Fraunhofer IZM

Annual Report 2021 / 2022

Researched for Practice, Developed for Reliability

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»Research keeps you motivated. That is the force of nature behind our successful business year.«

Prof. Martin Schneider-Ramelow
Acting Director of Fraunhofer IZM

Content

Preface

Dear Readers!

New goals to aspire to and new ways of thinking: That was the theme of 2021. It was a year that swung back and forth from the experience of a global pandemic and other worldwide challenges and humanitarian crises to optimism inspired by unexpected discoveries and a reborn spirit of community. This optimism carried all of us at Fraunhofer IZM through the second year shaped by the Coronavirus. Our laboratories remained open and active for research and development even under difficult circumstances. Fraunhofer IZM has continued to find solutions for the great challenges of the digital revolution and shaped important social and technological trends – not least in terms of quantum and neuromorphic computing, green ICT, the new 5G and 6G mobile communications standards, trustworthy electronics, and bioelectronics for medical technology.

Looking back at the year behind us, we can see a great number of exceptional developments and projects at our Institute:

- With the support of the Senate of Berlin, we have set up the Quantum Packaging Lab and contributed to other quantum projects that have taken us an important step closer to applied quantum technology with its potential to reshape our future lives.

- Two flagship Fraunhofer projects, ZEPOWEL and eHarsh, were brought to a successful conclusion with the contributions of Fraunhofer IZM. This included the development of extremely energy-efficient and modular IoT nodes that can help rein in the power needs of fast-growing node-based infrastructures.
- Our researchers and their partners on the GlaRA project, with the support of the Federal Ministry of Education and Research, have shown that even small to medium enterprises can realize high frequency applications with a glass package platform that uses glass interposers.
- On the EU project PolyCE, the experts here at the Institute have been supporting the exploration of a truly holistic circular economy for the synthetic materials used in electrical and electronic devices. Their recommendations for effective plastic recycling were presented at the end of the project to Frans Timmermans, EU Commissioner for Climate Protection and Vice-President of the EU Commission.
- The Omniconnect project, funded by the Ministry of Education and Research, has developed a 60 GHz radar module for medical and care technology to help detect the placement of people and objects in residential homes and help older or frail patients navigate their lives independently.
- Sensor transponders equipped with antennas, microbatteries, and microsensors were designed on the Sens4Bee project: The autonomous sensor systems are planned for use in tracing how different environmental factors affect the behavior of humanity's greatest insect friends: Honey bees.
- Numerous client workshops helped bring together our researchers with partners from industry, including the hit online workshop series on »Advanced Packaging: Simulation, Technology, and Reliability«, which was a particularly rewarding activities that attracted several hundred participants.
- And last, but not least, the new Textile Prototyping Lab could be formally launched in September 2021 in cooperation with the weißensee University of the Arts Berlin. It will help us expand the smart textile activities at our Institute.

None of these technological feats would have been possible without the many domestic and transnational partnerships. All meaningful research is a team effort. This makes me even happier about the many years of productive cooperation between our Institute and the Key Research Area Microperipheral Technologies at the Technical University of Berlin. Two new professorships were formally introduced there in 2021 and are scheduled to be staffed in 2022. Alongside our cooperative academic work in Berlin, our partnerships with the Technical Universities of Dresden, Cottbus-Senftenberg, and Delft have also become increasingly important for us. At Cottbus, we were able to launch the iCampus2 project as an innovation hub with the support of the Ministry of Education and Research, followed by several new projects in the field of high frequency sensor systems. Our Dresden site, Fraunhofer IZM-ASSID, has also intensified its work with the Center Nanoelectronics Technologies (CNT) of Fraunhofer IPMS. The synergies gained from this have already led to new insights and excellent results concerning heterointegration technologies on 300mm wafers, e. g. refining the interposer technologies with passive and active components.

2021 has also been a year of looking forward at the Institute itself as well: The hard facts show how resilient we have become at Fraunhofer IZM as a result of facing the challenges of the COVID-10 pandemic. We welcomed new experts and increased our numbers to more than 300 people (and 132 students). Our operating budget has grown by about EUR 3 million to more than EUR 42 million, with an exceptional share of more than 40 percent coming from direct industry partnerships. Our Dresden colleagues deserve a special mention here for the sheer variety of their industry-driven research.

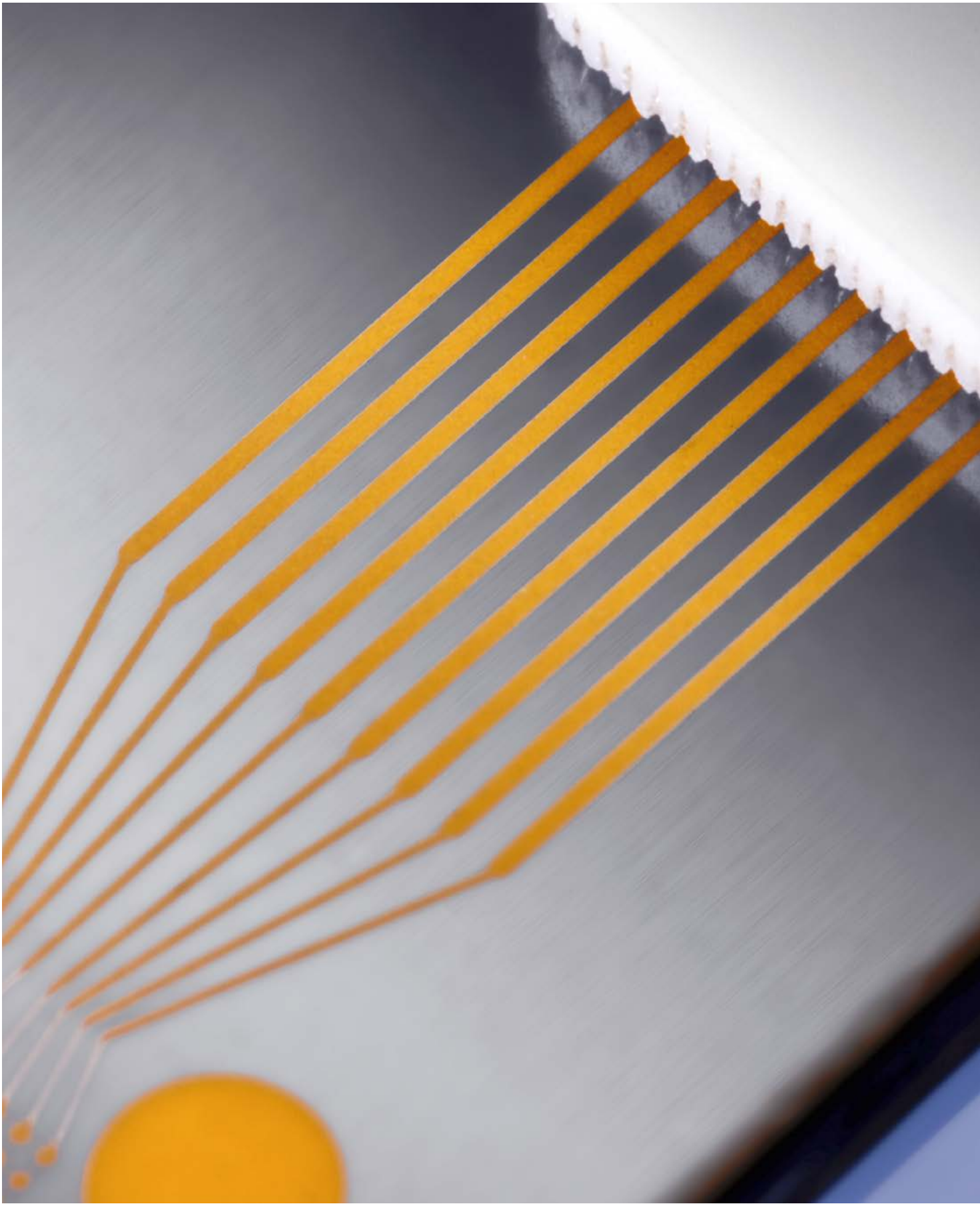
My personal and special thanks go to the extremely motivated people of Fraunhofer IZM: In a time of constant worries and challenges, they could be relied upon to find new impulses, turn their visions into actual reality, and show how we all can learn from each other. Be it in our offices in the Institute or at home, be it in our laboratories, during the SAP introduction or at Start-A-Factory: Thank you so much for your great work!

