Department for Economics, Technology and Research and to Michal Olszewski, sdeputy mayor of Warsaw*

| Fraunhofer IZM at Trade Shows 2014 (Selection) | |
|---|---|
| **AAL-Congress** | January 2014, Berlin |
| **European 3D-TSV Summit** | January 2014, Grenoble, FR |
| **Photonics West** | February 2014, San Francisco, USA |
| **Laser Optics Berlin** | March 2014, Berlin |
| **Smart Systems Integration** | March 2014, Vienna, AUT |
| **SMT** | May 2014, Nürnberg |
| **PCIM** | May 2014, Nürnberg |
| **Semicon Russia** | May 2014, Moskau, RUS |
| **ECTC** | May 2014, Orlando, USA |
| **Sensor+Test** | June 2014, Nürnberg |
| **ESREF** | September/October 2014, Berlin |
| **Semicon Europa** | October 2014, Grenoble, FR |
| **IMAPS** | October 2014, San Diego, USA |
| **Compamed** | November 2014, Düsseldorf |
| **Electronica** | November 2014, Munich |
| **Semicon Japan** | December 2014, Tokio, JPN |

# WORKSHOPS 2015

**Regular workshops at Fraunhofer IZM's Application Center**
We are holding several workshops again this year, focusing on transferring know-how from our experts to you.

You have a choice of three different kinds of workshops:

- Workshops on latest international technological trends focus on current technological developments with regard to designing future technology
- Workshops on trends for medium-sized businesses present fully-developed technologies already in application
- Hands-on-workshops combine market-relevant know-ledge transfer with practical work in the laboratories or at machines

Depending on demand we offer workshops in the different categories.

Please contact us if you are interested, we will tell you the dates for coming workshops and we will also be happy to organize individual events for your company.

For more information, go to
www.izm.fraunhofer.de/events

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**[1] Seminar Reliability Management**
Fraunhofer IZM runs seminars on »Reliability Management« on a regular basis. Their focus is on methods for reliabilty assurance in the development and manufacturing of electronic systems.

**What will you learn?**
- External conditions relevant for reliability
- Stress tests based on failure mechanisms and aging models
- System reliability assessment
- Condition monitoring

Potential participants: Quality managers and reliabilty engineers responsible for product development and quality assessment.
**Date: June 11–12, 2015**

**[2] Workshops on die and wire bonding**
Quality and reliability aspects of wire bonds are discussed in this workshop and practical bond tests are carried out on test substrates.

**What will you learn?**
- Die-, US-wedge/ wedge- and TS-ball/wedge-bonding
- Heavy wire- and ribbon bonding
- Visual inspection
- Pull- and shear test analyses

Potential participants: technicians, managers, developers and construction engineers.

**[3] Working Group Design Conformity for WEEE / RoHS / EuP**
At the meetings which regularly take place at Fraunhofer IZM, companies prepare for the development and production of products which conform with the WEEE, RoHS and EuP Directives

**What will you learn?**
- Current trends in international law
- Methods and tools for the development of environmentally compatible products
- Declaration of substances

The working group is supported by ZVEI, BITKOM and FED, and is organised and coordinated by Fraunhofer IZM.

Potential participants: Managers and technicians responsible for development and production processes conforming with the directives.
**Dates: June 9 and November 17, 2015**

**[4] Trends in electronics for automotive applications – new packaging concepts**
This workshop is designed to discuss international research and development trends in electronics for automotive applications.

**What will you learn?**
- High-temperature electronics
- Sensor packaging
- Packaging and EMC of power electronics
- Reliability

Potential participants: international packaging experts and developers, particularly from the automotive sector.

**[5] Workshop Micro Battery and Capacitive Energy Harvesting**
This workshop focuses on micro batteries and their combination with capacitive converters for energy harvesting.

**What will you learn?**
- Development of micro batteries that can be integrated
- Ultra-low power battery management
- Research results of EU-project MATFLEXEND
- Flexible materials, wearable electronics, integration in textiles
- Material development, device optimization, simulation

Potential participants: material developers of mcro batteries and nano-materials for energy harvesters, as well as developers of energy supply technologies for miniaturized electronics and integration into textiles.
**Date: April 27, 2015**

**[6] Working Group System Reliability of Packaging Technologies**
For several years the workgroup has served as a forum to discuss and scrutinize challenges and solution approaches of industrial applications and research with partners from the industry.

**What will you learn?**
- Process influences, whisker forming, electromigration
- Long-term reliability
- Filed behavior of complete systems

The working group is supported by ZVEI and FED. The meetings are organized and coordinated by Fraunhofer IZM.
Potential participants: Packaging experts from research and industry.

