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FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

ANNUAL REPORT 20/21

CONTENT

PREFACE

RESEARCHING FOR APPLICATION, DEVELOPING FOR RELIABILITY

Dear readers,

Deserted corridors instead of hustle and bustle, a cleanroom in emergency mode, the faces of colleagues hidden away: an extraordinary year, one we're unlikely to forget in a hurry, has come to an end. Implementing the many changes needed, continually adjusting to new circumstances, was the order of the day, both at home and in the workplace. Looking back, we met most of these challenges amply, but »normal« remains a long way off.

Although we clearly will not bid farewell to the Corona pandemic in 2021, other societal issues also demand our attention. Issues like continuing to ensure the possibilities of microelectronics are harnessed, or developing eco-friendly technologies and efficient resource usage.

Microelectronics can make a tremendous contribution. Be it in quantum technologies, next-generation computing, 5G/6G technologies, artificial intelligence or bioelectronics – new principles and technologies have to be developed and optimized.

A multitude of outstanding project results again testify to the capabilities to the collective expertise of the Fraunhofer IZM team. We are also researching microelectronics solutions for combatting the Corona virus, including with 2-megapixel sensors, UV rapid sterilization of FFP3 face masks and a platform for the development of innovative treatment strategies. Just some of our results include:

- An innovative, miniaturized LIDAR system was developed for robotics, representing a significant step forwards in deploying extreme miniaturization to advance system integration technologies.
- PCB embedding was applied in 5G/mm-wave technology.
- Photonic sensor systems, as technology solutions highly complex and energy-efficient in equal measure, were implemented for monitoring of manufacturing processes used for composite materials.
- The system integration value-added chain was extended to include innovative »system-on-a-chip« and »system-in-package« solutions on wafer and substrate level. An example of this is the high-sensitivity medical diagnosis platform based on 3D graphics.
- Fraunhofer IZM's system integration strategy was extended to include the Chiplet approach.
- Biomedical applications, such as biocompatible embedding of thin ASICs in flexible substrates, were developed.
- Using the investments from the »Research Fab Microelectronics Germany«, technologically optimized, resource efficient and industry compatible process lines and support services for product manufacturing were achieved.

In parallel to the considerable changes to the institute's operation, for example, with online meetings becoming the rule, rather than the exception, Fraunhofer IZM also saw a number of structural highlights in 2020, a few of which we'd like to present here:

- Electronics Goes Green 2020+ went hybrid with more than 250 participants last year, setting new benchmarks for the conference.
- We celebrated 10 years of Fraunhofer IZM-ASSID as an online event.
- The establishment of »Research Fab Microelectronics Germany«, in which Fraunhofer IZM is included as partner, led to a number of overarching cooperations and successful projects.
- The international Panel Level Packaging Consortium 2.0 entered its second round.
- The high performance centers »Functional Integration in Micro- and Nanoelectronics« in Dresden and the Berlin Center for Digital Transformation were extended into Phase II.
- The Fraunhofer IZM satellite in Cottbus began its extended research and development program: first projects as part of the iCampus initiative, including a medical 60-GHz radar for contactless monitoring of vital parameters, have already been carried out.
- Fraunhofer IZM also took center-stage again in terms of public outreach, with its hugely boosted profile across all relevant social media channels particularly striking.
- The blog REALIZM gained a sustainable, loyal following in the microelectronics community this year and was lauded by the German Research Foundation (DFG).

All this led to our being able to end 2020 on a successful note, despite the pandemic. Particularly in uncertain times, creating new ideas, maintaining a robust customer portfolio and having stable cooperations available is paramount to ensure downtimes can be compensated and that a perspective for moderate growth in the future is possible. Our thanks here go also to the other research institutes like the Research Center for Microperipheric Technologies at the TU Berlin, but also the TU Dresden, the Brandenburg University of Technology (BTU) Cottbus-Senftenberg and the HTW Berlin – all essential partners in aspects of basic science and early career support.

We would also like to extend our sincere thanks to our partners from industry and research, funding bodies and funding administrators at federal and Länder levels, as well as to our supporters in associations and committees.

Above all, however, we'd like to take this opportunity to personally express our appreciation for all our team members, who bravely faced the year's challenges with squared shoulders, and without whom the excellent development of the institute would not be possible. Particularly in light of the exceptionality of the year 2020, we want to extend our heartfelt gratitude to you all for your steadfast support, continual efforts and loyal collegiality!

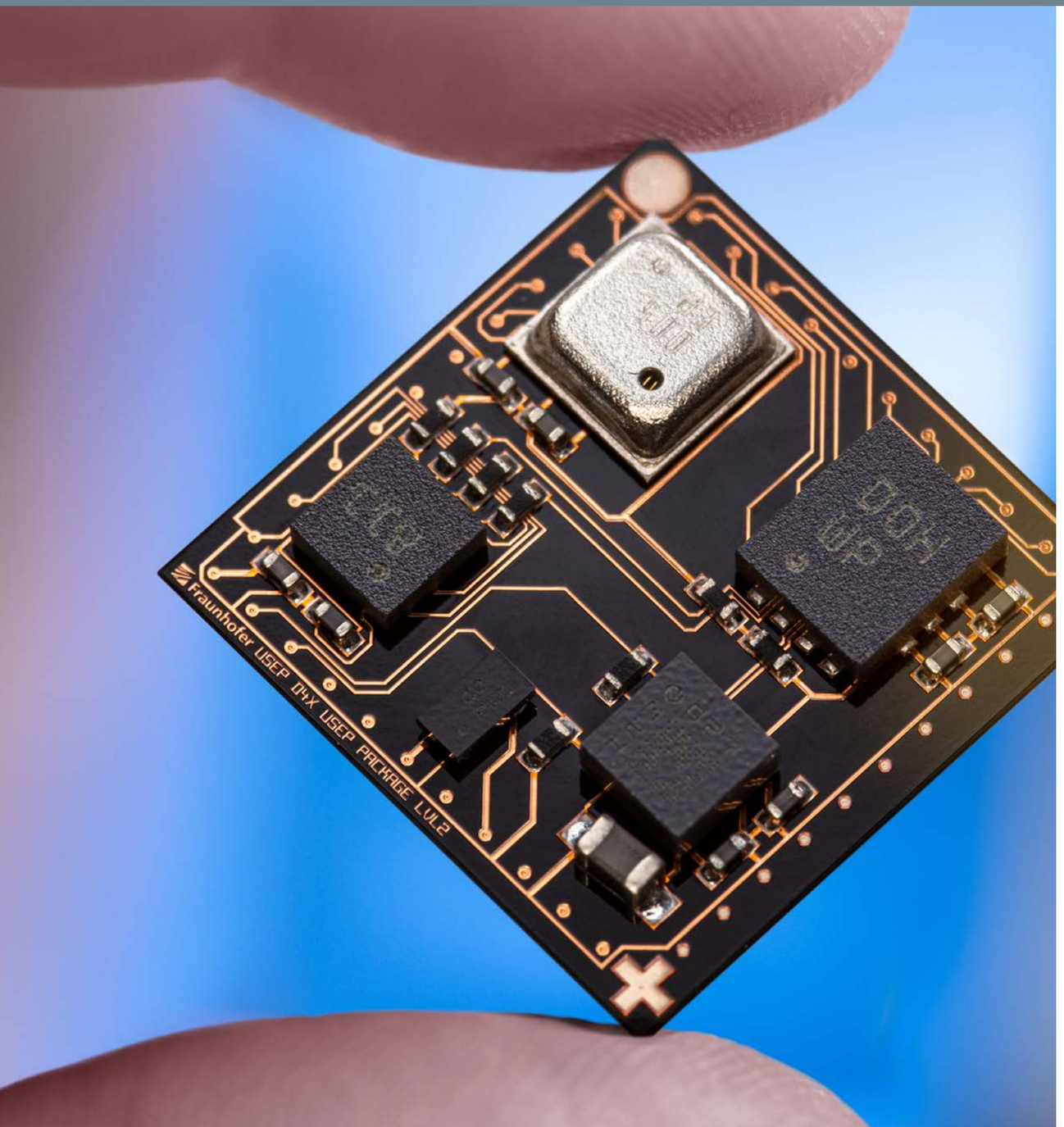
We hope you all find inspiration, new ideas and enjoyment in reading this edition of our annual report and look forward to our future cooperation.

Stay healthy, stay safe – kindest regards,

Prof. Dr.-Ing. Dr. sc. techn. Klaus-Dieter Lang
Head of Fraunhofer IZM (managing)

Prof. Dr.-Ing. Martin Schneider-Ramelow
Head of Fraunhofer IZM (acting)

CORE COMPETENCIES



FROM WAFER TO SYSTEM

Intelligent electronic systems – available everywhere and to everyone! In order to make this possible, components need to have exceptional properties. Depending on the application, they need to function reliably at high temperatures, be extremely miniaturized and moldable to individual build spaces or even flexible, and have outstanding lifetime. The Fraunhofer Institute for Reliability and Microintegration IZM helps companies around the world develop and assemble robust and reliable electronics to the very cutting edge and then integrate them into the required application.

With more than 440 employees, the Institute develops adapted system integration technologies on wafer, chip and board level. Research at Fraunhofer IZM means designing more reliable electronics and making reliable lifetime predictions.

Working together with Fraunhofer IZM
Fraunhofer IZM's research results are highly relevant to industries such as the automotive industry, medical engineering, industrial electronics and even lighting and textiles. Semiconductor manufacturers and suppliers of related materials, machines and equipment, but also small companies and start-ups can choose the approach that best suits their needs – from easily accessible standard technologies through to high-end disruptive innovation. As partners, our customers profit from the advantages of contract research, by selecting between exclusive release of a product innovation, improving a workflow or qualifying and certifying a process.

Contract research
Often a successful cooperation project begins with a preliminary consultation phase that is usually free-of-charge. Fraunhofer only begins billing for its research and development services once the parameters of the cooperation have been defined. Customers retain ownership of the material project outcomes developed within their contract, as well as the applicable usage rights to the produced inventions, property rights and the know-how.

Project funding
Some development challenges require pre-competitive research. In these cases, teaming up with companies and research institutes and public funding support is more effective than operating solo. The institute cooperates closely with numerous universities, including the Technical Universities of Berlin and Dresden and the BTU Cottbus-Senftenberg, to ensure that the preparation for future cooperation with industry is optimal.

HETEROINTEGRATION: CUTTING THROUGH OLD PARADIGMS

Heterogeneous integration increases not only the degree of miniaturization, but also the functional density of microelectronics. This approach is regarded a potential solution for companies in a vast range of industries, vying for competitive advantages in their market and trying hard to stay cost-effective.

Heterogeneous integration is addressing this challenge from another paradigm – instead of pushing for smaller and smaller structures (»More Moore«), here system functionalities from different manufacturing approaches other than, but also including, CMOS, are in its focus (»More than Moore«). In contrast to a monolithic system-on-chip, this approach puts as many functionalities as possible into one single device, which may either be a 3D-integrated silicon device (3D chip) or a system-in-package (SiP), which typically is not limited to silicon as a core material. While – clearly – SoC offers highest scalability for large volumes, the concept is inherently limited in its functional complexity to functions that can be built together in the same or highly compatible manufacturing processes. If, for example, functions from different manufacturing environments (III-V semiconductors, MEMS- or integrated passive components) are combined into a systemic function, this approach is bound to fail.

for the heterogeneous integration od 3D chips individual functional components are mounted on a thin silicon substrate, before their backside contacts are interconnected on a high-density interposer by means of so-called through-silicon vias (TSVs). Ultra-fine-pitch flip chip bonding is the pacesetter for this kind of small form factor integration.