And it would be remiss of me to forget all of our partners in academia and industry, our supporters in federal and state government, and the sponsors behind our projects.

It would be easy to expect that we all want to return to normality now. But instead, I actually wish for even more energy and the strength to face our future with confidence, verve, and a critical mind – in a dialogue with each other, in research, and in new and inspiring ideas.

Enjoy our annual report!

Martin Schneider-Ramelow
Director



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 438 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.

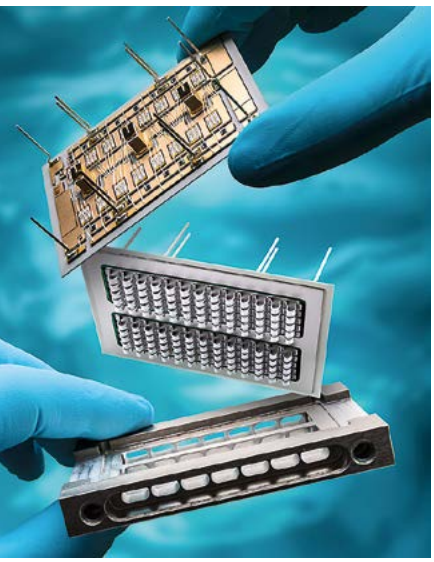
Contract research

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.

System Integration & Interconnection Technologies



Half bridge module for a directly cooled AC/DC converter for a Formula 1 car

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.

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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 80 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
- Thin wafer processing and integration technology
- Heterogeneous Integration
- Wafer-level packaging, fine-pitch bumping and interconnect technologies
- Hermetic MEMS and sensor packaging
- High density flip-chip assembly
- Sensor development and integration
- Hybrid photonic integration
- Photonic and plasmonic system development

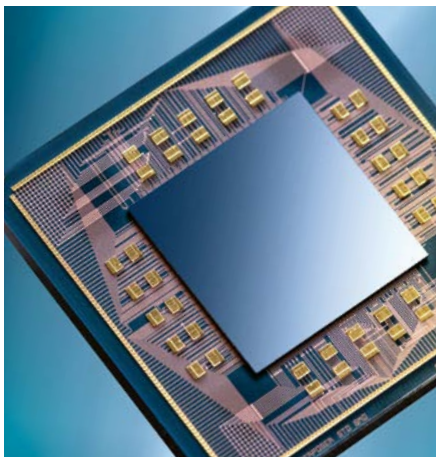
At both sites, the department operates leading-edge process lines that permit a high degree of processing flexibility, particularly for 200 – 300 mm wafers. The lines are characterized by a high adaptability and compatibility between the individual sub-processes and are particularly equipped for production-related 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/nano interconnect and pillar bumps with solder cap (Cu, SnAg, CuSn, Au, AuSn, In, InSn, nano-porous Au)
- Pre-assembly (thinning, thin wafer handling, laser grooving, laser dicing, plate dicing)
- 3D assembly (D2D, D2W, W2W)
- 3D wafer-level stacking
- Wafer bonding, direct bond interconnects (DBI) - W2W (12"), (adhesive, soldering)
- 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.



Trial interposer used to verify the designs and functionality of the Risc-V process developed in the USeP project using 22FDX® technology

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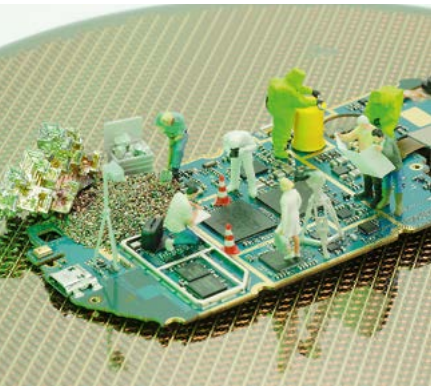
Environmental & Reliability Engineering



Environmental and reliability tests are an indispensable part of new tech developments at Fraunhofer IZM

Reconciling progress in microelectronics with the needs of our environment has become a key priority in the industry. Fraunhofer IZM is a pioneer in this field. The »Environmental and Reliability Engineering« department has been supporting new technical developments and the innovation of more sustainable, durable, and greener electronics for over two decades. With its unique combination of environmental performance and reliability checks, the department can offer services in the areas:

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

Our interdisciplinary team develops processes and models and supports our partners in integrating environmental and reliability criteria in the design and development process. We can help identify weak points and untapped potential at an early stage in the introduction of new technologies, materials, processes, components, and applications and find suitable solutions for our partners.

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.

The environmental footprint of actual products and of the fundamental technologies that make them possible has gained considerable salience in the industry. We are also assisting suppliers and smaller enterprises in defining and meeting specific climate and 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, tailored specifically to the given use case, offer new pointers for optimization for the relevant parameters (such as the materials, geometries, and process design) to achieve the new reliability standards expected in the supply chain and in actual use.

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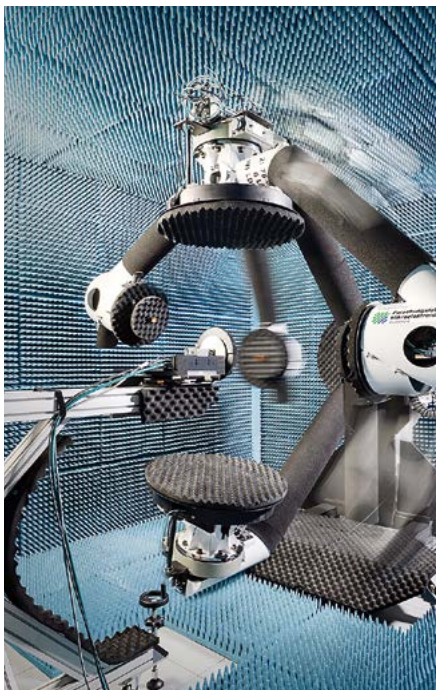
RF & Smart Sensor Systems

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, antennas, and components (up to 220 GHz)
- RF system integration and module design with particular attention to signal and power integrity
- Development of highly integrated radar sensor systems
- Design and construction of autonomous wireless sensor systems for industrial use
- Development of microbatteries and power supply and power management systems for autonomous devices
- Tools for the optimized design of microsystems and server-client software architectures for IOT applications



Automated antenna measuring station for near and far-field measurements at up to 325 GHz