# PROMOTING YOUNG TALENTS

The future of our research area depends on an ongoing influx of young talent from the life sciences. Fraunhofer IZM has been supporting up-and-coming researchers and technicians for over 16 years and has long been reaping the rewards. One key measure is our apprenticeship system. However, 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.

**2014 Girls' Day at Fraunhofer IZM**
Fraunhofer IZM has hosted a special Girls' Day program for over a decade. In 2014, 11 girls visited the institute for a fun and inspirational day of microelectronics. After a short introduction and get-to-know-you quiz, the girls disassembled (note: older generation) mobile phones, and reassembled them after a short discussion of the various components. The girls were then treated to a tour of the Fraunhofer IZM departments and got to try their hand here and there - including automated PCB soldering, embedding, grinding, analyzing electronic components and cycle testing. The girls were even front-and-center for the assembly of an electronic circuit – in this case, a glowing figure – and the metallization of a structured PCB, including polishing and cross-section microscopy.

The day ended with a tour of the grey room, which provides a birds eye view of the work in the various cleanrooms.

**Fraunhofer IZM: Open for talent**
Together with FemTec, Fraunhofer IZM tries to help female high-school seniors specializing in Math and Science plan their tertiary education. On April 23, the institute opened its doors to 30 high-school seniors as part of the »Talent Take-Of« program.

After a short introduction to the institute and its research areas, the students toured several labs, including Advanced System Engineering, Thermal & Environmental Analysis, Electronics Condition Monitoring, Adaptive System Integration, the textile laboratory and the perennial favorite: the cleanroom. The students not only had a unique glimpse of life in the research setting and the opportunity to ask about processes and machines, but were also put straight to work measuring the thermal stress of electronic components.

The day was rounded off with a Q&A, in which Fraunhofer IZM researchers fielded both technology questions and questions about their personal career paths. The take-home message for the majority was: many different paths lead to Fraunhofer IZM!

**Fraunhofer IZM and EnterTechnik – Technology training for young women**
In 2014, Fraunhofer IZM again joined 15 other Berlin-Brandenburg companies for EnterTechnik – A Technology Training Year for Young Women. The program offers females with intermediate and senior high-school certificates a tour of Berlin tech-companies in a variety of product areas – from mobility, urban planning, medical and precision engineering, to high-tech and ICT.

During their internship at Fraunhofer IZM, four young women learnt all about working as a Microtechnologist in various laboratory areas. After their lab rotation, the interns decided between cleanroom processes, material assessment and substrate technology.

In 2014, we also saw direct evident that such programs make a difference. One participant, Jessica Kazuch, overcame an initial skepticism of a career in the sciences and began an apprenticeship as Microtechnologist in September, leaving no doubt that Fraunhofer IZM will continue offering internships in technology careers to women.

**Internships & the Ecology Gap Year – Energy efficiency of industry servers**
Following the 2013 assessment of tablet recycling and repair, in 2014 our Ecology Gap Year intern teamed up with a rotation student to study the thermal management of industry servers. The results give insight into the power and resource efficiency of these devices.

**Fraunhofer Executive Board names July Kierdorf as top apprentice**
The Berlin Chamber of Industry and Commerce (IHK) has again named a Fraunhofer IZM trainee Apprentice of the Year. This ranks Microtechnologist July Marie Kierdorf among the year's 12 best Fraunhofer-Gesellschaft apprentices, which was acknowledged with a special award ceremony at the Fraunhofer Gesellschaft's Munich headquarters last November.

July Marie Kierdorf is the latest success story in Fraunhofer IZM's longstanding, excellent training program. Kierdorf's three-year apprenticeship covered all aspects of PCB manufacturing and embedding technology. Her primary supervisor was Stefan Karaskiewicz. Luckily for Fraunhofer IZM, July Marie Kierdorf has joined Fraunhofer IZM's research partners at the TU Berlin Research Center for Microperipheric Technologies, so her expertise will be close at hand.