This kind of side-by-side integration can use e. g. sensor chips, communication chips, or control and number crunching chips for doing some upfront calculations of the sensor parameters (»embedded AI«), prior to sending the data to cloud storage. Besides silicon interposer technology, the fan-out packaging (FO) concept is emerging as a platform technology, eventually replacing a large percentage of the >1000 package types on the market. Technological questions, however, persist – e.g. how to deal with different functionalities which all require a different set of design guidelines, or how to interconnect and how to interface with the other elements in a heterogeneous concept. And not least among them: How to test these sizes with the high functional densities, also across domains beyond just electrical signals, e.g. photonic or even biochemical signals.

As Fraunhofer IZM positions itself at the forefront of technology for heterointegration, the Institute has been involved in one of the biggest efforts of the IEEE-ECS community in the past 10 years, answering the roadmapping needs of this dynamically evolving field.

With players from R&D and industry, 22 technology working groups were formed and assigned their respective tasks in the matrix, covering possible areas of application from medical, safety, and security to automotive, power, and so on. Fraunhofer IZM has taken over a leading role for the SiP integration activities of the roadmap, with a list of prospective technologies that the industry can use as a toolbox for the near future.

10 YEARS OF FRAUNHOFER IZM-ASSID

In May 2020, Fraunhofer IZM-ASSID in Dresden celebrated its tenth anniversary. This decade has seen IZM-ASSID transcend the borders of Germany with its achievements in the field of wafer level system integration, especially 3D integration, and become a globally renowned R&D partner.

Thanks to the support it has received from the Federal Ministry of Education and Research and the Free State of Saxony, a research and development pilot line for wafer level packaging and 3D integration (8"/12") was implemented in Dresden in 2010, and ever since then it has benefited from ongoing further development. Through its global collaboration with system users and plant and material manufacturers, IZM-ASSID has become one of the leading providers in the field of heterogeneous wafer level system integration, the scope of which extends from the development phase through to qualified low volume manufacturing.

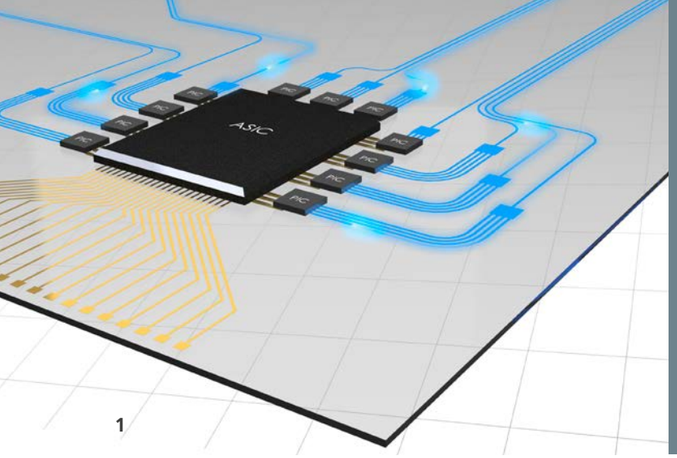
3D Integration for tomorrow's products

The IZM-ASSID has developed and prototyped wafer-level packaging and system integration technologies to enable 3D integration with through-silicon vias (TSVs). The modular approach of the systems is needed wherever small, energy-efficient and highly functional electronics are important. The focus is on technologies and materials for systems that combine several electronic components in miniaturized form, i. e. medical devices or applications in safety and automation technology and the automotive industry.

Research at industry level – With ISO certification

In April 2020, the International Certification Group (ICG) certified the IZM-ASSID's management system for »research, development, and services in electronics packaging«. This certification marks another important milestone for the IZM-ASSID's provision of professional client-specific process development services.

IZM-ASSID will continue along this route as part of Fraunhofer IZM in future in order to develop and implement outstandingly successful scientific and technical solutions for the challenges of a digitalized society in the spheres of IoT, AI and HPC. IZM-ASSID would like to thank all its partners in industry, science and politics for the confidence they have shown and for the successful collaboration.



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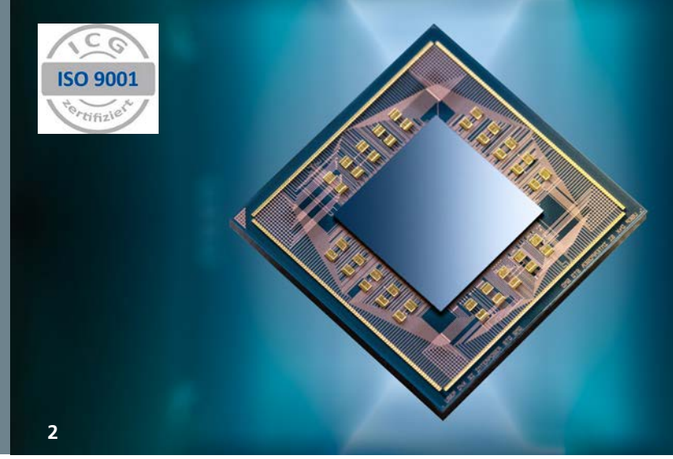

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SYSTEM INTEGRATION & INTERCONNECTION TECHNOLOGIES

The »System Integration and Interconnection Technologies« (SIIT) department is the largest in the institute. Its work focuses on heterogeneous system integration. The combination of various materials, devices, and technologies opens up a wide range of application areas such as medical engineering, automobile production, aviation, industrial electronics, or communication technology. Highly integrated electronic and photonic systems, modules, and packages are developed and manufactured for specific individual requirements. The complete value creation chain of the individual products from conception, design, and technology development to industrializable production is covered. The department focuses on the design, implementation and analysis of power electronic and photonic systems.

Our scope of services includes, for example:

- Electronic and photonic circuit carriers: multilayer conventional, rigid, and flexible printed circuit boards, partly with integrated components; mold packages with rewiring; integration of optical waveguides in printed circuit boards
- Conformables: stretchable, thermoplastic, and textile assemblies
- Assembly: high-precision chip placement, automated SMD assembly, flip-chip technology, automated optical fiber coupling, and micro-optics assembly
- Interconnection technologies: soldering; sintering; transient liquid phase bonding (TLPB) and bonding of components; micro-optics and chips; wire and ribbon bonding; galvanic metal deposition and sputtering; screen printing, stencil printing, and contactless material dosing by jets; application of polymer lenses; integrated optical waveguides in thin glass; development of new interconnection technologies
- Encapsulation: embedding in printed circuit boards; transfer and compression molding; potting and protective lacquering; underfilling and glob-top
- Processed materials and techniques: fiber composites; encapsulation compounds; soft solders; sintered materials; glass structuring; mechanical and chemical metalworking

Our employees' many years of experience in combination with state-of-the-art equipment for processing large-format manufacturing in the entire production process (610 x 457 mm²; 18" x 24") is unique worldwide. Approximately 2,500 m² of laboratory space are available, 600 m² of which are cleanrooms of ISO classes 5 - 7. Here, the production of complex electrical or photonic circuit carriers, the assembly of components on and embedding in circuit carriers or housings, as well as the bonding and encapsulation of the components, is carried out.

The finished systems are electrically and mechanically tested and evaluated. For documentation and analysis purposes, we use imaging techniques for structure resolution down to the nm range, optical function measurement techniques, and chemical analysis down to the sub-ppm range.

WAFER LEVEL SYSTEM INTEGRATION

The department »Wafer Level System Integration« (WLSI) focuses its research activities on the development of advanced packaging and system integration technologies and offers customer-specific solutions for microelectronic products used in smart systems. Around 60 scientists at two sites – Fraunhofer IZM in Berlin and the institute branch ASSID – All Silicon System Integration Dresden (IZM-ASSID) – conduct research in the following key areas:

- 3D integration including Cu-TSV and wafer stacking
- Wafer-level packaging and fine-pitch bumping
- Hermetic MEMS and sensor packaging
- High density flip-chip assembly
- Sensor development and integration
- Hybrid photonic integration
- Photonic and plasmonic system development

At both sites, the department operates leading-edge process lines that permit a high degree of processing flexibility, particularly for 200 – 300 mm wafers. The lines are characterized by a high adaptability and compatibility between the individual sub-processes and are particularly equipped for production-related and industry-compatible development and processing. Both sites have a completely ISO 9001:2015-certified management system to guarantee highest quality standards in project and process work.

The department's already outstanding technological expertise is continuously extended within numerous research projects and the gained know-how can be transferred at development stage to SME partners. WLSI has established a broad cooperation network with manufacturers and users of microelectronic products, as well as tool suppliers and material developers in the chemical industry.

The department's technological know-how is focused on the following areas:

- Heterogeneous wafer-level system integration
- 3D wafer-level system in package (WL-SiP, CSP, WSI)
- Application-specific Cu-TSV integration: via middle, via last, backside TSV
- Cu-TSV interposer with multi-layer RDL and micro cavities
- Glass interposer with TGV
- High-density interconnect formation: micro bump or pillar (Cu, SnAg, CuSn, Au, AuSn)
- Pre-assembly (thinning, thin wafer handling, laser grooving, laser dicing, plate dicing)
- 3D assembly (D2D, D2W, W2W)
- 3D wafer-level stacking
- Wafer bonding (adhesive, soldering, direct)
- Direct bond interconnects (DBI) – W2W (12")
- Micro sensor development and integration
- MEMS packaging (hermetic)
- Simulation and characterization of photonic und plasmonic components & systems
- Photonic system integration (incl. e.g. polymer waveguides)

The service portfolio for industrial partners comprises process development, material evaluation and qualification, prototyping, low- and middle-volume manufacturing and process transfer. Newly developed technologies can be adapted to customer-specific requirements.

1 *Concept design of an electro-optical glass interposer for co-packaging*

2 *Trial interposer for testing the design and functionality of the USeP project's Risc-V processor made with the 22FDX® technology*

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ENVIRONMENTAL & RELIABILITY ENGINEERING

New microelectronics systems have to cope with more demanding functional requirements and working conditions. At the same time, they are expected to be cost-efficient and environmentally friendly in production and in active use. The »Environmental and Reliability Engineering« department supports new technical developments on their way to the market with environmental performance and reliability checks ranging from nano-characterization to system-level evaluation and optimization.

The department offers services in the areas:

- Environmental assessments and eco-design
- Resource efficiency, circular economy, and obsolescence research
- Reliability standards and testing procedures
- Failure mechanisms, lifetime models, and materials data
- Simulations for reliability analyses and optimization

With an interdisciplinary team processes and models are developed and applied that enable our partners to integrate environmental and reliability relevant criteria in the design and development process. We thus help to identify weak points and potentials at an early stage during the introduction of new technologies, materials, processes, components, and applications and to react appropriately.

Stemming the tide of electrical and electronics waste and reining in the resource hunger of the industry is one of the key challenges faced by all of society. Modern life has become unthinkable without electronics. A boon and a bane alike, electronics contribute to making climate change worse, but they can also be the key to saving resources and reducing our carbon footprint. More and more companies are committing themselves to finding innovative and sustainable solutions, for which they turn to the professional advice and services of Fraunhofer IZM.

The environmental footprint of actual products and of the fundamental technologies that make them possible has gained considerable salience in the industry, where improvements are being pursued on a much broader front. Increasingly stringent standards and environmental specifications have gained new relevance even for smaller-scale enterprises and suppliers who might not yet have set themselves any particular climate or resource efficiency targets.

Legislators and consumers alike are increasing pressure on manufacturers in the form of toughened standards and specifications for products that are easier to tear down, to repair, and to keep in working order for a longer overall product lifespan. Methods for application-specific reliability checks are playing an important role in these efforts to extend the lives of particularly resource-intensive electronic components.