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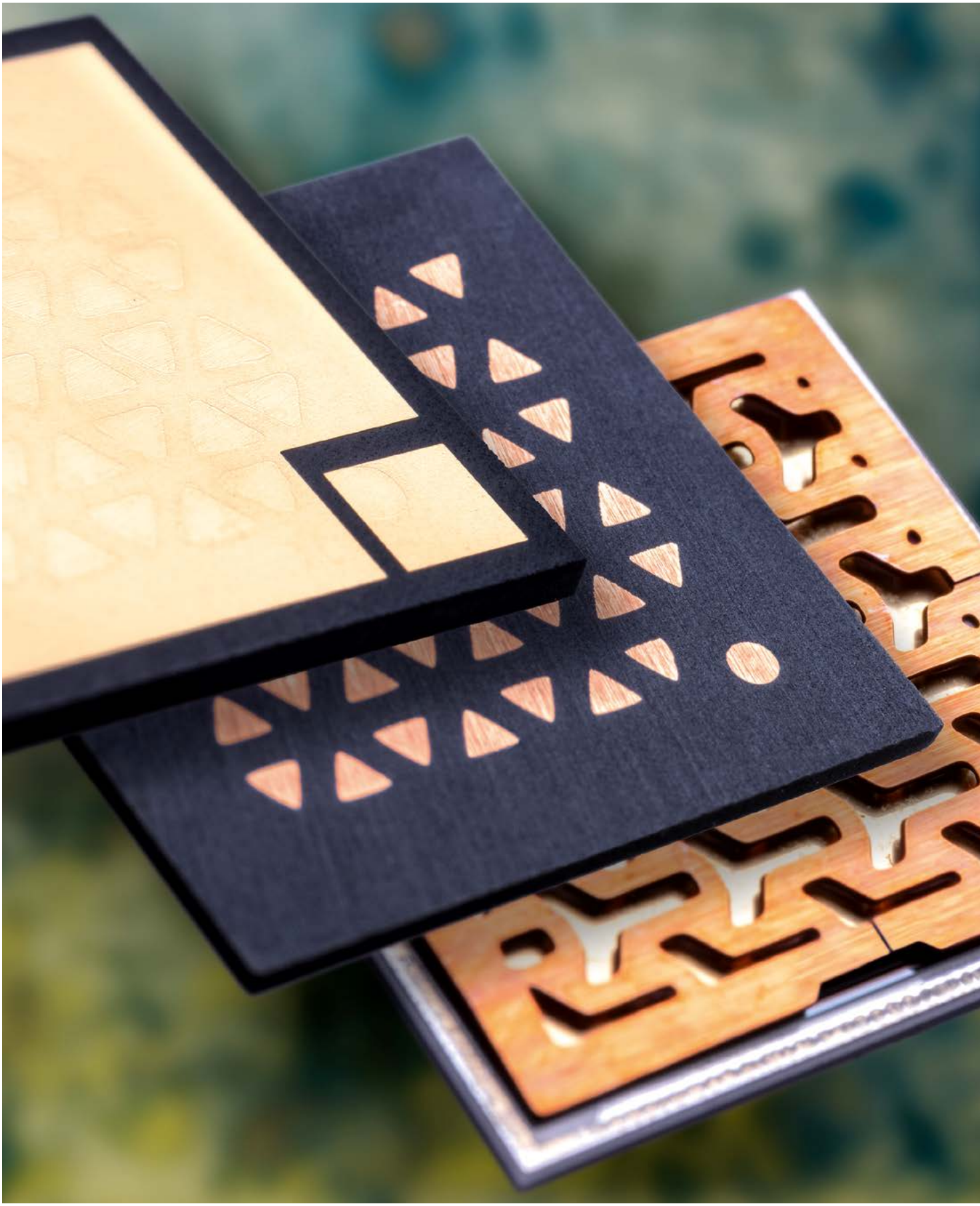


Fraunhofer

A Strong Network

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from 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.

For the modernization and extension of their equipment the 13 research facilities received around 350 million euros from the Federal Ministry of Education and Research during the start up phase.

In 2021 FMD started steady operations and now provides a One-Stop-Shop, combining the scientifically excellent technologies, applications and system solutions of the cooperating institutes in the field of micro- and nanoelectronics.

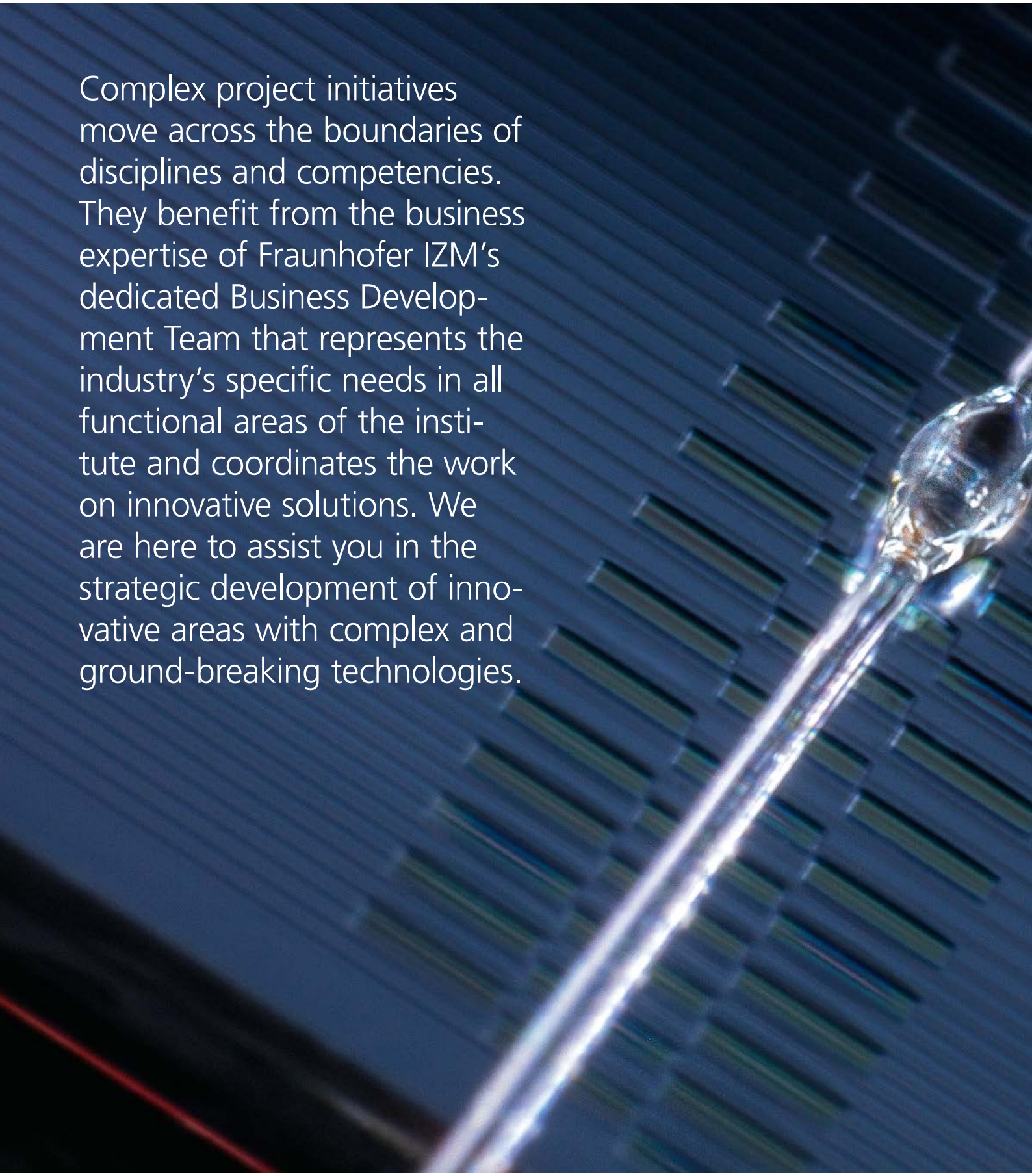
The activities of the Fraunhofer Group for Microelectronics and the FMD are coordinated by the joint office in Berlin.

High-performance Centers

The High-Performance Center »Functional Integration of Micro- / Nanoelectronics« supports SMEs in Saxony with know-how in 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-ASSID, as well as the Technical Universities Dresden and Chemnitz and the HTW Dresden are members of the Center.