*1 Full concentration at the Talent Take Off*

*2 Junior scientists visiting Fraunhofer IZM's EMC Lab*

# FRAUNHOFER IZM FACTS & FIGURES

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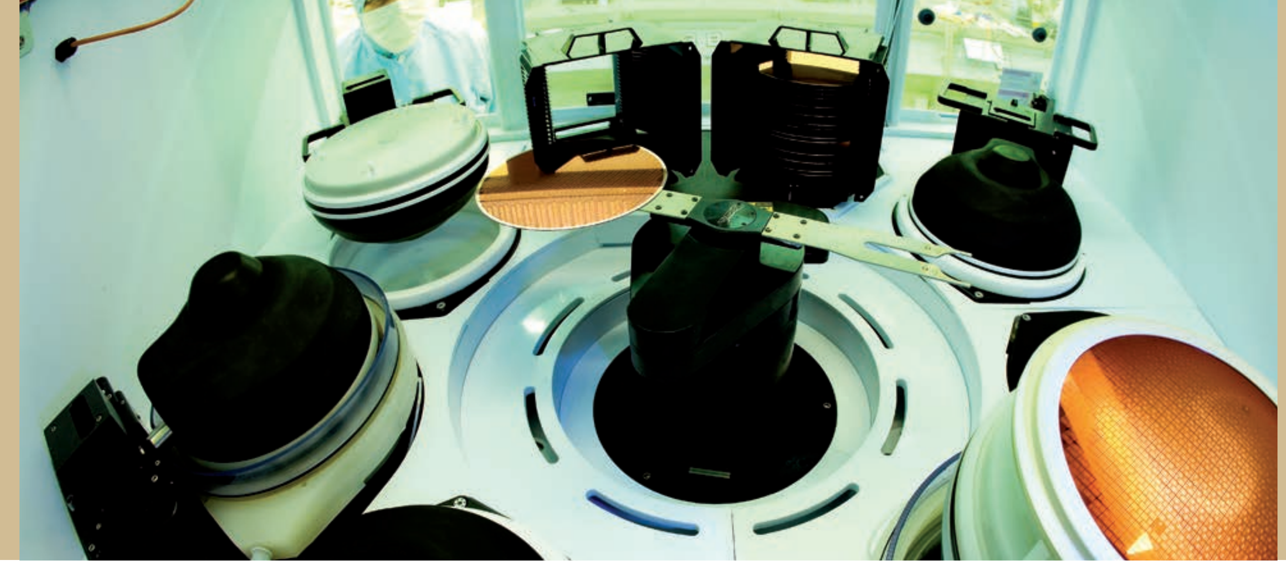

# FRAUNHOFER IZM IN FACTS AND FIGURES

**Financial overview**

Fraunhofer IZM's 2014 turnover was 27.7 million euros. Income from contract research for German and international industry and trade associations remained stable, with an increase of 1 percent from 2013, totaling 10.8 million euros in 2014. Similarly, public funding by the German federal government, the German Länder and the EU also remained stable at 11.8 million euros.

Fraunhofer IZM financed 82.1 percent, or 22.6 million euros of its operating budget with external revenue.

**Core infrastructure investment**

In 2014, Fraunhofer IZM allocated 0.7 million euros of core funding to ongoing equipment maintenance and replacement. The investment focused on expanding Fraunhofer IZM's infrastructure and increasing the efficiency of existing equipment.

The fact that this sum is comparatively low compared to previous years is due to the fact that the establishment and launch of the new Research and Development Center AdaptSys (Hetero-integration Technologies for Application-Specific Multifunctional Electronics) facilitated the purchase of new modern equipment and systems. Funded by the European Fund for Regional Development (ERDF), the Land Berlin and the German Federal Ministry of Education and Research (BMBF) with a total of 40 million euros since 2012, the new innovation hub is now largely completed.

For more information about the AdaptSys center's equipment and services, please see Page 34.
However, AdaptSys was not Fraunhofer IZM's sole focus. The institute also invested approximately 2.1 million euros into refurbishing and modernizing other laboratories. For example, a new ground-floor clean room spanning 480-m² lab space in Berlin-Wedding was completed using core funding.

**Human Resources**

In 2014, employee levels at the Fraunhofer IZM branches in Berlin, Dresden/Moritzburg and Oberpfaffenhofen remained stable. At the year's end, the institute as a whole had a staff of 223.

The institute also continued its tradition of providing apprentices and students with the opportunity of hands-on experience in Fraunhofer IZM's offices and labs. In total, the departments and administration took a total of 121 interns, Masters students and student assistants under its wing in 2014.

Moreover, Fraunhofer IZM continued its commitment to providing apprenticeships. A new addition to the institute's traditional qualifications of Microtechnologist and Business Administrator was the profession Office Manager. Moreover, the number of Fraunhofer IZM apprentices rose to 10 last year.

| Fraunhofer IZM 2014 | |
|---|---|
| **Turnover** | 27.7 million euros |
| **External revenue** | 22.6 million euros (82.1 percent of total turnover) |
| **Sites** | Berlin, Dresden and Oberpfaffenhofen |
| **Number of staff** | 354 (including 121 student assistants, master students, interns and 10 apprentices) |

1

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# AWARDS

**Klaus-Dieter Lang awarded the Fraunhofer Medal**
On 16 December Fraunhofer IZM's director Klaus-Dieter Lang received a very special honor: In recognition of his services and achievements, the Fraunhofer Board has decided to award him the Fraunhofer Medal. The Medal was formally presented by Professor Alfred Gossner on behalf of the Fraunhofer Society on the occasion of the symposium on »Microelectronic Packaging in the 21st Century«. In his laudatory statements, Professor Gossner paid particular tribute to Lang's expertise in the spirit of Joseph von Fraunhofer – excellence in linking scientific creativity with the efficient management of innovation. Professor Lang has been a formative force for the Fraunhofer IZM ever since the foundation of the institute in 1993. In 2011, he took charge of both the running of the institute and the chair of »Nano Interconnect Technologies« at the Technical University of Berlin. The scientific excellence achieved under his leadership has led the Fraunhofer IZM to be recognized as Germany's premier research institute for electrical engineering leading by the German Science Council.