The reliability of technologies is benefitting from constant progress and refinement in testing methods and simulation models. A lot of attention is currently aimed at warpage and corrosion, but depending on their use case, the reliability of electronic components is understood and analyzed in terms of all important fatigue mechanisms or other forces affecting the components, including mechanical vibration, heat, humidity, changes in temperature, or voltage and power loads. These tests and simulations, in some cases tailored specifically to the given use case, offer new pointers for optimization to achieve the new reliability standards expected in the supply chain and in actual use.
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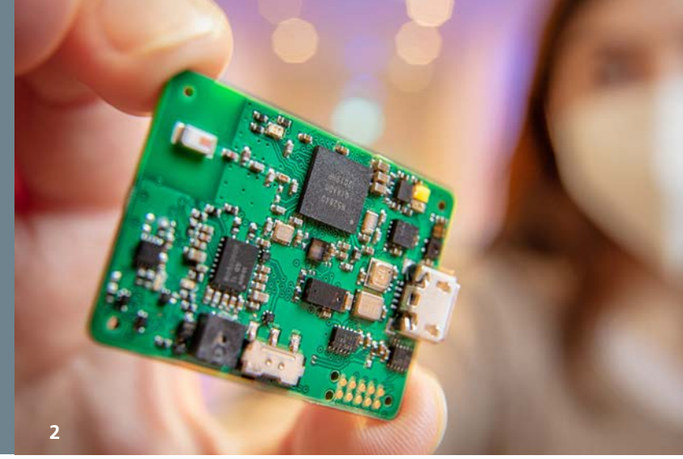

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RF & SMART SENSOR SYSTEMS

What do so seemingly unrelated applications like radar sensing, 5G, 60 GHz communication systems, or autonomous sensors have in common? With regard to research and development they share a common technological background: large bandwidths, robustness, and a commitment to maximum energy efficiency are the defining criteria. Other features such as controllable antennas, beamforming, and protections against signal deterioration are also attracting increasing attention.

Meeting these exacting standards needs the tight integration of circuit design and technology development (hardware/package co-design) just as much as genuine cooperation between software and hardware developers (hardware/software co-design). With this in mind, the department RF & Smart Sensor Systems combines the intensive technological know-how of Fraunhofer IZM with our in-depth expertise in firmware and hardware development.

Our activities focus on:

- RF design and characterization of materials, packages, and components (up to 220 GHz)
- RF system integration and module design, with due consideration for signal and power integrity
- Development of micro batteries, power supply, and power management systems
- Design and implementation of self-sufficient wireless sensor systems for industrial use
- Tools for the optimized design of microsystems and server-client software architectures

The work of the department is characterized by its effective combination of the practical insights won from our many successful projects, our extensive range of state-of-the-art equipment, our wealth of experience with modelling tools, and our unfailing dedication to a systematic approach.

1 *Modularization comes to circuit boards: Digital voice recorder with module-embedded components*

2 *SWARM: IoT device built for tough industrial applications*

BUSINESS UNITS & INDUSTRY SECTORS

FRAUNHOFER – A STRONG NETWORK

The Fraunhofer-Gesellschaft
The Fraunhofer-Gesellschaft, headquartered in Germany, is the world's leading applied research organization. With its focus on developing key technologies that are vital for the future and enabling the commercial exploitation of this work by business and industry, Fraunhofer plays a central role in the innovation process. As a pioneer and catalyst for groundbreaking developments and scientific excellence, Fraunhofer helps shape society now and in the future. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 75 institutes and research institutions throughout Germany. The majority of the organization's 29,000 employees are qualified scientists and engineers, who work with an annual research budget of 2.8 billion euros. Of this sum, 2.4 billion euros is generated through contract research.

Research Fab Microelectronics Germany
Fraunhofer IZM and its 12 partners have been operating the nationwide distributed Research Fab Microelectronics Germany since April 2017. More than 2,000 scientists from the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP make the FMD the largest world-leading R&D alliance for micro and nanoelectronics.

Established to promote active research and development at its sites across Germany, the FMD began its final ramp-up in 2020. Most of its approx. 350 million euros in financial support from the German Federal Ministry of Education and Research (BMBF) went into modernizing the equipment and facilities of the 13 constituent institutes. Another common thread in the FMD's strategic development over the course of 2020 was the production and adoption of a concept to ensure the ongoing operation of the research fab beyond the end of the original project period.

In addition to its range of services for its clients in industry, the FMD also offers a wide variety of cooperation opportunities for its partners in science and academia, including joint work in collaborative projects or joint labs operations. The services extend to the opportunity to test concepts from fundamental research for their applicability in real-world use cases. Past cooperation projects between the FMD and academic partners include the ASCENT+ project, the »iCampµs« research collaboration, and the Joint Smart Beam-Lab in Duisburg.

Centers of Excellence
The goal of the »Functional Integration for Micro- / Nanoelectronics« Center of Excellence is above all to support SMEs in Saxony with sensor and actuator technology, measurement technology, and mechanical engineering and construction by rapidly transferring research results into innovative products. The Fraunhofer institutes ENAS, IIS, IPMS, and IZM, as well as the TU Dresden and Chemnitz and the HTW Dresden are also members. The Berlin Center for Digital Transformation is a cooperation between the four Berlin Fraunhofer institutes FOKUS, HHI, IPK and IZM. Its work focuses on technologies and solutions that advance increasing digitalization and networking in all areas of life.

AUTOMOTIVE AND TRANSPORTATION | MEDICAL ENGINEERING | SEMICONDUCTORS

INDUSTRIAL ELECTRONICS | INFORMATION AND COMMUNICATION

Complex project initiatives move across the boundaries of disciplines and competencies. They benefit from the business expertise of 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 to assist you in the strategic development of innovative areas with complex and ground-breaking technologies.

AUTOMOTIVE AND TRANSPORTATION

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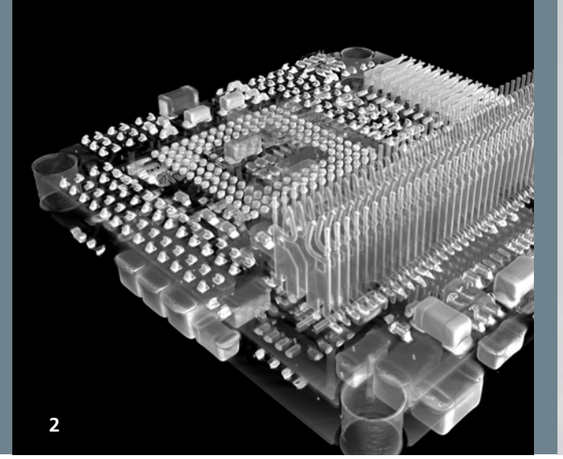
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Modern traffic systems have to be safe, environmentally friendly and cost-efficient. High-performance, reliable and, in some cases, highly miniaturized systems are key goals for developers creating innovative forms of transport and traffic systems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

Assembly of highly miniaturized electronic modules by embedding components in PCB substrates

The increasing functional density of electronic modules enables the development of new and increasingly complex applications. To meet these challenges, advanced PCB technologies are being investigated to allow the flexible manufacturing of highly integrated multi-components, packages, and modules. The best miniaturization potential can be achieved by embedding unpackaged or passive ICs. One alternative would be the embedding of SMD components, which allows a large number of commercially available components to be used and opens up the technology for a wide range of applications

Wafer-level packaging for hermetic vacuum capping of infrared sensors

In the European project APPLAUSE, Fraunhofer IZM is investigating technologies and processes for the wafer-level packaging of micro bolometers on 200 mm wafers. The process development involves the creation of silicon cap wafers for the hermetic vacuum encapsulation of the large MEMS pixel array structures (FPA) created by the project partners. Two package topologies are being compared for this purpose: a single wafer cap over the bolometer wafer, and a compound lid consisting of a silicon frame and flat lid.

The technological evaluation of the overall packaging process involves the combination of different technologies, including silicon etching, electrodeposition of gold-based bonding rings (also on the bolometer side), wafer bonding with AuSn transient liquid phase bonding for permanent hermetic vacuum encapsulation, and the integration of an anti-reflective coating for improved optical performance.

Structure of power electronics – planar connections

In addition to die-attach – the planar connection of power semiconductors –two-dimensional connections to cooling units on the next level are also decisive for the performance and reliability of power electronic modules. There are essentially two technologies available for these two-dimensional connections, which can be up to a few square centimeters in size: soldering or silver sintering. These come with challenges, one relating to bulges occurring in the large-area interconnect partners and others relating to the three-dimensional design of the cooler structures. The latter must be taken into account in particular when setting the temperature profiles during soldering. In silver sintering, ensuring uniform contact pressure is particularly crucial.

3D radar sensors for autonomous cars without blind spots

For automated driving to become truly secure, Fraunhofer IZM researchers teamed up with their project partners on the KoR-Rund project to develop 3D radar modules that can be positioned relatively freely on the vehicle and integrated into a sensor network to enable a 360° all-round view. The vehicle's surroundings can be analyzed in real time and simultaneously from all perspectives. To enable this seamless mapping of the vehicle surroundings, the scientists developed packaging methods for reliable radar sensors with revolutionary free-form surfaces that allow any antenna shape and mount on the vehicle to be realized in the future. The IZM researchers were instrumental in simulating, building, and testing the mold technologies for the 3D radar sensor technology.

The project is co-funded by the Federal Ministry of Education and Research BMBF.

1 *Module for novel planar SATCOM terminals (AVISAT project)*

2 *CT scan of a sensor module built with the embedding technology*

3 *Panel-level molding for 3D freeform radar sensors*

MEDICAL ENGINEERING

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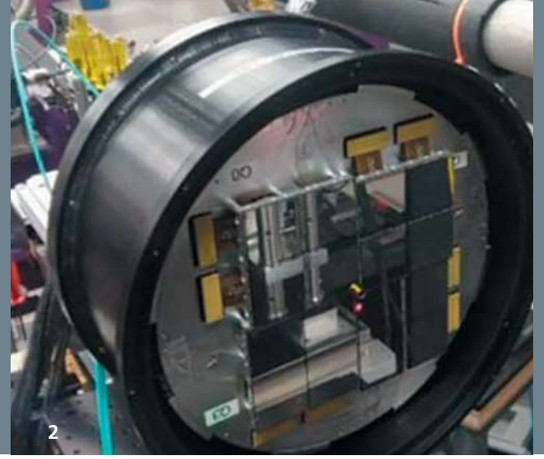

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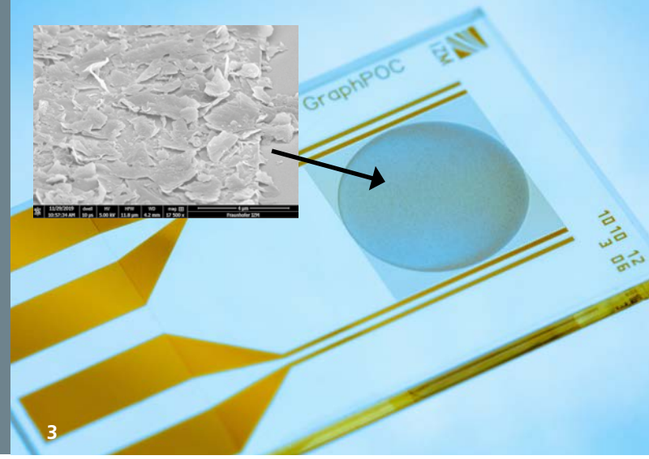

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Over the past years, the innovation potential of microelectronics has led to considerable progress in medical technology. Fraunhofer IZM has been front and center in this development process for 20 years. Our know-how in microtechnology and innovative integration processes helps manufacturers realize innovative new medical engineering products, that meet all legal requirements. Of course, Fraunhofer IZM also performs customized reliability analyses, bio-compatibility assessments, as well as the risk assessment according to ISO 14971 standards, which is required for the development of new products.