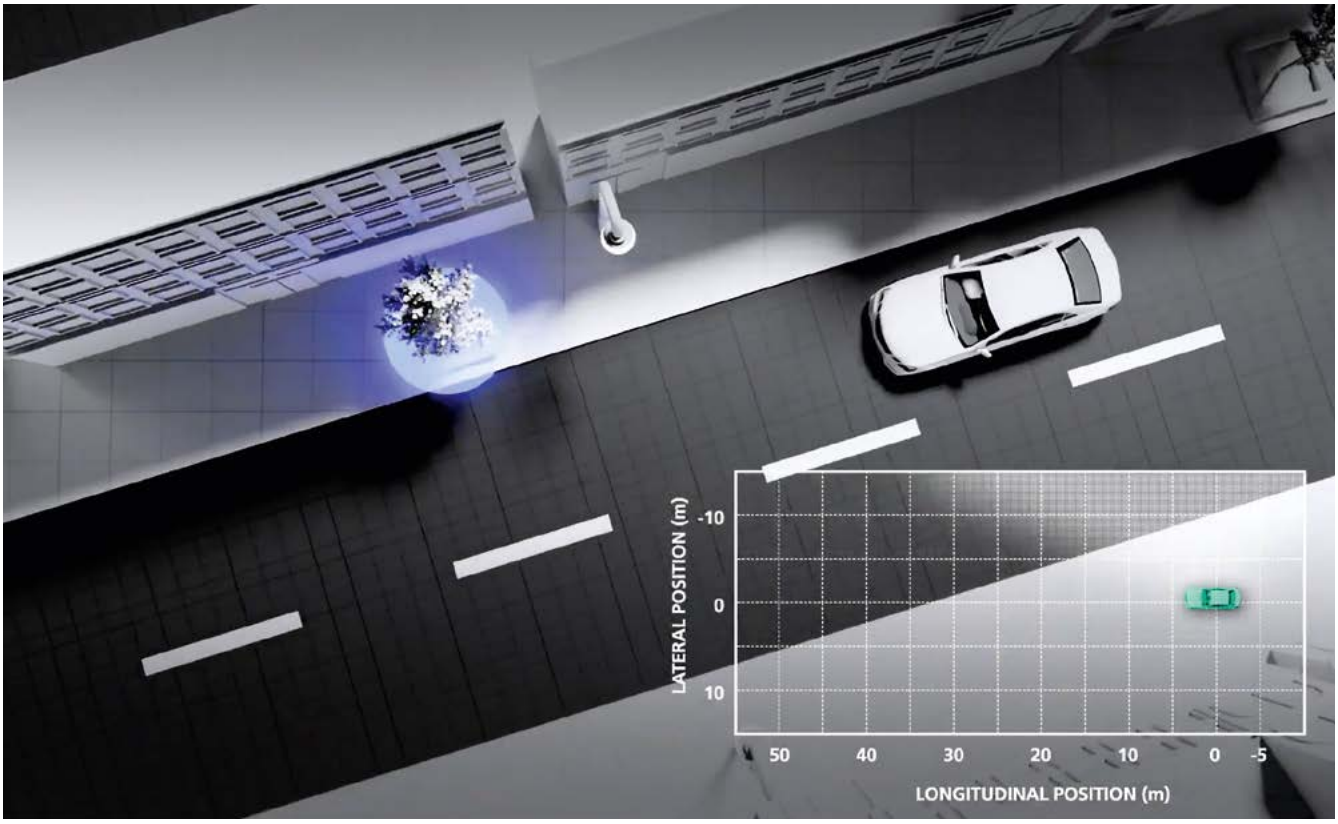
The »Berlin Center for Digital Transformation« is a collaborative venture involving the four Berlin-based Fraunhofer institutes FOKUS, HHI, IPK und IZM. Its work focuses on technologies and solutions that advance increasing digitalization and networking in all areas of life.



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.

Business Units & Industry Sectors

Automotive and Transportation



Cameras and radar for a safer time in traffic

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.

Test environment for robust and durable wireless communication

In industry or the smart cities of the future, wireless communication (5G and 6G) components need to be operational over many years even under harsh environmental conditions. A new test environment was created to help establish the necessary reliability already at the design stage. It uses the specific lifecycle data for different polymers that could be used as carrier materials for high frequency antennas, but may be affected by thermal stresses. The demonstrated workflow includes tests and simulations, and can be used to design long-lasting and reliable antenna functionality.

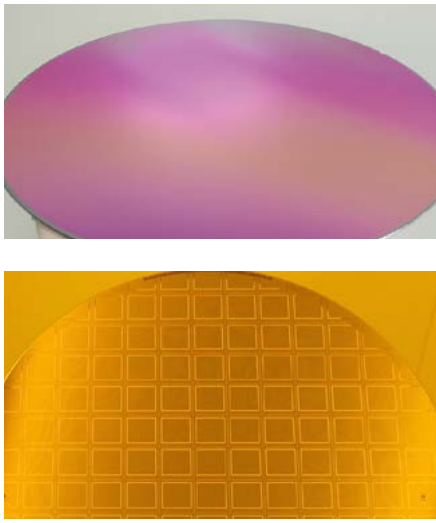
AI-driven self-validation of critical electronic systems

The SesiM project on »Self-validating complex electronic systems in safety-critical mobility applications based on greybox models« is pursuing an AI-based state monitoring technology to ensure the optimized operation of automotive and rail systems. Its concept relies on digital fingerprints of mechatronic assemblies that can respond proactively to aging and other critical changes that can affect operational safety. It captures and processes the changing effects of manufacturing processes and different material properties, external and internal stresses in actual operations and state monitoring sensor data, and uses these datapoints to form an innovative model.

Funded by the Federal Ministry for Economic Affairs, the project was formally launched on July 1, 2021, with partners including Siemens AG, Robert Bosch GmbH, AUCOTEAM GmbH, GÖPEL electronic GmbH, GESTALT Robotics GmbH, and the University of Stuttgart.

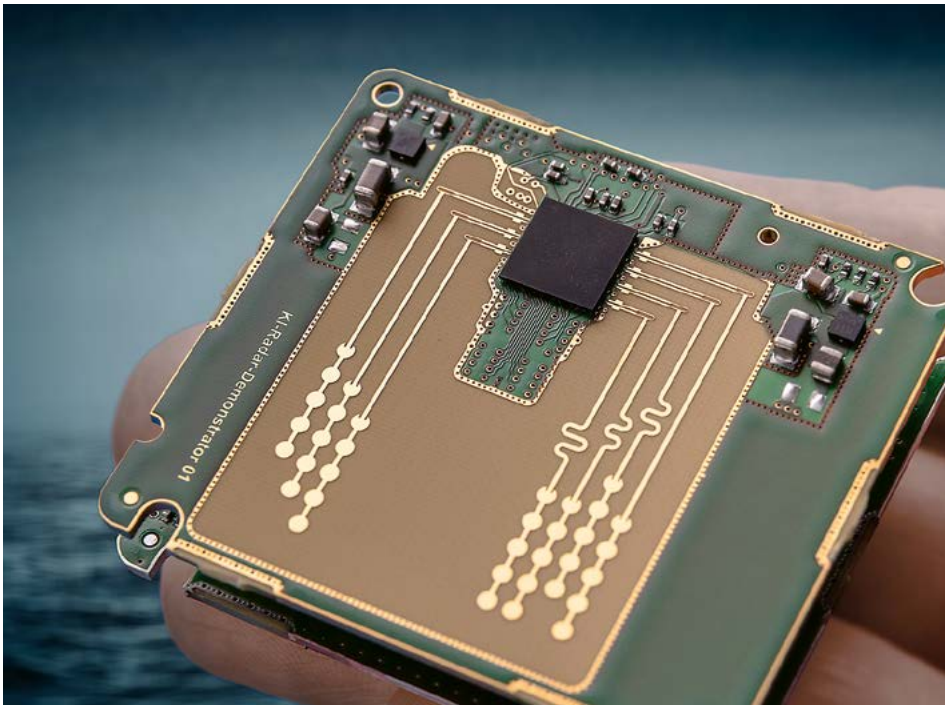
Wafer-level packaging-processes for the cost-efficient production of infrared cameras

For the EU project APPLAUSE, Fraunhofer IZM is developing wafer level packaging processes for the hermetic vacuum encapsulation of large MEMS pixel arrays for infrared thermal sensors used in automotive safety applications. Gold-tin bonding rings ensure the reliable encapsulation of the 200 mm wafers and compatibility in later processing stages. Wafer caps, frames, and lids are constructed in silicon with antireflective coating for improved optical performance. Bolometer sensor wafers with tiny and very thin MEMS membranes (pixels) are post-processed to integrate the sealing rings and capping components by wafer bonding prior to being stacked and sealed.