**IZM researcher honored as a Fellow of IMAPS**
Dr. Ivan Ndip has been honored as a Fellow of the International Microelectronics Assembly and Packaging Society (IMAPS) for his numerous technical contributions and multiple leadership roles in the society. He received the Award during the 47th International Symposium on Microelectronics that took place in San Diego, USA, in October 2014. IMAPS is the largest society dedicated to the advancement and growth of microelectronics and electronics packaging technologies worldwide. Ivan Ndip has made significant contributions in the field of electromagnetic modeling, design and optimization of microelectronic components, modules and systems for RF and high-speed applications.

**Victoria Schuldt receives Clara von Simson Award**
Victoria Schuldt's Diploma thesis »Immobilization of mRNA and magnetic force actuated particle transfer for on-chip automation of cell-free protein synthesis« was part of a cooperation between Fraunhofer IZM and IBMT within the Fraunhofer flagship project »Cell-Free Bioproduction«. The study, submitted to the TU Berlin's Faculty III Department of Biotechnology, was selected as winner of this year's Clara von Simson Award, which recognizes excellent female graduates, particularly from the life sciences and technology disciplines. Schuldt's nomination was not only based on the quality of her thesis, but also on her interdisciplinary approach, her focus on practical application and her commitment to social responsibility.

**FED PCB Design Award for Alireza Rezaei**
IZM researcher Alireza Rezaei scooped up the PCB Design Award at the 22nd FED (German Association for Electronic Design) congress in September. It was the second time that Alireza Rezaei's work was singled out by the FED. In 2012, he made it though to the nominations for the award's final selection round. This year, he outshone the competition in the category 3D/Build Space The award is also recognition of the cutting-edge research and development by Rezaei's colleagues in the Fraunhofer IZM »Sensor Nodes & Embedded Microsystems« (SNEM) research group.

**Fraunhofer IZM scientists appointed Honorary Professors in Berlin and Aalborg**
In August both Eckart Hoene and Martin Schneider-Ramelow were appointed Honorary Professors. Eckart Hoene, who has worked at Fraunhofer IZM for 17 years and is research group leader for »EMC in Power Electronic Systems« is holding lectures on power electronic packaging, design and electromagnetic compatibility (EMC) at the Faculty of Engineering and Science in Aalborg, Denmark, over the Winter Semester 2014/2015. Martin Schneider-Ramelow, Department Head for »System Integration & Interconnection Technologies« at Fraunhofer IZM, is an internationally renowned specialist in the quality and reliability of wire bonding. The materials expert was appointed Honorary Professor by the Technische Universität (TU) Berlin, thereby further cementing the intertwining of application-oriented research and teaching, as well as the close collaboration between the TU Berlin and Fraunhofer IZM.

**IZM Research Award for improved humidity protection in electronic devices**
How can encapsulation be used to protect microelectronic components from humidity, ideally beginning right at the wafer lever? The research done by Tanja Braun offers industrial users important answers to these questions, a fact recognized with this year's Fraunhofer IZM Research Award. Tanja Braun is a respected expert for polymer encapsulations for electronic devices. She receives the prize for her research on the »Characterization, processing, and reliability testing of encapsulation materials for microelectronics«.

In her doctorate research at TU Berlin, Tanja Braun investigated mechanisms of moisture diffusion in particle filled epoxy resins. She is a sought-after speaker at conferences around the world and frequent host of international workshops. Having authored over 100 publications, her work has contributed substantially to winning five best paper awards.

The research award was presented to Dr Tanja Braun by the institute's director Klaus-Dieter Lang on 16 December 2014 as part of the special »Microelectronic Packaging in the 21st Century« event in Berlin.