»Fraunhofer vs. Corona« campaign
The COVID 19 pandemic of 2020 figured prominently not only in all of our lives, but also in research. Fraunhofer scientists were involved in numerous projects to combat the pandemic, with the following activities a brief selection of IZM's contributions to Corona research.

Corona rapid test in less than 2,5 hours
After a development time of only six weeks, Bosch launched a new rapid test in March 2020 that produced results at the test site in under 2.5 hours, instead of the two days needed beforehand. The technical solution was based on a PoC analysis platform developed with Fraunhofer IZM as part of the EU project CAJAL4EU. The main goal of the project was to develop miniaturized biosensor technology platforms that enable fast, robust, user-friendly, and cost-effective multi-parameter in-vitro testing applications.

High-resolution x-ray cameras for SARS-CoV-2 research
Free electron lasers, as installed at institutes like DESY in Hamburg or SLAC in the U.S., are used to investigate the structures of chemical bonds or molecules. For this study, a special high resolution x-ray camera allowed an international team of researchers to successfully investigate the protease structure of the SARS pathogen in liquid water. In contrast to cryogenically cooled samples, the method makes it possible to investigate chemical bonds at near body temperature. Fraunhofer IZM contributes silicon pixel chip modules, which are assembled into a complete x-ray detector. Four electronic readout chips are flip-chip-bonded onto a silicon sensor chip at a size of 13.5 cm². The complete epix10k2M detector consists of 16 such modules with 2 million x-ray sensitive pixels in total.

BEAT-COVID – new therapies against the pandemic
On the BEAT-COVID project, Fraunhofer researchers from several institutes are developing inde-pendent and novel therapy strategies on the basis of platform technologies that can power the rapid and targeted development of new drugs against the as yet unknown pathogens that may emerge in the future. Fraunhofer IZM is helping Fraunhofer ITEM improve its professional in-vitro technologies (P.R.I.T.), a system in which cell cultures can be directly exposed to aerosols, such as COVID-19, or other antiviral drugs, in a defined environment to monitor their reaction. The IZM researchers are working on ways to enable the evaluation of cell viability in-situ – i.e. while the cells are still exposed to the aerosols in the P.R.I.T. box.

Graphene-based rapid infection diagnostics
Fraunhofer IZM researchers are working with project partners from industry and healthcare to develop a convenient graphene oxide sensor platform that makes it possible to detect acute infections, such as sepsis, or antibodies to the coronavirus in just a few minutes. The special feature of the sensor platform is its choice of materials: Graphene oxide is unique in that it is an electrically conductive and biocompatible material that allows particularly reliable sensor performance. Its use in microelectronics has so far been restricted to its original 2D form. However, Fraunhofer IZM researchers are now applying it in 3D flake structures. This three-dimensional shape increases the measurement area and improves the accuracy of the measurements.

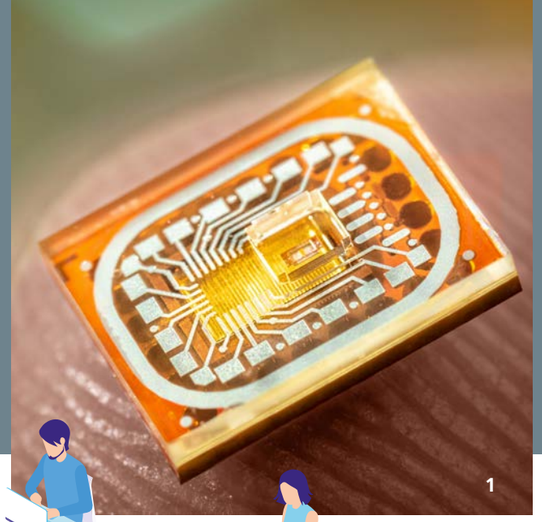
The project is co-funded by the Federal Ministry of Education and Research BMBF.

1 *#FraunhofervsCorona*

2 *High-resolution x-ray camera*

3 *An SEM micrograph of a graphene-based biosensor's surface*

SEMICONDUCTORS



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This business unit specializes in the integration of semiconductor elements and the production of sensors for the assembly of complex heterogeneous system-in-package (SiP) solutions. Fraunhofer IZM offers its clients holistic services – from developing the original concepts and designing the processes to characterizing and testing the reliability of the finished systems. The institute's facilities cover all relevant processes for manufacturing sensors and wafer-level packages, allowing the production of hermetically sealed sensor packages and even entire 3D systems.

Hermetic wafer level capping for MEMS packaging
Fraunhofer IZM has established a new wafer level capping technology for hermetic or quasi-hermetic first-level device sealing. The technology is based on cap structures with bond frames and optional recesses on temporary carrier wafers, subsequently transfer-bonded to the device wafer. The bond frames and cap outlines can be defined with near-complete freedom by mask aligner lithography and related patterning processes. This means that arbitrary cap structures with irregular forms, sizes, and pitches are possible. The bond frames can be made of adhesives, metals, or solders to provide purely mechanical or air-tight device sealing on the target wafer.

Glass interposer concepts for the cost-efficient realization of custom applications
Fraunhofer IZM has developed a generic glass interposer concept for different via diameters and wafer designs based on fixed TGV positions and geometries. These technologies allow the fast and cost-efficient realization of customer-specific applications. Compared to silicon interposers, glass interposers have numerous advantages: the dielectric materials promise very high signal integrity, a low dielectric loss in the high-frequency range as well as less impact of cross-talk. The concept can serve the entire process chain: 100 GHz concept, design, simulation, realization, and characterization.

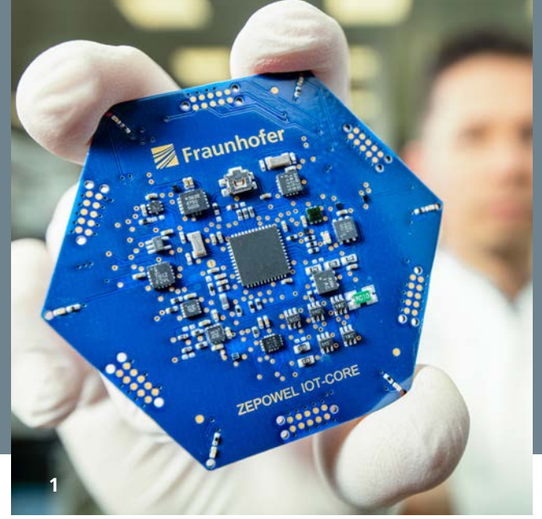
Novel technology for motor inverters with record power density
Two ECPE Lighthouse projects have revealed how the power density of industrial converters with an output of 63 kW can be increased by a factor of 4 by using semiconductors based on silicon carbide. The volume of the systems could be reduced with a new ultra-low-inductance power module that gets the most out of the semiconductors' properties to achieve a high switching frequency of 140 kHz and allow the passive components to be shrunk down. Furthermore, a novel EMC filter topology and improvements to the semiconductors controls lowered the loss potential of the components with high ripple currents, which again helped shrink the size of the heat sink in particular.

Low-inductance SiC power module with conventional packaging and interconnection technology
In the Speeddrive project, a semiconductor module was developed for use in the turbine converters of biogas plants with three-phase alternating current, modelled on an Infineon IGBT module in terms of its housing, the arrangement of electrical pin contacts, and the overall size of the module. Replacing the IGBT chips with SiC chips allows for faster and thus lower-loss switching, resulting in increased switching frequency at the system level. To increase the nominal power of modules without compromises on their size, insulation ceramics with particularly good thermal performance were chosen to improve heat dissipation away from the chips.

1 *Hermetically sealed glass package with TGVs for a radar level sensor which is operated at 160 Ghz. (GlaRA: BMBF)*

2 *Motor inverter with I/O EMC filters for a record power density of 3.5 kW*

INDUSTRIAL ELECTRONICS



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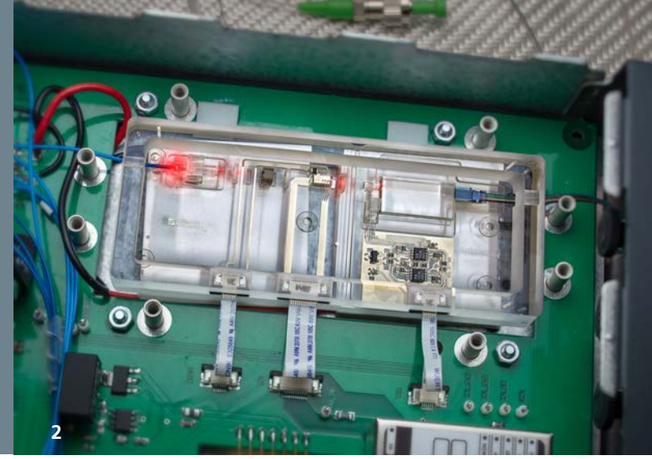

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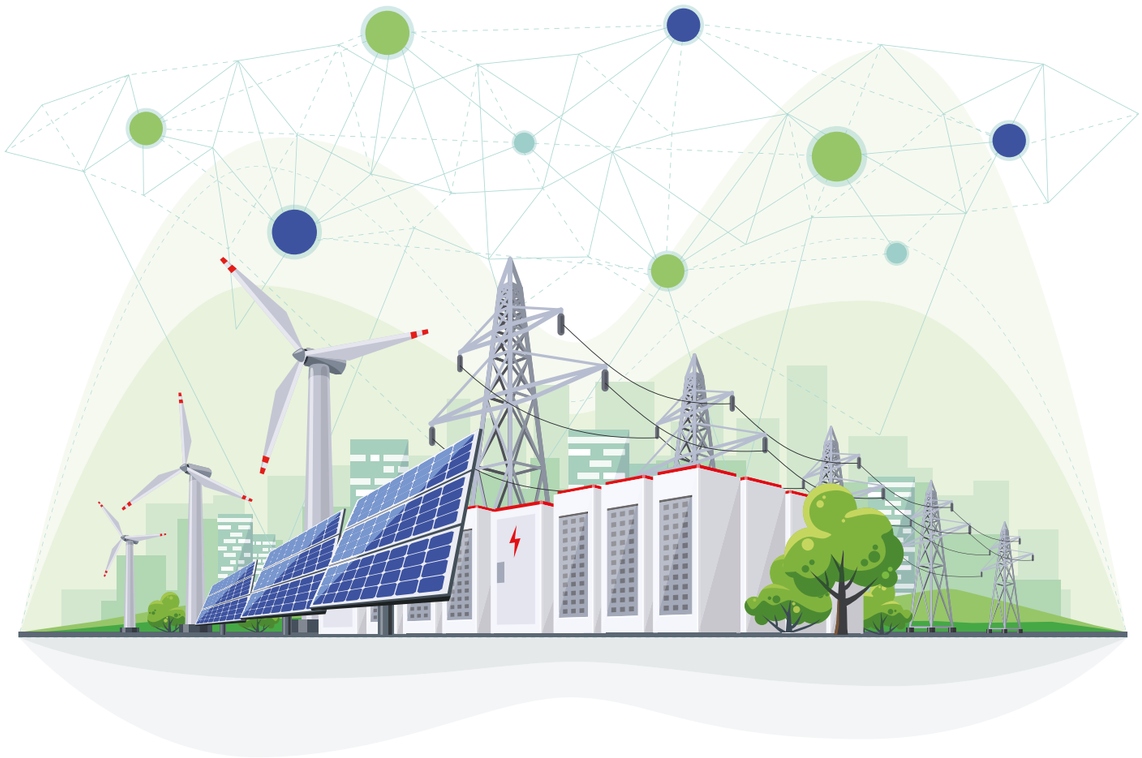


In recent years Fraunhofer IZM's industrial electronics specialists have concentrated on the visionary concept of Industrie 4.0. Particular emphasis was placed on the work on cyber physical systems (CPS) and autonomous, specifically high-reliability radio sensors that record and process the relevant monitoring and / or video data on site and distribute it via standard interfaces when and where the user needs it. Industrie 4.0 means much more than CPS integration: 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.