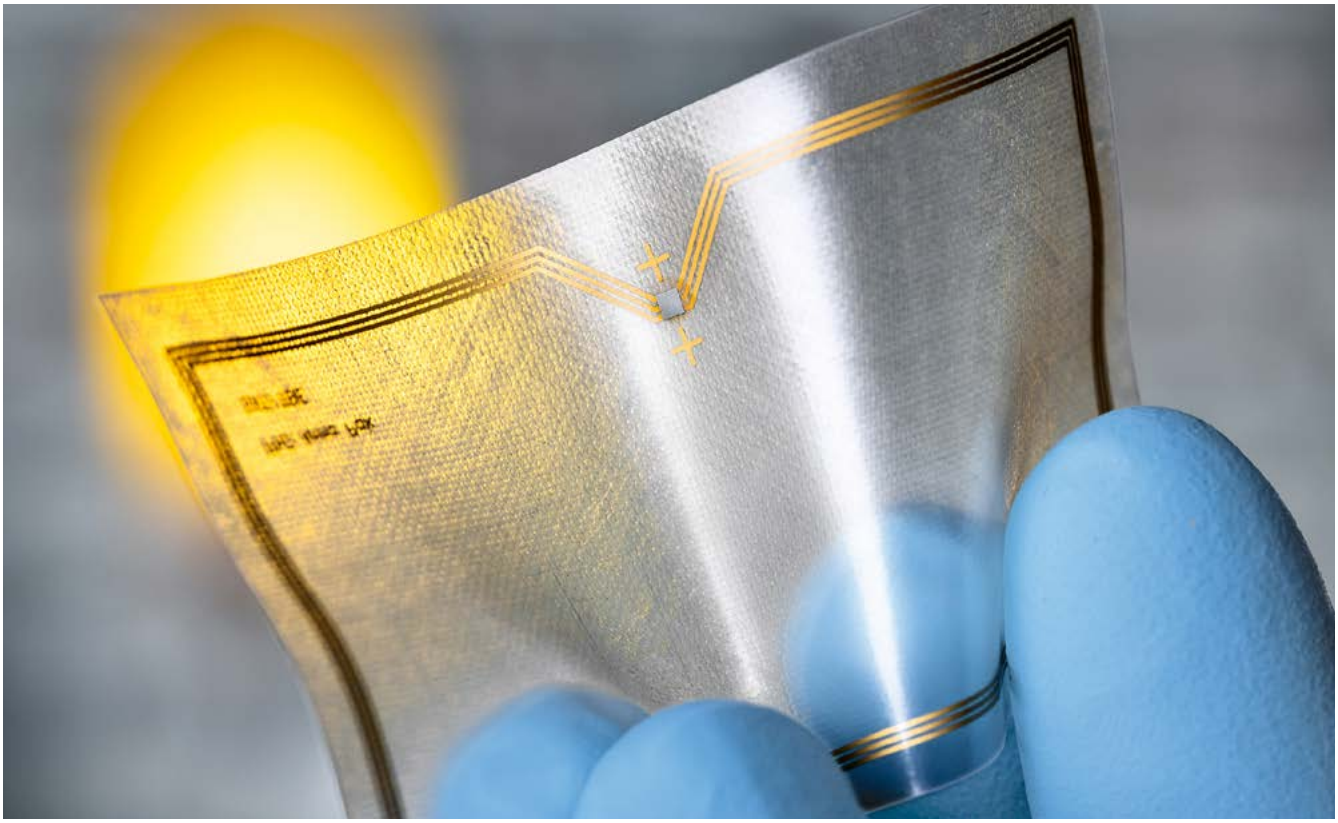


A 200 mm cap wafer encloses the sensors in a vacuum to lay on an antireflective coat (APPLAUSE)

Frontend for a high-resolution radar system with AI support for processing data for cooperative autonomous driving



Medical Engineering



A means for the wireless charging of flexible implants with integrated electronics to interface with neural tissue.

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.

Powering microimplants by ultrasound

As medicine is looking into substituting its traditional pharmaceuticals with electroceuticals, bioelectronic medicine is using implantable devices with electronic components that are able to stimulate and record activity from the peripheral nerves. Delivering energy to small active implants that are located deep inside the body remains an unresolved challenge, but Fraunhofer IZM is developing a unique platform for the EU project Moore4Medical that uses ultrasonic waves to wirelessly deliver power to and communicate with deep implants. In particular, micromachined ultrasound transducers, as opposed to traditional piezoelectric crystals, are used. These allow for miniaturization, do not contain any toxic materials, and are compatible with CMOS electronics and their processes.

Implantable cuff for the ultrasound neuromodulation of peripheral nerves

Ultrasound is emerging as a new technology for modulating neural activity. By contrast to more conventional electrical neuromodulation, ultrasound has the power to interact with human tissue with better spatial resolution. Its exceptional accuracy allows it to focus on structures as small as a single neuron and promises far greater specificity in neuromodulation therapy. For the EU-funded Moore4Medical project, Fraunhofer IZM is developing and characterizing an array of miniature, micromachined ultrasound transducers (MUTs), embedded in flexible substrates and fitted on an implantable cuff for the ultrasound neuromodulation of peripheral nerves.

Using radar technology for the care and support of dementia patients

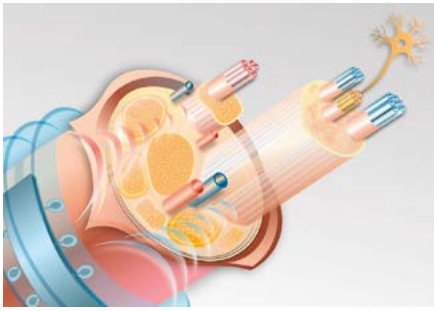
The aim of the BMBF-funded project is to provide custom support for people affected by dementia. The unique table developed for the project communicates with its users by word, image, and sound. The backbone of this approach is a radar system that recognizes the user's movements and gestures and responds according to the situation. A frequency-modulated continuous wave (FMCW) radar has been combined with a multiple input/multiple output (MIMO) technology to enable it to detect gestures. The reduced detection range allows the high resolution required to track speeds, angles, and distances, and an optimized signal-to-noise ratio (SNR-ratio) ensures better target detection.

Origami F²E – Free form electronics

To produce 3D electronically functionalized components and surfaces, films are printed and configured in two dimensions, before being given their final three-dimensional shape by industry-grade thermoforming and back-molding processes. This novel concept for integrating electronics gives polymer processing enterprises completely new application options beyond the traditional circuit board. For the »F²E – Free Form Electronics« subproject of the »Origami« cooperative project funded by the Ministry of Education and Research, Fraunhofer IZM has developed new packaging and interconnection technologies that can fulfil the special requirements of thermoplastic substrates, specifically the issue of temperature stability in the tough conditions that the systems would experience during manufacturing.