*1 Viktoria Schuldt received the TU Berlin's Clara-Simson Award for her research*

*2 From left to right: Prof. Klaus-Dieter Lang, Research Award recipient Dr. Tanja Braun, head of the Award Committee Prof. Martin Schneider-Ramelow*

*3 Prof. Klaus-Dieter Lang is awarded the Fraunhofer Medal by Prof. Alfred Gossner of the Fraunhofer Board of Directors*

*4 Dr. Ivan Ndip receiving the IMAPS Award from Dr. Voya Markovich (IMAPS First Past President and Chairman of the 2014 IMAPS Society Awards Committee)*

# DISSERTATION, BEST PAPERS, EDITORIALS

## Best Papers

**Dion Manessis wins ESTC 2014 Best Paper Award**
TU scientist Dionysios Manessis and his Fraunhofer IZM colleagues Andreas Ostmann, Rolf Aschenbrenner, Stefan Karaszkiewicz and July Marie Kierdorf took the Best Paper Award at the 5th Electronics System Integration Technology Conference (ESTC), held in Helsinki last September. Their manuscript presented the system-in-package (SiP) development of a micro-SD card integrated into a remote control for wireless medical applications.The research was part of the EU project WiserBAN, whose goal is an innovative, miniaturized and energy-efficient wireless microsystem for various medical applications.

**Best Paper Award at the Itherm Conference in Orlando**
Together with partners from Germany, France and Belgium Fraunhofer IZM's Charles-Alix Manier and Hermann Oppermann won the Itherm Conference Best Paper Award in the category »Emerging Technologies Track« at the 14th IEEE Itherm Conference in Orlando. First authorship is held by Bernhard Wunderle from the TU Chemnitz. The award was also an acknowledgement of Fraunhofer IZM's role in this exemplary international joint project as the source of innovative concepts for a holistic approach to design, technology development and testing under industry conditions.

**ECTC Interactive Presentation Award**
2014 saw the introduction of the interactive poster for the first time at the ECTC conference, held in Orlando, Florida, in May. The new medium allows participating researchers to interact more directly with their colleagues. Fraunhofer IZM's Lars Brusberg was the first to receive accolades in this new category. His outstandingly dynamic and informative interactive presentation paper »C02-Laser Drilling of TGVs for Glass Interposer Applications«, which he produced together with IZM colleagues Marco Queisser, Marcle Neitz, Henning Schröder and Klaus-Dieter Lang, drew the conference's first Interactive Presentation Award.

**Tracking down common-mode interference: Fraunhofer IZM team wins Best Paper Award at IPEC Hiroshima**
Takashi Masuzawa and his colleagues at Fraunhofer IZM (Eckart Hoene, Stefan Hoffman and institute director Klaus-Dieter Lang) have found a way to simplify the prediction of common-mode interference factors that play a role in EMC filter insertion loss. Their paper entitled »A Modeling Method of Stray Magnetic Couplings in an EMC Filter for a SiC Solar Inverter«. won them the Best Paper Award at the International Power Electronics Conference Hiroshima »ECCE Asia« in May 2014.

## Dissertation

Ostmann, A.
**Transfer of electroless nickel metallization process in microsystem technology**

## 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)

**Mechatronik (Verlag I.G.T. Informationsgesellschaft Technik mbH)**
Ansorge, F. (Editorial Board)

**Smart Systems Integration 2014 Conference Proceedings**
K.-D. Lang (Co-Editor)

**13th Electronic Circuits World Convention ECWC 2014 Congress Proceedings**
K.-D. Lang (Co-Editor)



# LECTURES

## Technical University Berlin

**Prof. K.-D. Lang**
- Hetero System Integration Technologies
- Assembly of Multi-functional Systems
- Assembly and Interconnection in Microelectronics

**Dr. R. Hahn**
- Miniaturized Energy Supply Systems

**Dr. B. Curran**
- Design, Simulation and Reliability of Microsystems

**Dr. I. Ndip**
- Electromagnetics for Design and Integration of Microsystems
- High-Frequency Measurement Techniques for Electronic Packaging
- Numeric Computation of Fields