Glass interposer technology for high-frequency applications

As part of the publicly funded (BMBF) joint project GlaRA, radar sensors were developed to be especially suitable for smart industry and process measuring applications due to their excellent distance resolution, accuracy, beam focusing capabilities, and overall tiny dimensions. This feat was made possible with a robust glass interposer technology for broadband mm-wave modules for frequencies above 100 GHz, which was used to construct and characterize system-in-package (SiP) designs. Fraunhofer IZM has developed an industry-ready process for glass via metallization with high aspect ratios. A wafer bonding process (for wafers with max. 300 mm diameter) hermetically packages the assembled components by connecting two glass wafers, fitted with the required vias and cavities.

Hybrid integrated glass benches for photonics

Optical systems can be built with combined electro-optical components and electronic controls using laser-structured and thin-film metallized glass benches. Thin glass is also used in custom-shaped fittings to enable their automated assembly with industrial alignment systems on six axes, with less than one-micrometer accuracy. This allows high-quality optical beams to be shaped and coupled to perform optical measuring tasks. With the concept capable of working with large-format panels, it can scale perfectly in terms of the size and number of systems and individual thin-glass packages produced.

ZeroPower construction kit for sensor applications

The Fraunhofer flagship project ZEPOWEL is making progress towards a more resource-efficient Internet of Things, courtesy of extremely energy-efficient and modular hardware. The project works on IoT nodes that consume significantly less energy themselves, while also pursuing energy savings in how these nodes network with each other. An IoT core developed for the project at Fraunhofer IZM enables the connection of a wide variety of IoT modules. Intelligent algorithms optimize the available resources through dynamic power management during runtime. A consistent hardware-software co-architecture has been shown to reduce energy consumption by a factor of 5 compared to the current state of the art.

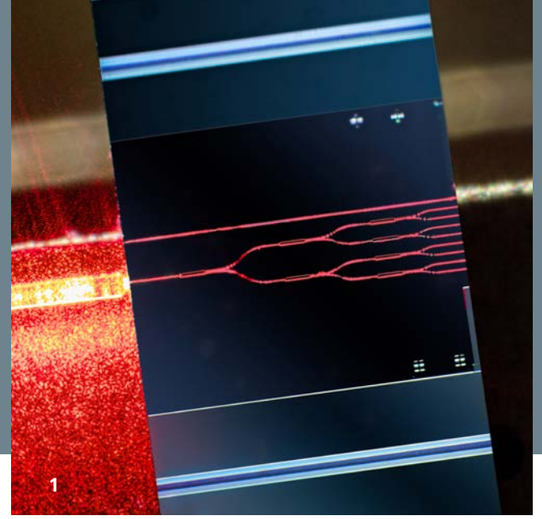
High-performance modular system for sensor applications

The Berlin Center of Excellencer has given birth to SWARM, an IOT device developed for tough industrial use with a focus on versatile applicability and fast and simple configuration. Its modular architecture allows the features and functions of the system to be levelled up with standard market sensors and helps make the IoT device operational in record time. The SWARM devices can also be connected to a distributed network for synchronized measurements at different locations, and actuators can be controlled with the integrated interfaces. The IoT device is readily accessed via Bluetooth using an Android app or Python application; its data can be stored and processed locally or in the cloud.

1 *The Fraunhofer flagship project ZEPOWEL is paving the way for a truly universal Internet of Things. The autonomous sensor nodes automatically go into deep-sleep mode when inactive.*

2 *Hybrid integration of a micro-electrooptical array for sensor applications on a glass substrate (40 x 100 mm²)*

INFORMATION AND COMMUNICATION



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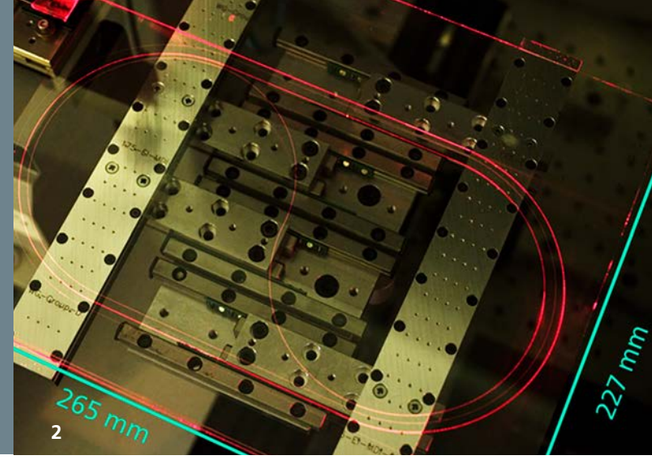

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The new era of increasing connectivity and digitalization creates new challenges for the design and assembly of ICT systems: The efficient sharing and storing of data needs ever larger data centers and the means to transmit electric and optical signals. Digitalization itself brings its own challenges: There is increasing demand for highly dynamic networks that can transport, process, and analyze data. Fraunhofer IZM offers comprehensive solutions for these challenges with more than two decades of experience in the field of system integration.

Long-length monomodal waveguides in thin glass
Fraunhofer IZM has succeeded at taking an important step for process development of electrical optical circuit boards (EOCB) in optical data transmission at the level of circuit boards. The fabrication process for single-mode optical waveguides in large-format thin glasses has improved transmission characteristics and process homogeneity to reduce propagation losses to (0.059 ± 0.001) dB/cm. These results published at ECTC 2020 are promising for several current trends, including functionalized glass as an attractive substrate candidate for co-packaging, which should enable more efficient data processing in data centres.

Tests for robust and durable electronic end devices
The fundamental technical prerequisites for electronics to enjoy long service lives are robustness, durability, and repairability, properties that consumers need to be able to understand and compare. Test approaches are being developed to enable this as part of the EU PROMPT project. PROMPT stands for »Premature Obsolescence Multi-Stakeholder Product Testing Programme; the project is planned for a duration of four years and is coordinated by Fraunhofer IZM. Its aim is to develop an independent testing program that helps estimate the life expectancy of products as they come to market. The focus for Fraunhofer IZM lies on rechargeable batteries, general electronics, and mobile devices.

Modular bodies as a case study of ecodesign
Modular product design enables longer product lives, facilitates repair and reuse, and can thus contribute to more sustainable product concepts. Several lifecycle assessments of individual technologies, such as embedding components, connectors, or smartphones, have revealed the considerable environmental potential of manufacturing modular devices. However, only if usage habits change towards longer use will the added expense of modular design pay off. Under certain conditions, embedding technology can help improve the environmental footprint of smart devices.

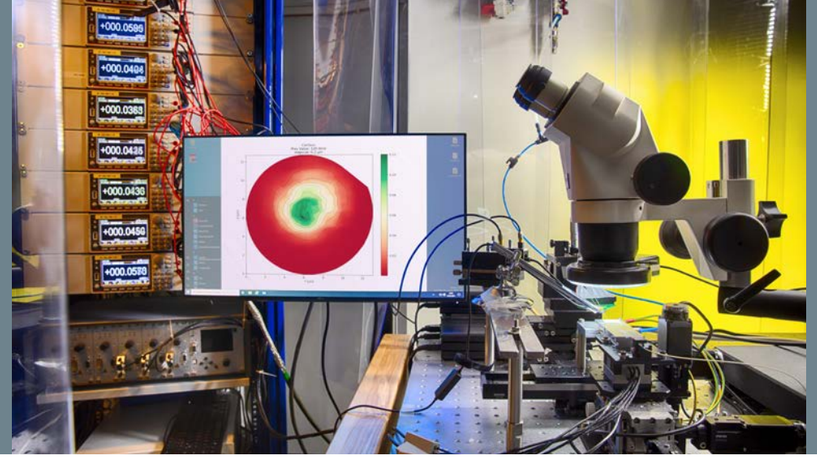
Drop tests with high-speed cameras for mobile systems
The lifespan of electronic devices such as smartphones can be significantly shortened by accidental drops. As consumers demand more sustainable products, tests need to be developed to assess how robust products are in practice. Fraunhofer IZM offers a comprehensive range of reliability tests, including methods for testing robustness against mechanical shocks. The tumble test now adds simulated random drops to its range; the tester allows repeated random drops from two heights (50 cm and 1 m). A high-speed camera and lighting equipment enable an accurate analysis of the fall dynamics and the moment of impact and help pinpoint potential design improvements

Beyond 5G
Setting up a European value chain for the production of radio frequency modules for next-generation mobile communications is the stated goal of the European Beyond5 project. Based on SOI technology, the project intends to create a European technology platform for communication and sensor modules to support applications like mobile broadband (5G), the Internet of Things (IoT), or connectivity for autonomous vehicles. Fraunhofer IZM is collaborating with its partners on the development of a 5G communication and a 77 GHz radar module. Building on the proposed assembly concept, the work includes the specification, design, and construction of the antennas and packages, supplemented by work on material characterization and the testing and reliability characterization of the finished modules.

1 *Test-Kit for high accuracy self-alignment assembly technology for the integration of light sources and detectors with photonic integrated circuits*

2 *Single-mode wave-guide spiral (>2 m) diffused into regular commercial thin glass*

LABS & SERVICES



Forschungsfabrik Mikroelektronik Deutschland

SYSTEM INTEGRATION

Wafer-Level Packaging Line

Fraunhofer IZM operates two process lines (cleanroom class 10 – 1000) in Berlin (975 m²) and Dresden (ASSID, 1000 m²), that offer our customers various wafer-level packaging services from development stage to prototyping and small volume production. Different substrate materials (e. g. silicon, III/V, ceramic and glass) and wafer sizes (4" –12") can be processed. Project and process work on both lines is executed in compliance with ISO 9001:2015 management standards.

Process Modules (up to 300 mm):

- Cu-TSV integration (via-middle and via-last-processes)
- Silicon and SiC plasma etching – DRIE (TSV, cavities)
- Thin-film deposition (sputter, CVD, photolithography (resolution up to 0.5 µm), reactive ion beam etcher)
- PECVD process chamber (200/300 mm) for the deposition of TEOS oxide, Silane oxide and Silane nitride
- High-density thin-film multilayer (Cu/polymer RDL)
- Wafer-level bumping (Cu-Pillar, SnAg, Ni, Au, In, AuSn)
- Wafer thinning und thin wafer dicing (blade, laser grooving and stealth dicing)
- Wafer bonding – permanent and temporary
- Wafer level assembly up to 300 mm (D2W)
- Automatic inline wafer measurement system (200/300 mm) for layer thickness, topographies, roughness as well as TTV/warpage/bow
- Fully automated electric wafer measurent system

Substrate Line

In the substrate area panel-size substrates (460 x 610 mm²) can be prepared for resist and PCB lamination, solder resist and cover lays can be applied and developed after exposure. Track geometries with down to 2 µm width are under development.

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 PCB substrates
- Realization of smallest vias, mechanically as well as with a laser
- Quality assessment and X-ray microscopical analysis

Mold Encapsulation Lab

The lab offers various encapsulation processes, related material and package analysis and reliability characterization tools as a one-stop-shop. The focus is on FO-WLP/PLP on sensor packages with freely accessible surface and on power SiPs.