Glass-interposer for photonic packaging

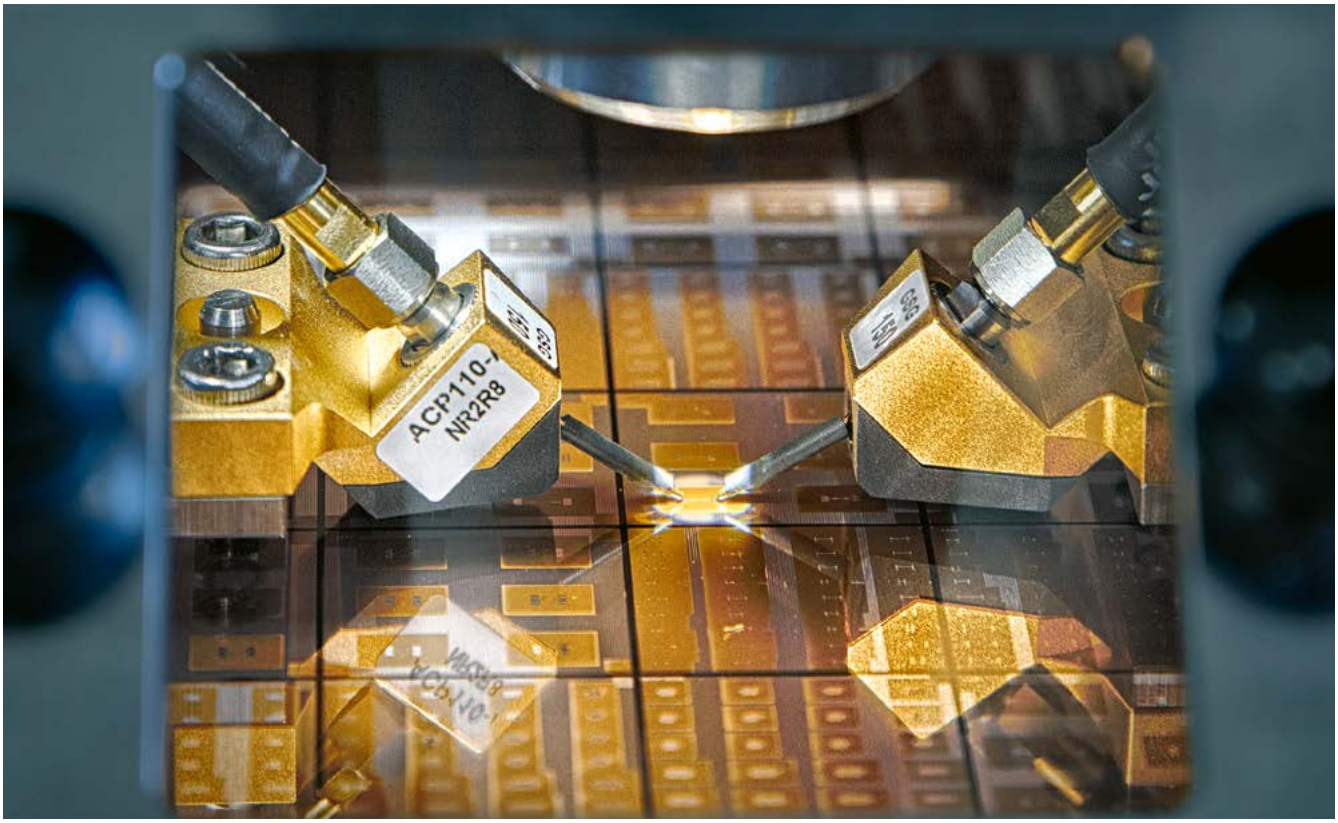
PhotonicLEAP, a European Horizon 2020 collaborative research project, is exploring disruptive technologies that will drive down the cost of integrated photonic packaging and testing processes. Fraunhofer IZM is contributing to the project by investigating thermal TGVs and developing and producing novel functionalized thin glass interposer wafers. Currently designed at 200 mm in diameter and planned to scale up to 300 mm, these will serve as a glass substrate for embedding optical PICs and driver ICs. All optical, electrical, and thermal coupling are provided on the wafer level. Laser-structured thin glass is again used to seal the new photonic packages for easy integration as SMT components, common in electronics designs.



top:
Delivering power to microimplants by ultrasound

bottom:
A speaking table to facilitate care for dementia sufferers

Semiconductors



Electrical characterization of substrates and components up to 500 GHz at temperatures from -40 °C to 180 °C

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.

RoDosH – Investigating the impact of humiduty diffusion in sealed housings

The microclimate in system enclosures is elementary in the investigation of defects that may be attributed to humidity, but there remains a lack of reliable information about the microclimatic conditions inside electronic housings.

The aim of the RoDosH project is to investigate the local microclimate in packages for power electronic applications and to understand the effective local loads and stresses, with particular focus on temperatures and humidity, but also consideration for storage conditions. The work on this project intends to allow the simulation of the interior climate of a system under development, even before first testing is possible. Its findings would provide a basis for optimizing test conditions in order to be able to make relevant lifetime estimates for power electronics in sealed housings.

This project was supported as part of the ECPE joint research program.

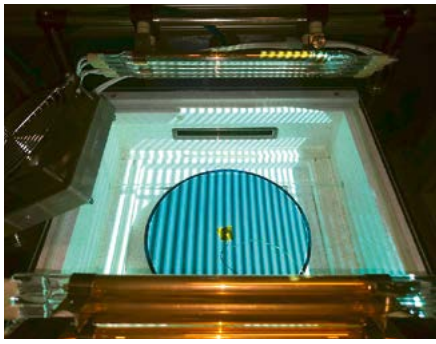
SiC-interposer with through silicon carbide vias

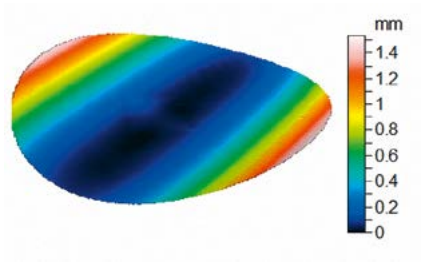
Research and development efforts have been intensifying in the field of silicon carbide (SiC) components in recent years. One force fueling this trend is the evolution of the automotive and energy markets with its demand for new and advanced approaches for integrating SiCs.

The established integration concepts for silicon chips can be adapted to SiCs to tap into the superior electrical and mechanical properties of SiCs when compared to silicon. Electrical vias in SiCs – called through silicon carbide vias or TSiCV – are fundamental for the development of new SiC 2.5 and 3D integration concepts.

Validated warpage modelling for fan-out wafer level packaging

The production of fan-out wafer level packaging is a multi-step process. In that process, the combination of different materials creates intrinsic stresses that can cause warpage in the affected wafers. New materials testing (pTMA) procedures were integrated in the simulation workflow for technology concepts to model these warpage effects and predict how wafers change in terms of shape and size during the essential processing steps. Using these insights, designs can be assessed and optimized in terms of chip placement and the choice of materials.