**Dr. M. Niedermayer**
- Design Methods for Smart 3D Microsystems

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

**Dr. J. Jaeschke**
- FEM Simulation of Micro Sensors and Actuators
- Reliability of Microsystems

**Dr. M. Töpper, Dr. H. Walter**
- Micro-/Nano-Analytics

**Dr. M. Töpper, Dr. J. Jaeschke**
- Technologies and Materials for Microsystem Technologies

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

**Prof. M. Schneider-Ramelow, Dr. M. Töpper**
- Basic Materials and Physical-chemical Principles of System Integration

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

**Dr. T. Tekin / Dr. D. Pouhè**
- Electromagnetic Compatibility

## Beuth Hochschule für Technik Berlin

**Dr. H. Schröder**
- Optoelectronics

## German University in Cairo, Campus Berlin

**Dr. T. Tekin**
- Photonics

## HTW, Hochschule für Technik und Wirtschaft Berlin

**Dr. H. Walter**
- Basic Materials for Microsystem Technologies

## Hochschule für Wirtschaft und Recht Berlin

**Dr. U. Geißler**
- Material Engineering

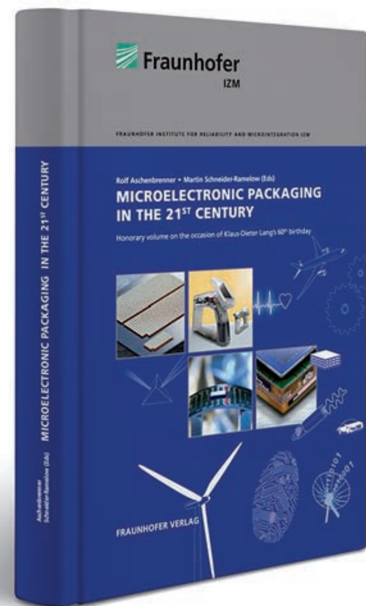
# MEMBERSHIPS (SELECTION)

| Organization | Name | Role |
|---|---|---|
| **4M Multi Material Micro-Manufacture Association** | E. Jung | Representative of Fraunhofer IZM |
| **AMA Fachverband Sensorik, Wissenschaftsrat** | Dr. V. Großer | Member |
| **Bayerisches Innovationcluster »Mechatronik und Automation«, Fachgruppe Mikro-Mechatronik** | Dr. F. Ansorge | Chairman |
| **CATRENE – EAS Working Group on Energy Autonomous Systems** | Dr. R. Hahn | Member |
| **Deutscher Verband für Schweißtechnik DVS** | Prof. K.-D. Lang | Executive Board |
| **Deutscher Verband für Schweißtechnik DVS Arbeitsgruppe »Bonden«** | Prof. M. Schneider-Ramelow | Chairman |
| **EcoDesign Japan 2015** | Dr. N. F. Nissen | International Co-Chair |
| **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)** | Harald Pötter | Member Executive Committee |
| **IEEE Component, Packaging and Manufacturing Technology Society** | R. Aschenbrenner | Fellow |
| Technical Committees: | | |
| Green Electronics | Dr. N. F. Nissen | Technical Chair |
| Emerging Technologies | E. Jung | Technical Chair |
| Wafer Level Packaging | Dr. M. Töpper | Technical Chair |
| Photonics - Communication, Sensing, Lighting | Dr. T. Tekin | Technical Chair |
| IEEE CPMT German Chapter | R. Aschenbrenner | Chair |
| **IMAPS (Signal/Power Integrity Subcommittee)** | Dr. I. Ndip | Chair |
| **IMAPS International 2014** | Dr. I. Ndip | General Chair |
| **IMAPS Deutschland** | 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 |
| **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 | Member |
| **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 Kongress** | Prof. K.-D. Lang | Head of Scientific Committee |
| **Technologiestiftung Berlin (TSB)** | Prof. K.-D. Lang | Member of the Board of Trustees |
| **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)