- Precision assembly and compression molding on wafer and panel level (610 x 460 mm²)
- Redistribution in 2D (PCB-based and thin film) and 3D (TMV)
- Transfer molding of SiPs for sensors and power
- Process simulation and analysis of material models

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

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 COB processes

Soldering Lab

- Vapor phase soldering with vacuum enables manufacturing of voidless large area solder joints for power electronics
- Hermeticity test
- Fluxless soldering of printed circuit assemblies using active gas in oxygen free Nitrogen or vapor phase atmosphere
- 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

MATERIAL ANALYSIS

Moisture Lab

- Comprehensive simulation-based reliability assessment of humidity-induced phenomena in microelectronic components and systems
- Surface analysis through atomic force microscopy
- Analysis methods for sorption, permeation and diffusion of water in materials
- 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

- Testing of hetero highly integrated of power modules
- Active cycling of power modules for lifetime assessment
- Calorimetric measurement of the effectiveness of highly efficient devices

DESIGN

High Frequency Lab

- Free-space measuring station up to 170 GHz, Fabry-Perot resonators up to 140 GHz and THz system for HF material characterization
- Semi-automatic sample station with thermal chamber (-60 °C to 300 °C)
- EMC and test environment for wireless communication systems in the multi-gigabit and terabit-range
- Antenna measuring system for up to 330 GHz
- Test lab for mm wave modules for radar and communication, signal source (AWG) and spectrum analyzer up to 325 GHz
- Time range measuring station (sample oscilloscope up to 70 GHz/BERT up to 64 Gbit/s)

Microelectronics Lab

- Development and qualification of mechatronics systems and energy-efficient wireless sensor systems
- PXA for range calculation, conformity checks, and failure analyses; allows the recording of very fast signals (from 162 µs)

Further laboratories include:

- Micro Battery Lab with 10-meter battery development and assembly line
- Laboratory for Textile-integrated Electronics (TexLab)
- Photoelectron spectroscopy and electron spectroscopy for chemical analysis (ESCA)
- Corrosion Lab
- Electronics Condition Monitoring Lab (ECM) for functional tests of electronic systems under environmental stress, salt spray, shaker
- Qualification and Test Center for Electronic Components (QPZ)
- Thermo-mechanical Reliability Lab
- Thermal & Environmental Analysis Lab

EVENTS

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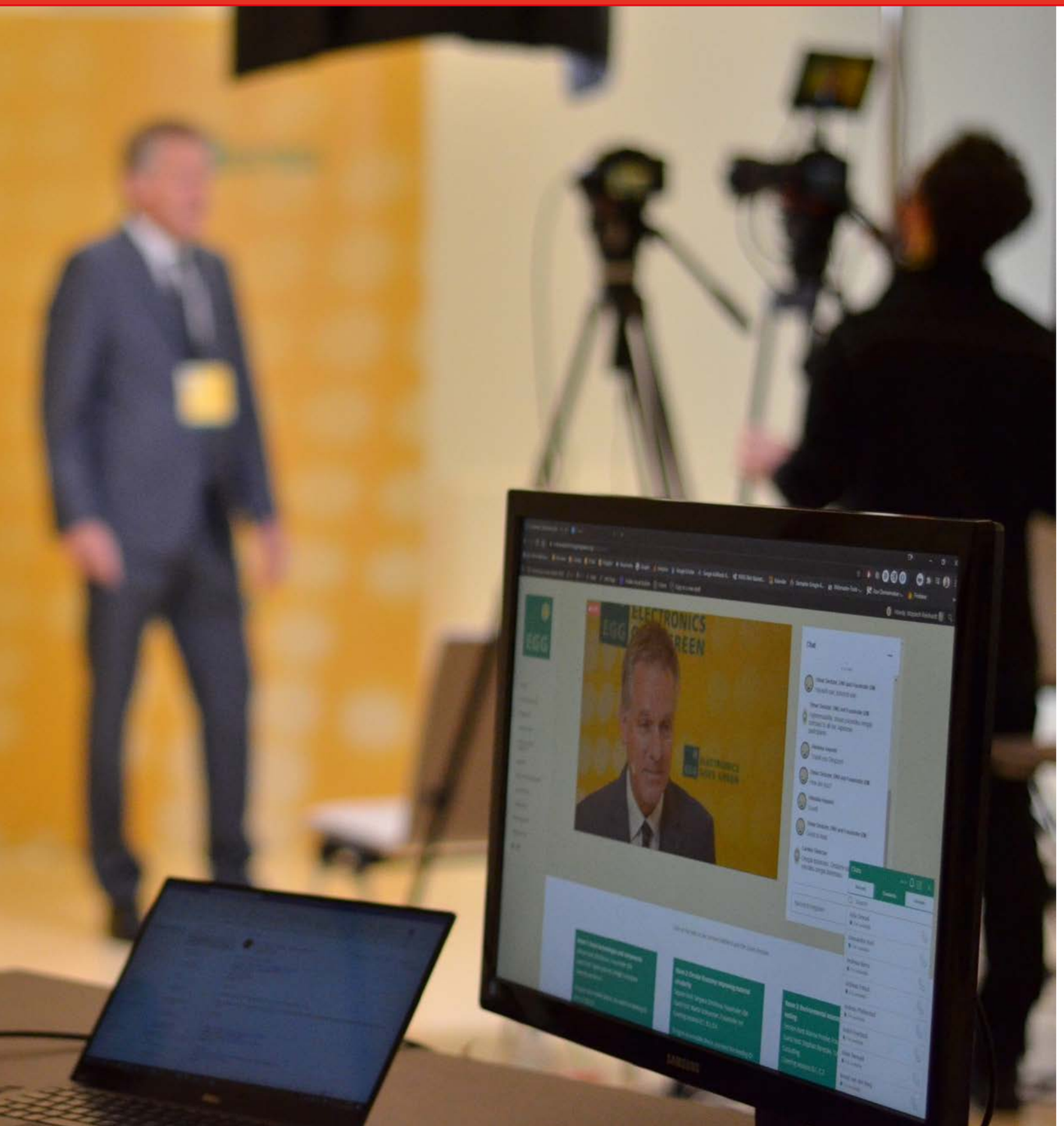

EVENTS & WORKSHOPS

2020 was a year lost to the COVID-19 pandemic. To contain the spread of the virus, people were prevented from gathering in groups, a decision taken in the interest of public health that brought massive repercussions for the event sector in its wake. After many events were postponed or cancelled outright after the initial shock, the industry soon realized that novel solutions had to be found and new paths had to be taken. Fraunhofer IZM was very quick out of the starting gates with its choice to move conferences and workshops into the virtual realm, and the decision was rewarded with some extremely positive experiences in return. The picture was less positive for tradefairs and exhibitions, which are harder to transition to online formats. The search for a truly satisfactory solution for our clients, partners, and other interested parties is still very much active. Even with online services and formats allowing us to stay in contact even in these difficult times, we are sincerely looking forward to the next opportunity – very soon – to meet you all in person again.

Consortium Meeting PLP 2.0

After the international Panel Level Consortium 1.0 achieved its ambitious goals for the project in 2019 with significant technical progress in the field of large-area fan-out panel level packaging, a new consortium has been formed to continue on that trajectory. The PLC 2.0 consortium is dedicated to exploring new opportunities for higher wiring density, made possible with more granular wiring geometries at a 2 µm scale. This includes new research into copper migration, the displacement of embedded components, and warpage on large-area panels.

While the kick-off meeting in early 2020 could still be held in person at Fraunhofer IZM in Berlin, later meetings and interactions had to move to the digital realm. This did not, however, stop the individual sites from making progress towards their ambitious goals.

Electronics Goes Green 2020+: Recycling management and $C0_2$ neutrality in production chains

For the sixth time, Fraunhofer IZM organized the world's largest conference on sustainability in electronics in September, which had to be held online for the first time due to the COVID-19 pandemic.

250 participants had the opportunity to watch pre-recorded presentations on an online platform created especially for the conference and to participate in a virtual live event on September 1. Eelco Smit, Senior Director Sustainability at Philips, opened the live event with his keynote speech on »Best Practices in Sustainability – What Can We Learn?«. In his presentation he introduced the Philips Sustainability Program, which is developed every five years. In the afternoon Sarah Chandler, Senior Director of Operations Product Development and Environmental Initiatives, presented Apple's roadmap up to 2030 and explained that the company wants to achieve zero CO_2 emissions in the manufacture of its products in ten years at the latest. In addition to the two keynotes, the live day featured six interactive sessions and an exciting panel discussion on the topic of »Recycling as Circular Ecomomy!?«. Even the exchange and networking with like-minded participants was possible thanks to numerous options on the online platform.

1 *Live and in colour – Electronics Goes Green launches its new online format live from the Fraunhofer Forum*

2 *Kicking off the PLC 2.0 consortium at Fraunhofer IZM*

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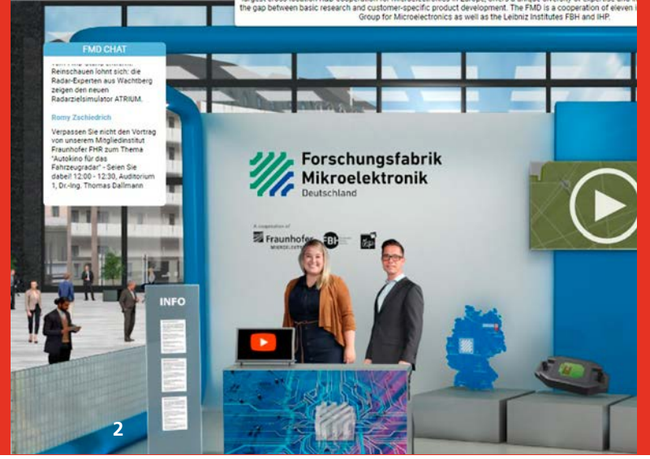

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Online series »IZM Photonics: In Glass We Trust«
2020 was also a year of ad-hoc meetings and digital get-togethers to keep in touch with clients and partners. The first series of these meetings, organized specifically with this in mind, was all about photonics packaging. In the 45-minute sessions, we show what is possible with glass in this area and how participants can use the findings for their industry or in joint projects. The first session was attended by more than 50 outside guests, a figure that rose to almost 100 bookings for the second session. There is already great interest in reviving the format in 2021.

No more excuses: EU Commissioner Frans Timmermans underlines that effective recycling of high-tech plastics is possible
More than 200 international participants joined the virtual workshop »Circular Product Development – The Secrets to Design for and from Recycling« on April 15, 2021, which took place within the framework of the EU project PolyCE. The experts from the PolyCE consortium presented their experiences and findings on the holistic circular economy for high-tech plastics as well as best-practice strategies developed in line with the motto »Design for Recycling«. An additional highlight was the appearance of Frans Timmermans, Commissioner for Climate Action and Vice President of the EU Commission, who is responsible for the Green Deal. He was given recommendations for action for effective plastics recycling.

Fraunhofer IZM at the Virtual Photonics Days
This year's Photonics Days, organized by the Competence Network for Optical and Microsystems Technologies in the Berlin-Brandenburg Region OpTecBB e. V., were also hosted in an online format with virtual English-language seminars by approx. 100 local and international speakers discussing everything from photonic integration to the role sensors can play for improved data communication.

Fraunhofer IZM was out in force at two of these sessions. Dr. Henning Schröder joined Wojciech Giziewicz of Corning Optical Communications GmbH & Co. KG to introduce the first set of seminars on »Innovative Fibre-Optics – Part I«, welcoming speakers from Spain, Poland, Israel, and – of course – Berlin. With around 250 attendees from around the world, the session covered new requirements for optical fibres, optical mode adjustment, spectral losses, mechanical robustness and performance reliability, connector designs, and production and packaging technologies.