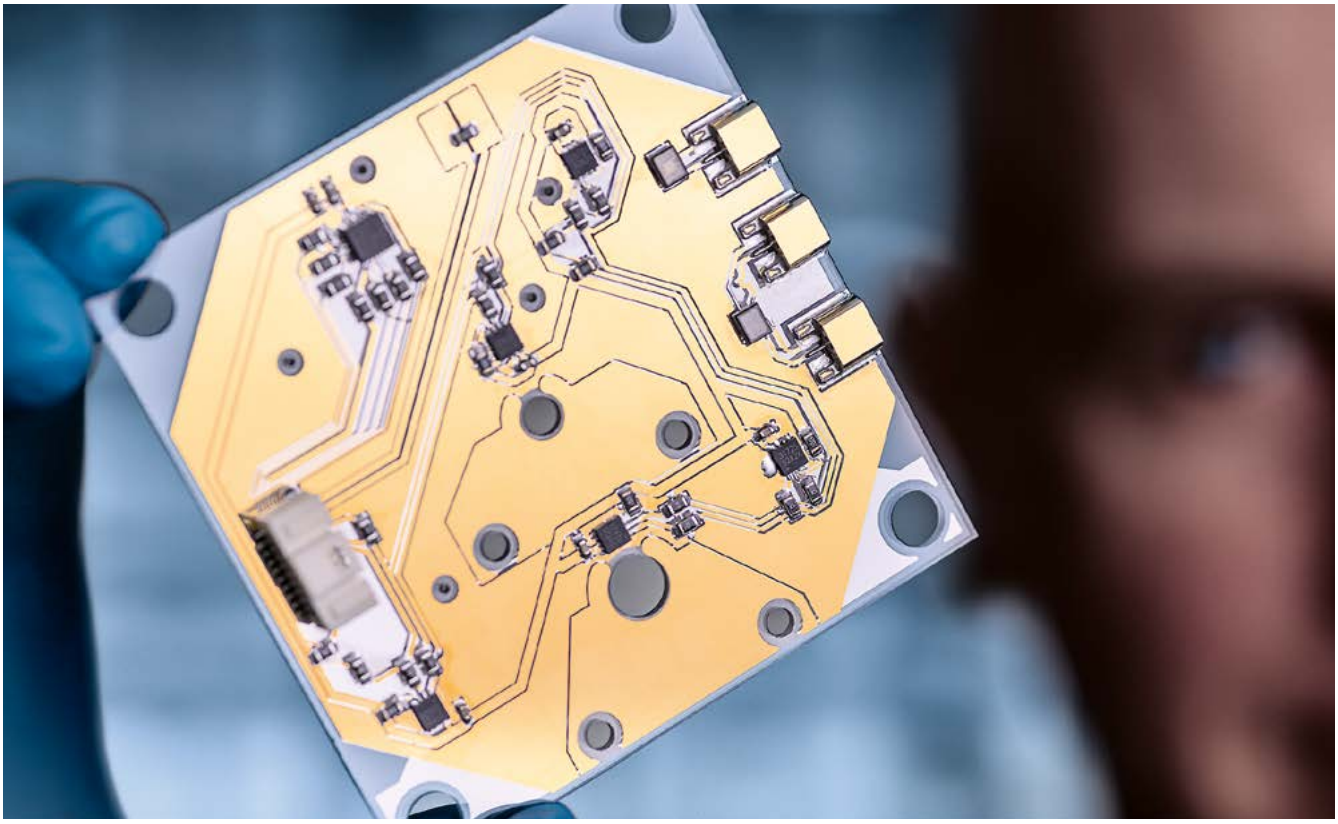




top:
Analyzing the heat deformation of a molded Si wafer with the Shadow-Moiré method

bottom:
An EMC-encapsulated wafer deformed after exposure to heat

Industrial Electronics



Optical and electrical functionalization of glass for LiDAR applications

In recent years Fraunhofer IZM's industrial electronics specialists have concentrated on the visionary concept of 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: 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.

Process development for Industry 4.0 manufacturing environments

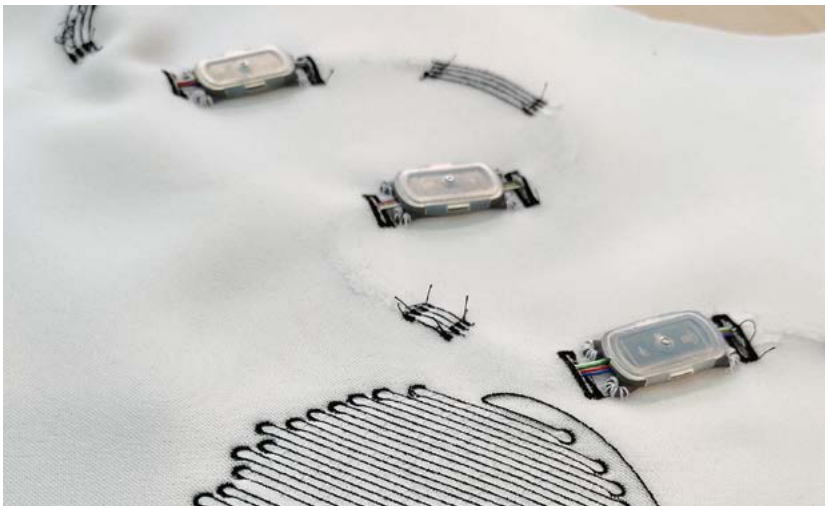
Inline or integrated sensors are used for SMD assembly in the SiEvEI 4.0 project, run by Fraunhofer IZM with its partners Siemens, Wibu-Systems, Sensorik Bayern, Wagenbrett, and the University of Bielefeld and supported by the Ministry of Education and Research. Its aim is to track product quality during process development and actual manufacturing operations in order to find and introduce potential improvements. A combination of expert know-how and process data, aided by AI/machine learning processing, allows knowledge-driven, automated process optimization in several relevant processing phases that can capture and include even indirect forces at work. The approach was modelled at Fraunhofer IZM for the balling processes of its project partner Wagenbrett.

Highly robust sensor technology for monitoring wastewater

Illegal discharges into wastewater systems not only cause environmental damage. They also entail massive financial burdens for system operators. In the European project "SYSTEM", a network of decentralized sensors was set up with 24 partners from 7 countries, the data from which are made available to police authorities and supply network operators through a real-time monitoring system. The task of Fraunhofer IZM, working with the Warsaw University of Technology and the company Blue Technology, was to provide a sensor system that can measure pH and conductivity autonomously in sewers for 14 days and transmit the data wirelessly to the monitoring system.