| Company | Location |
|---|---|
| Advanced Semiconductor Engineering Inc. | Kaohsiung (TPE) |
| AEMtec GmbH | Berlin |
| Agilent Technologies Inc. | Santa Clara (USA) |
| Airbus Defense & Space | Ulm |
| Alenia Aeronautica SpA | Rom (I) |
| Allegro Micro Systems LLC | Worcester (USA) |
| alpha-board gmbh | Berlin |
| Altatech | Montbonnot-Saint-Martin |
| AMO GmbH | St.Peter/Hart (A) |
| Apple Inc. | Palo Alto (USA) |
| Applied Materials Inc. | Santa Clara (USA) |
| Asahi Glass Co., Ltd. | Chiyoda (J) |
| Astrium GmbH | Bremen |
| A.S.T. Group | Wolnzach |
| AT&S AG | Leoben (A) |
| Atotech Deutschland GmbH | Berlin |
| AUDI AG | Ingolstadt |
| Austriamicrosystems AG | Unterpremstätten (A) |
| Awaiba GmbH | Nürnberg |
| B/E Aerospace Inc. | Lübeck |
| Baker Hughes INTEQ GmbH | Celle |
| Baumer-Hübner GmbH | Berlin |
| Balluff GmbH | Neuhausen a.d.F. |
| BIOLAB Technology AG | Zürich (CH) |
| Blackrock Microsystems LCC | Salt Lake City (USA) |
| BMW AG | München |
| Brose Fahrzeugteile GmbH & Co. KG | Coburg |
| Bundesdruckerei GmbH | Berlin |
| Cascade Microtech GmbH | Thiendorf |
| COGO Optronics GmbH | Berlin, Boulder (USA) |
| Compass EOS | Netanya (IL) |
| CONTAG GmbH | Berlin |
| Continental AG | Nürnberg, München, Frankfurt, Regensburg |
| Converteam SAS | Berlin |
| Corning Glass | Corning (USA) |
| Daimler AG | Stuttgart |
| Datacon GmbH | Radfeld (A) |
| Denso Corp. | Kariya (J) |
| Deutsche Bahn AG | Berlin, Frankfurt, München, Dessau |
| DIEHL Stiftung & Co. KG | Nürnberg, Frankfurt, Wangen |
| Disco Corporation | Tokyo (J) |
| Elbau GmbH | Berlin |
| Endress & Hauser GmbH & Co. KG | Maulburg |
| ESYS GmbH | Berlin |
| EV Group (EVG) | St. Florian am Inn (A) |
| Excelitas Technologies Corp. | Pfaffenhofen |
| FiconTEC Service GmbH | Achim |
| Fujifilm Electronic Materials | Tokio (J) |
| Fujitsu Technology GmbH | Augsburg |
| Gesellschaft für Maschinendiagnose mbH | Berlin |
| GLOBALFOUNDRIES INC. | Dresden |
| Heraeus Holding GmbH | Hanau |
| Hitachi Dupont | USA, J, D |
| Höft & Wessel AG | Hannover |
| Hytech AG | Brügg (CH) |
| IMC GmbH | Berlin |
| Idex | Fornebu (NO) |
| Infineon Technologies AG | Mainz, München |
| Isola USA Corp. | Chandler (USA) |
| Jenoptik/ESW GmbH | Hamburg-Wedel |
| John Deere & Company | Mannheim |
| Leuze electronic GmbH & Co. KG | Owen |
| Maicom Quarz | Posterstein |
| MDISchott Advanced Processing GmbH | Mainz |
| MED-EL GmbH | Innsbruck (A) |
| METALLEX AG | Uetikon (CH) |
| Microelectronic Packaging GmbH | Dresden |
| Microepsilon GmbH | Ortenburg |
| Micro Systems Engineering Inc. | Lake Oswego (USA), Tel Aviv (IL) |
| Nanotron Technologies GmbH | Berlin |
| NXP Semiconductors AG | Hamburg, Eindhoven (NL) |
| OC Oerlikon Balzers AG | Balzers (LI) |
| Olympus Deutschland GmbH | Hamburg |
| Oree Inc. | Ramat Gan (IL) |
| Osram Opto Semiconductors GmbH | Regensburg |
| Ovesco Endoscopy AG | Tübingen |
| Pac Tech Packaging Technologies GmbH | Nauen |
| PANalytical B.V. | Almelo (NL) |
| Paulmann Licht GmbH | Springe-Völksen |
| Philips Technology GmbH | Aachen |
| PrimeSensor GmbH | Berlin |
| Ramgraber GmbH | Hofolding b. Brunnthal |
| Robert Bosch GmbH | Stuttgart, Reutlingen, Hildesheim, Waiblingen |
| Samsung Advanced Inst. of Technology | Suwon (ROK) |
| Schaeffler Technologies GmbH & Co. KG | Herzogenaurach |
| Schaffner Holding AG | Luterbach (CH) |
| Schleifring GmbH | Kaufbeuren |
| Schlumberger AG | F, USA |
| Schweizer Electronic AG | Schramberg |
| Semikron GmbH | Nürnberg |
| Semsysco GmbH | Salzburg (A) |
| Sensitec GmbH | Lahnau |
| Siemens AG | Karlsruhe |
| SPTS Technologies Ltd. | Newport (UK) |
| Süss MicroTec AG | Garching, München |
| Swissbit Germany AG | Berlin |
| TDK-EPCOS AG | München |
| Thales Group | Frankreich |
| The Dow Chemical Company | USA |
| The Valley Group - A Nexans Company | Bethel (USA) |
| Valeo GmbH | Wemding |
| Varta AG | Ellwangen |
| Vectron Systems AG | Havant (UK) |
| Vishay Beyschlag GmbH | Heide |
| Volkswagen AG | Wolfsburg |
| WRS Materials | San Jose (USA) |
| Würth Elektronik GmbH & Co. KG | Niedernhall, Rot am See |
| X-Fab Semiconductor Foundries AG | Erfurt |
| Xyratex AG | Auerbach |
| ZF Luftfahrt AG | Calden |

# PUBLICATIONS (SELECTION)



*»Microelectronic Packaging in the 21st Century«*
*Honorary volume on the occasion of Prof. Klaus-Dieter Lang's 60th birthday.*
*Eds: Martin Schneider-Ramelow and Rolf Aschenbrenner*
*Published by Fraunhofer Verlag, ISBN 978-3-8396-0826-5*

*Ansorge, F.*
**Qualität durch Schulungen: Bleifrei Löten in der Medizintechnik**
Medizintechnik Bayern, München 2013, Germany