Events with Fraunhofer IZM participation (selection)	
3D & Systems Summit	January, Dresden
IERC 2020	January, Salzburg, AT
SPIE. Photonics West	February, San Francisco, USA
embedded world	February, Nuremberg
German Microwave Conference	March, Cottbus
IZM Contributions at Fraunhofer Expert Sessions	May/October, online
IEEE ECTC	June, online
PCIM Europe	July, online
SMTconnect	July, online
IMAPS 2020	October, online
Photonic Days Berlin/Brandenburg	October, online
Fraunhofer Solution Days	October, online
COMPAMED	November, online
SEMICON Japan	December, Tokio, JP

On day 2, the team of the European Horizon 2020 project MASSTART hosted a special webinar to introduce all project partners and their current progress with their project. Fraunhofer IZM heads the consortium under the careful management of Tolga Tekin, pursuing the ambitious goal of reducing costs for mass-produced photonic high-speed transceivers to €1/Gb/s or even lower. Again, almost 250 viewers were logged in, and all presentations were recorded and are available for viewing on the project's website https://masstart.eu/.

IMAPS Workshop for System Integration with over 200 participants
Extremely small and powerful components can be created through system integration. But how can the great challenges of different technologies, sizes and materials, as well as electrical and mechanical connections and reliability, be mastered? Fraunhofer IZM answered these questions together with its colleagues from Fraunhofer USA at IMAPS 2020. More than 200 participants watched the presentations of the internationally renowned Fraunhofer experts and exchanged ideas in live Q&A. This workshop was part of this year's IMAPS 2020, 53rd Symposium on Microelectronics: www.imaps2020.org.

Seminar »Reliability of Electronic Systems«
As innovation cycles keep accelerating and introducing ever more complex and demanding requirements for electronic components and systems, reliability assessments are becoming more and more important. The two-day »Reliability of Electronic Systems« seminar is hosted annually and was again organized by our Environmental and Reliability Engineering team. Even with the limitations of an online format, the Fraunhofer IZM researchers made clever use of interactive opportunities, such as shared whiteboards or small-group discussions, to introduce the audience to relevant methods and tools that can be integrated in the regular electronics product development process. The audience was particularly excited about the potential of condition monitoring as part of a circular economy concept.

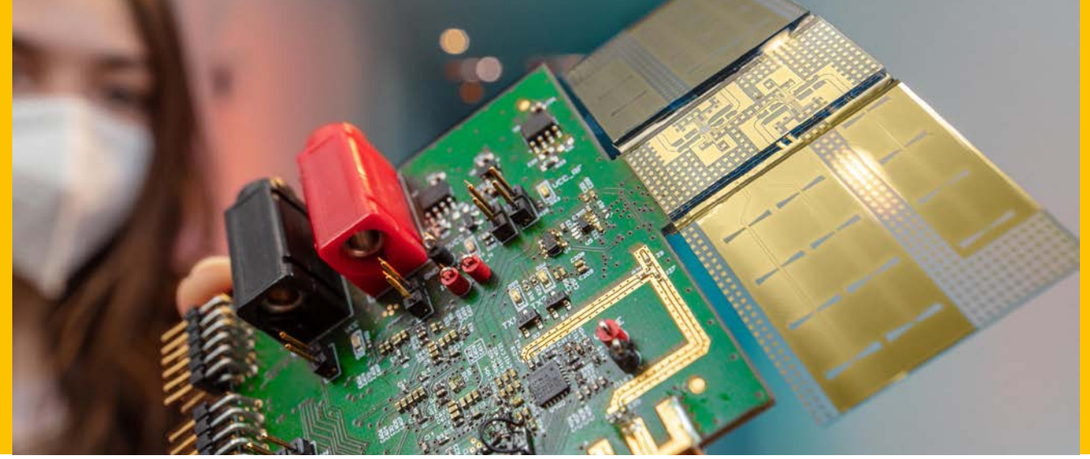
Selection of events organized by Fraunhofer IZM	
Panel Level Packaging 2.0	February, Berlin
Workshop: Ecodesign Learning Factory	March, Berlin
Lab Course: EMC Optimized Design	March, Berlin
Workshop: Wide-Bandgap User Training	September, hybrid
Electronics Goes Green 2020+	September, online
Session: Data Center Interconnects	October, online
Workshop: Parasitic Effects in Power Electronics	October, online
Online Course: From Wafer to Panel Level Packaging	October, online
Webinar: In Glass We Trust	November, online
Compliance and Environmental Management in the Electronics Industry	November, online
Workshop: Reliability of Electronic Systems	November, online

1 *EU commissioner Frans Timmermans and the PolyCE consortium's recommendations*

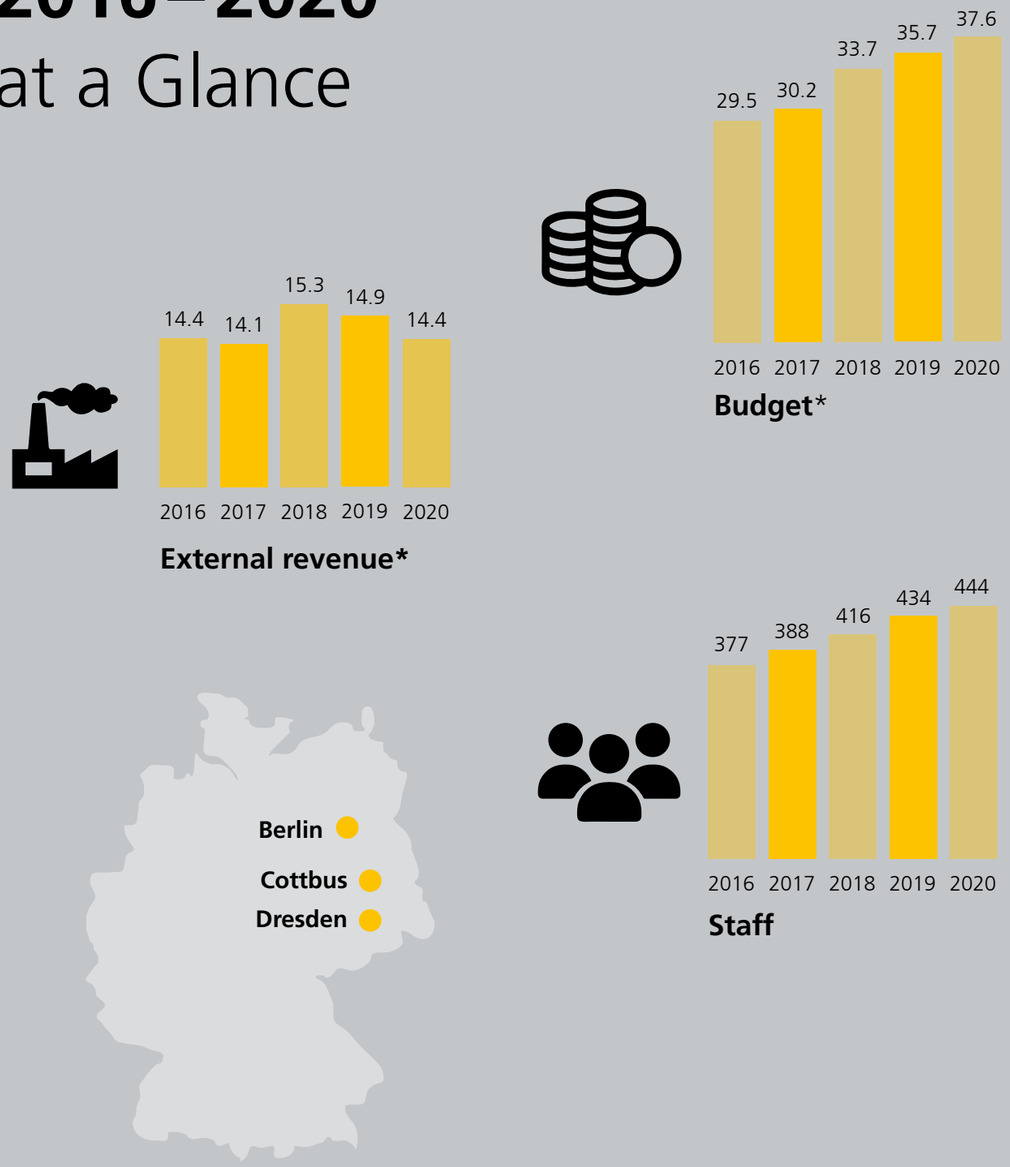
2 *Always at your (virtual) service– IZM's professionals at the Fraunhofer Solution Days*

3 *One of 2020's last in-person conferences – the 3D Systems Summit*

FACTS & FIGURES



2016–2020
at a Glance



* in million euros

FRAUNHOFER IZM IN FACTS AND FIGURES

Financial situation
2020 saw a continuation of the positive performance of the previous year, with revenue increasing by a further 5.4 percent to a sum of 37.6 million euros over the course of the year. The Institute covered 75.8 percent of its operating budget from outside revenue. External projects accounted for 28.5 million, representing a two-percent increase over 2019.

The share of publically funded projects increased by a full eight percent to 14.1 million euros. Beyond this, direct industry commissions represented 38.4 percent of the Institute's budget, with the total amount of 14.4 million euros unchanged from the previous year.

Hardware and equipment
In 2020, a sum of 1.6 million euros was invested for regular equipment replacement and refurbishment. These investments were made in a number of targeted individual interventions to upgrade the technical facilities and improve the efficiency of existing equipment. Another 1.4 million euros was dedicated to a range of smaller construction projects, mostly for the modernization and expansion of the Institute's physical infrastructure. Data communication and media, coolant, and pressurized air services for the research labs and cleanrooms were also improved.

These investments improved the Institute's ability to integrate its facilities for the growing Research Fab Microelectronics Germany (FMD). A further million euros was invested into new equipment for the FMD.

HR development
The continued commercial success of Fraunhofer IZM allowed the Institute to create new jobs in 2020, increasing its headcount from 285 to 303 colleagues at its three sites in Berlin, Dresden/Moritzburg, and Cottbus.

The Institute also gives students a chance to combine their academic studies with applied scientific work in the offices and labs of Fraunhofer IZM. By the end of 2020, no fewer than 133 interns, bachelor and master students, and student assistants had benefited from these opportunities at Fraunhofer IZM. The Institute is also proud to offer young people qualified apprenticeships, training eight aspiring microtechnologists and office management assistants in 2020.

Fraunhofer IZM in 2020	
Budget	37.6 million euros
External revenue	28.5 million euros (78.6 percent of total turnover)
Sites	Berlin, Cottbus and Dresden/Moritzburg
Laboratories	>8,000 m²
Staff	444 (including 133 student assistants, bachelor and master students, interns and 8 apprentices)

AWARDS, EDITORIALS, DISSERTATIONS

Awards

Young Engineer Award of PCIM Europe 2020
Kirill Klein has won the Young Engineer Award of PCIM Europe 2020 for his paper on »Low Inductive Full Ceramic SiC Power Module for High-Temperature Automotive Applications«. In the prize paper, Kirill Klein and his co-authors introduce a fully ceramic power module designed to extend the range of electric vehicles at lower system costs by optimally utilizing silicon carbide semiconductors.

Exceptional Technical Achievement Award
On March 19, 2021 the IEEE Electronics Packaging Society (EPS) has announced the winners of the 2021 Society Major Awards, and our group leader Dr. Tanja Braun, together with Intel's Beth Keser, was honored with their »Exceptional Technical Achievement Award«. Dr. Braun receives the award for her pioneering contributions as well as her leadership in fan-out wafer level packaging and the transition to panel level packaging.

Other awards

Nomination for Falling Walls Award
Prof. Melanie Jaeger-Erben was nominated for the Falling Walls Award for her contribution »Breaking the Wall to Inclusive and Socially Sustainable Technology«.

EBL 2020: Best Paper Award for David Schütze
»Constructing Highly Miniaturized and Robust Wireless Sensor Nodes with PCB Embedded Components«
K.-F. Becker, C. Tschoban, C. Voigt, T. Löher, S. Kosmider, A. Ostmann, L. Böttcher, M. Schneider-Ramelow und K.-D. Lang

Prize of the German Research Foundation
Fraunhofer IZM's blog was awarded first prize in the ideas competition for international research marketing.