*Ansorge, F.; Ifland, D.; Baar, C.; Lang, K.-D.*
**Challenge: Additive Manufacturing in the Field of Electronics; ESA Workshop Additive Manufacturing for Space Applications**
Nordwijk, 2014

*Ansorge, F.; Ifland, D.; Baar, C.; Lang, K.-D.*
**Neue Substrate durch Embedding von Komponenten auf Basis von 3D-Druckverfahren**
Proceedings Handlungskonferenz Mikrosystemtechnik (3D Druck für Prototyping), 2014, Berlin, Germany

*Ansorge, F.; Ifland, D.; Baar, C.; Lang, K.-D.*
**Next Generation Substrates – wie elektronische Systeme maskenlos gedruckt werden**
Proceedings EBL Tagung, 2014, Fellbach, Germany

*Ansorge, F.; Ifland, D.; Baar, C.; Lang, K.-D.*
**Next Generation Substrates – Maskless Lithography for Electronics Manufacturing**
Proceedings Fraunhofer DDMC, 2014, Berlin, Germany

*Becker, K.-F.; Koch, M.; Voges, S.; Thomas, T.; Fliess, M.; Bauer, J.; Braun, T.; Aschenbrenner, R.; Schneider-Ramelow, M.; Lang, K.-D.*
**Precision Jetting of Solder Paste – A Versatile Tool for Small Volume Production**
Proceedings IMAPS International 2014, San Diego, USA

*Boettcher, L. ; Manessis, D.; Karaszkiewicz, S.; Hoene, E.; Ostmann, A.*
**Next Generation High Power Electronic Modules Based on Embedded Power Semiconductors**
Device Packaging Conference (DPC) 2014, Scottsdale, USA

*Boettcher, L. ; Manessis, D.; Karaszkiewicz, S.; Ostmann, A.*
**Embedding of Power Semiconductors for Innovative Packages and Modules**
Proceedings SMTA International Conference 2014, Rosemont, USA

*Braun, T.; Becker, K.-F.; Jung, E.; Voges, S.; Thomas, T.; Kahle, R.; Bader, V.; Bauer, J.; Aschenbrenner, R.; Lang, K.-D.*
**Fan-out Wafer Level Packaging for MEMS and Sensor Applications**
Proceedings Sensors and Measuring Systems 2014, 17. ITG/GMA Symposium, Nürnberg, Germany

*Braun, T.; Becker, K.-F.; Voges, S.; Thomas, T.; Kahle, R.; Bader, V.; Bauer, J.; Aschenbrenner, R.; Lang, K.-D.*
**Challenges and Opportunities for Fan-out Panel Level Packing (FOPLP)**
Proceedings IMPACT 2014, Taipei, Taiwan

*Braun, T.; Becker, K.-F.; Voges, S.; Thomas, T.; Kahle, R.; Bauer, J.; Aschenbrenner, R.; Lang, K.-D.*
**24"x18" Fan-out Panel Level Packing**
Proceedings ECTC 2014; Orlando, USA

*Brusberg, L.; Queiser, M.; Neitz, M.; Schröder, H.; Lang; K.-D.*
**CO2-Laser Drilling of TGVs for Glass Interposer Applications**
Proceedings ECTC 2014, Orlando, USA

*Curran, B.; Ndip, I.; Engin, E.; Bauer, J.; Pötter, H.; Lang, K.-D.; Reichl, H.*
**A Modeling Approach for Predicting the Effects of Dielectric Moisture Absorption on the Electrical Performance of Passive Structures**
Journal of Microelectronics and Electronic Packaging, Vol. 11, No. 3, pp. 115-121, 2014

*Dimitrova, G.; Nissen, N.; Stobbe, L.; Schlösser, A.; Schischke, K.; Lang, K.-D.*
**Tablet PCs Through the Lens of Environment - Design Trends and Impacts on the Environmental Performance**
Going Green Care INNOVATION 2014, Vienna, Austria

*Duan, X.; Hardock, A.; Ndip, I.; Schuster, C.; Lang, K.-D.*
**Optimization of Microstrip-to-via Transition for High-speed Differential Signaling on Printed Circuit Boards by Suppression of the Parasitic Modes in Shared Antipads**
Proceedings 2014 IEEE International Symposium on Electromagnetic Compatibility, Raleigh, USA

*Feix, G.; Hutter, M.; Hoene, E.; Lang, K.-D.*
**On Double Sided Cooling**
Proceedings ESTC 2014, Helsinki, Finland

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**Cover:**
Backbone of future sensor nodes: miniaturized assembly (10 x 15 x 3 $mm^3$) consisting of microcontroller, RF-receiver and integrated antenna