Editorials

Bioelectronic Medicine: Engineering Advances, Physiological Insights, and Translational Applications
Giagka, V. (Guest Editor)

Bioelectronic Medicine Journal
Giagka, V. (Associate Editor)

Electronics Goes Green 2020+ Proceedings
Nissen, N. F., Schneider-Ramelow, M. (Editors)

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

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

Dissertations

Hu, Xiaodong
»Influence of Bonding Temperature and Material on Anodic Bonding for Stress Sensitive MEMS«

Kaupmann, Philip
»A Novel Indirect Actuation Concept for MEMS Micromirrors«

Otto, Alexander
»Lebensdauermodellierung diskreter Leistungselektronikbauelemente unter Berücksichtigung überlagerter Lastwechseltests«

Schmidt, Michael
»Numerische Modellierung der lokalen mechanischen Beanspruchbarkeit eines epoxidharzbasierten Schaltungsträgersubstrats«

Steinbach, Axel Friedrich
»Anforderungen für den Einsatz modularer Messsysteme bei kognitiven und funktionellen Einschränkungen von Demenz- und Rheumapatienten«

LECTURES

German University in Cairo

Dr. T. Tekin
- Sensor Technology

University of Applied Sciences for Engineering and Economics in Berlin

Dr. R. Hahn
- Microenergy Systems

Prof. Dr. H.-D. Ngo
- Microsensors
- Micro System Technologies II
- Characterization of Semiconductor Sensors
- Microactuators
- Advanced Microsystem Technologies
- Cleanroom Technologies

Dr. H. Walter
- Materials in Microsystem Technology

Berlin School of Economics and Law

Dr. J. Winzer
- Integrated Product Design

Technical University of Berlin

Prof. Dr. M. Jaeger-Erben
- Sociology of Engineers I and II

Dr. J. Köszegi
- Design, Simulation and Reliability of Microsystems
- High-frequency Measurement Techniques in Microelectronic Packaging

Prof. Dr. K.-D. Lang
- Assembly Technologies for Microelectronics and MST

P. Mackowiak
- Assembly Technologies for Microelectronics and MST

Prof. Dr. H.-D. Ngo
- Manufacturing Technologies for Semiconductor Sensors

Dr. N. F. Nissen, Dr. A. Middendorf
- Environmentally Conscious Design of Electronic Systems

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

Dr. O. Wittler, Dr. J. Jaeschke
- Reliability of Integrated Microsystems

Delft University of Technology

Prof. Dr. V. Giagka
- Bioelectricity
- Active Implantable Biomedical Microsystems
- Neurostimulation

Dresden University of Technology

Jun.-Prof. Dr. I. Panchenko
- Micro-/Nanomaterials and Reliability Aspects
- 3D System Integration and 3D Technologies

Aalborg University

Prof. Dr. E. Hoene
- Design of Modern Power Semiconductors Components
- EMI/EMC in Power Electronics

COOPERATION WITH UNIVERSITIES (SELECTION)

Some of Fraunhofer IZM's university partners:
Aalborg University, Denmark
AGH University of Science and Technology, Poland
Binghampton University, USA
Delft University of Technology, The Netherlands
Eindhoven University of Technology, The Netherlands
Imperial College London, Great Britain
KU Leuven, Belgium
San Diego State University, USA
Tohoku University, Japan
University College London, Great Britain
University of Cádiz, Spain
University of New South Wales, Australia
University of Tokyo, Japan
University of Twente, The Netherlands
University of Utah, USA
University of Vienna, Austria
Uppsala University, Sweden
Albert Ludwig University of Freiburg, Germany
Berlin University of the Arts, Germany
Chemnitz University of Technology
Friedrich-Alexander University Erlangen-Nürnberg, Germany
Heidelberg University, Germany
Humboldt University of Berlin, Germany
Paderborn University, Germany
Rostock University, Germany
University of Bonn, Germany
University of Potsdam, Germany

To effectively implement its research goals, Fraunhofer IZM has established strategic networks with universities in Germany and abroad. Close cooperation with universities is an important pillar of Fraunhofer's success model. While the universities contribute their innovative ability and competence in basic research to the cooperation, 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
Since its foundation in 1993, Fraunhofer IZM has benefited from the successful cooperation with the Research Center for Microperipheric Technologies of the Technische Universität Berlin. In the 1990s, one of the world's first scientific institutions in the field of packaging and interconnection technology was established here. Since 2011, the traditional double appointment of Fraunhofer IZM director and Head of the Research Center has been held by Professor Klaus-Dieter Lang.

Fraunhofer IZM-ASSID cooperates with TU Dresden
Within the joint junior professorship »Nanomaterials for Electronic Packaging« of Fraunhofer IZM-ASSID and TU Dresden, junior professor Iuliana Panchenko and her team are working on new materials and technologies for fine-pitch interconnects in 3D/2.5D Si structures.

Cooperation with BTU Cottbus-Senftenberg
Fraunhofer IZM intensifies its cooperation with BTU in the branch office for high-frequency sensor systems in Cottbus. The research activities within the Innovation Campus (iCampµs) Cottbus focus on design, test procedures and characterization of integrated antennas, on co-design of chip-package antennas as well as system integration solutions for the realization of miniaturized radio frequency sensor systems.

COOPERATION WITH INDUSTRY (SELECTION)

AEMtec GmbH	Berlin
Ajinomoto Group	Tokyo (JP)
Amkor Technology, Inc.	Tempe, Arizona (USA)
AMO GmbH	St. Peter / Hart (AT)
ams AG	Premstätten (AT)
Amsterdam Scientific Instruments B.V.	Amsterdam (NL)
ASM Pacific Technology Ltd.	Singapore (SG)
AT&S AG	Leoben (AT)
Atotech Deutschland GmbH	Berlin
BASF SE	Ludwigshafen am Rhein
Berliner Nanotest und Design GmbH	Berlin
Boston Scientific Corporation	Marlborough, Massachusetts (USA)
Brewer Science, Inc.	Rolla, Missouri (USA)
CERN	Meyrin (CH)
Comelec s.r.l.	Ferriera di Buttigliera Alta (IT)
Daimler AG	Stuttgart
Corning Inc.	Corning, New York (USA)
CorTec GmbH	Freiburg im Breisgau
DISCO Corporation	JP
DuPont de Nemours, Inc.	Wilmington, Delaware (USA)
Dyconex AG	Bassersdorf (CH)
Evatec AG	Trübbach (CH)
Finisar Corporation	DE, USA
Fujifilm Electronic Materials	EU, USA
GEFRAN S.P.A.	Provaglio d'Iseo (IT)
GLOBALFOUNDRIES INC.	Dresden
IMASENIC Advanced Imaging S.L.	Barcelona (ES)
Intel Corporation	USA
Invensas / Xperi	Santa Clara, California (USA)
MED-EL GmbH	Innsbruck (AT)
Meltex Inc.	Tokyo (JP)
MENNEKES Elektrotechnik GmbH & Co. KG	Kirchhundem
Merck KGaA	Darmstadt
Multi Channel Systems MCS GmbH	Reutlingen
Nagase ChemteX Corporation	Osaka (JP)
OSYPKA AG	Rheinfelden
PANalytical B.V.	Almelo (NL)
Philips N.V.	Eindhoven (NL)
Picosun Oy	Masala (FI)
POSIC S.A.	Colombier (CH)
Reden B.V.	Hengelo (NL)
Rena Technologies GmbH	Gütenbach
Salvia BioElectronics B.V.	Eindhoven (NL)
Schmoll Maschinen GmbH	Rödermark
Semsysco GmbH	Salzburg (AT)
Shōwa Denkō K.K	Tokyo (JP)
Siemens AG, Siemens Healthcare	DE
SKW Associates, Inc.	Santa Clara, California (USA)
SLAC National Accelerator Laboratory	Menlo Park, California (USA)
STMicroelectronics N.V.	Amsterdam (NL)
Süss MicroTec SE	Garching near Munich

MEMBERSHIPS (SELECTION)

AMA Fachverband Sensorik, Wissenschaftsrat	H. Pötter	Member
Cluster Optik BB, Photonik für Kommunikation und Sensorik	Dr. H. Schröder	Spokesman
Deutsche Bundesstiftung Umwelt	Prof. K.-D. Lang	Reviewer
Deutsche Forschungsgemeinschaft	Prof. K.-D. Lang	Reviewer
Deutscher Verband für Schweißtechnik DVS	Prof. K.-D. Lang	Advisory Board
Deutscher Verband für Schweißtechnik DVS Arbeitsgruppe »Bonden«	Prof. M. Schneider-Ramelow	Chairman
ECPE Competence Centre	Prof. M. Schneider-Ramelow	Member
EURIPIDES Scientific Advisory Board	M. J. Wolf	Member
European Network High Performance Integrated Microwave Photonics	Dr. T. Tekin	German Representative
European Photonic Industrial Consortium (EPIC)	Dr. H. Schröder	Representative Fraunhofer IZM
European Technology Platform on Smart System Integration (EPoSS)	H. Pötter	Member Executive Committee
Forschungsfabrik Mikroelektronik Deutschland (FMD)	Prof. K.-D. Lang	Steering Committee
Heterogeneous Integration Roadmap (HIR)	R. Aschenbrenner	Chair Technical Working Group SiP
IEEE Electronics Packaging Society Photonics – Communication, Sensing, Lighting IEEE EPS TC Material & Processes IEEE EPS to Board of Governors	R. Aschenbrenner/Prof. K.-D. Lang Dr. T. Tekin Dr. T. Braun Dr. T. Braun	Fellow Technical Co-Chair Member Member
IMAPS International Microelectronics Assembly and Packaging Society IMAPS Europe/IMAPS Deutschland IMAPS Signal/Power Integrity Committee IMAPS Executive Council	Prof. K.-D. Lang Prof. M. Schneider-Ramelow Dr. Dr. I. Ndip Dr. Dr. I. Ndip	Fellow Past President/President Chair Director
IVAM Fachgruppe Wearables	E. Jung	Technical Chair
Organic Electronics Saxony (OES)	K. Zoschke, E. Jung	Representatives of Fraunhofer IZM
Photonics 21	Dr. R. Jordan	Board of Stakeholders
Photonics West Optical Interconnects Conference	Dr. H. Schröder	Chair
Semiconductor Manufacturing Technology Sematech	M. J. Wolf	Member
SEMI ESiPAT Group	Dr. T. Braun	Representative of Fraunhofer IZM
SEMI Europe Award Committee	Prof. K.-D. Lang	Member
Silicon Saxony e. V.	M. J. Wolf	Member
SMTconnect	Prof. K.-D. Lang	Head of Programme Committee
Strategischer Arbeitskreis Silicon Germany	Prof. K.-D. Lang	Member
Wissenschaftlich-technischer Rat der Fraunhofer-Gesellschaft	Dr. N. F. Nissen	Representative of Fraunhofer IZM

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PUBLICATIONS (SELECTION)

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WWW.IZM.FRAUNHOFER.DE

Schambeck, S.; Hutter, M.; Jaeschke, J.; Deutinger, A.; Schneider-Ramelow, M.
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Antenna Apparatus Having Bond Wires
EP 3 346 546 A1

Ndip, Ivan
Ribbon Bond Antennas
US 10,566,679

* The German patent title was translated into English. In the original the name is as follows: Mobiles optisches Analysegerät.

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Hermetic glass package with TGVs for a radar fill level sensor with an operating frequency of 160 GHz (the GlaRA project was sponsored by the Federal Ministry of Education and Research)