Packaging solutions for underwater applications

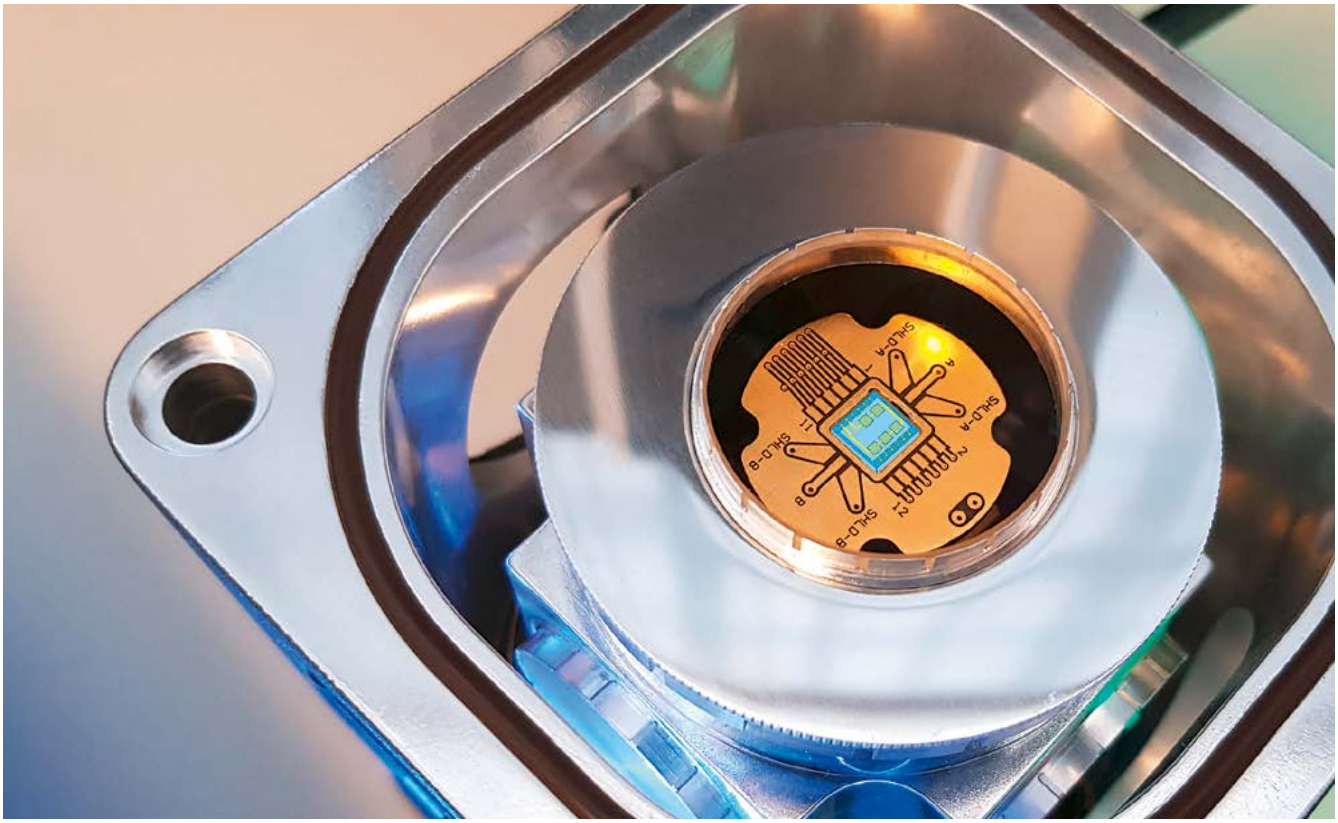
For the RoboSkin project supported by the Federal Ministry of Education and Research, Fraunhofer IZM researchers have developed a modular, pressure-neutral case design for maritime sensors. The system is used on the BOSS Manta Ray AUV (Autonomous Underwater Vehicle) by EvoLogics, integrated in special textiles made by TITV Greiz. The embedding technology is used to apply sensor systems with a range of functions, including pressure and orientation sensors or position lights. The resulting sensor skin can be easily reconfigured by simply swapping out the detachable sensors from their electrical and mechanical interfaces. Rapid manufacturing means that the systems can be produced at commercially viable prices in even small or medium production runs. Material analytics were used to optimize the designs for the required level of reliability by testing the materials' and cases' performance when immersed in water. For the DeepSea Protection project launched in 2021, the embedding and enclosure solutions for the pressure-neutral packaging are being refined for use in depths of 6,000 m.



left:
Autonomous sensor system for monitoring environmental conditions in sewers

bottom:
Current case design for a Bionic RoboSkin sensor skin mounted by Fraunhofer IZM's project partner TITV

Information and Communication



Cryo measuring system with a plan of the test chip

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.

Cryogenic integration technologies

The »Semiconductor-based quantum computing« (HalQ) project is developing and characterizing the components for a compact superconductive packaging technology for extremely low temperatures (cryo packaging). The necessary indium bumping process for pitches below 10µm is well established at Fraunhofer IZM. For the project, the ferromagnetic nickel bumps are replaced by copper to reduce potential interference by electromagnetic fields. For the super-conductive interposer, niobium and niobium-nitride are deposited, and conducting lines constructed for electrical tests. A cryo measuring station allows the characterization of circuits at temperatures below 4K for use in quantum computing.

Integration platform for low-cost 5G and radar system

In the European SERENA project, an RF platform for next-generation mobile communications (5G) and radar systems was developed together with nine other partners from six countries. The project pushes the boundaries for established semiconductor technologies by developing low-cost gallium nitride-on-silicon (GaN-on-Si) and silicon-germanium (SiGe) components, heterogeneous packaging technology, and an integration platform for ultra-high frequency radio wave systems. The SERENA architecture and platform bring significant improvements in terms of energy efficiency, cost, and functionality. Fraunhofer IZM was responsible for the RF design and the manufacturing and testing of the system integration platform.

Preparing for ecodesign regulations for cellphones and tablets

When deciding on ecodesign policy, the European Commission relies on the expertise of industry experts. Fraunhofer IZM is one of these expert sources and contributes know-how for mobile phones and tablets to help define standards in terms of repairability, software updates, reliability, and environmental effects in the supply chain. By the end of 2022, this preparatory work will lead into new regulations, including energy efficiency labelling, that are expected to bring significant energy, resource, and cost savings for end users.

Environmental effects for German mobile communications networks

The UTAMO project of the German Environmental Agency calculated the energy and resource consumption of the country's mobile communication networks, with 2019 chosen as the baseline year. The insights gained from these were used to predict several possible scenarios for developments until 2030. Fraunhofer IZM produced a complex calculation model in the project's runtime from January 2019 to November 2021 that quantifies the annual environmental impact of all mobile communication technology in production and active use.

Complex packaging solutions for the transceiver market

Fraunhofer IZM can draw on substantial expertise concerning high frequency design and signal integrity. One specific application of this is the institute's work on complex packaging solutions for the fast-growing transceiver market, where signal integrity is of essential relevance. Designs can be modelled for anything from simple electrical connections to highly complex interconnection approaches, including wirebonding or bumps between substrates, with the ability to cover the electrical behavior of transceiver packages up to 100GHz

Fiber access for 6G IoT (60GHz) devices via radio over fiber (RoF)

As the demand for bandwidth keeps increasing, there is an urgent need for new and more sophisticated solutions to access networks. Fiber communication systems such as "Radio-over-Fiber (RoF)" feature low attenuation, high bandwidths, and low latency. They combine modulated laser light (for high transmission bandwidths) with antenna communication systems wirelessly. Fraunhofer IZM is working on low-cost analog RoF architectures, ranging from solutions using standard commercial components to more complex miniaturized devices, where the entire systems are integrated into Photonic Integrated Circuits (PICs). Modelling, adjustments, and empirical trials are used to optimize data rates, channel cross-talk, latency, cost, and power consumption.

The European SERENA project has developed a high-frequency platform for mobile (5G) communication and radar systems

Labs & Services

System Integration

Wafer-Level Packaging Line 8" – 12"

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 12")

- Cu-TSV integration (via-middle and via-last-processes)
- Silicon and SiC plasma etching – DRIE (TSV, cavities)
- Multilayer thin-film deposition (PVD, CVD, ECD, lithography (resolution up to 0.5 µm), mask aligner, 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, Cu-Demascene)
- Wafer-level bumping (Cu-Pillar, SnAg, Ni, Au, In, UnSn, AuSn, Cu-nano interconnects, nanoporous Au)
- 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 metrology for layer thickness, topographies, roughness as well as TTV/warpage/bow
- Fully automated electric wafer measurement system (8"/12")

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.

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. Track geometries with down to 2 µm width are under development.

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

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 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-Pérot 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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Events & Promoting Young Talents

Not what any of us expected!

After we thought that 2020 was the year lost to COVID-19, we were all looking forward to meeting our clients and partners again, live and in person, at workshops, expos, or conferences to share about our work and our experiences.

But the pandemic had other plans for us. It meant that the team at Fraunhofer IZM had ample chance to perfect its online presence in a number of digital IZM events. We had an inkling of it in 2020, but this year gave us final proof: online formats are not taking away, but actually giving us more contacts with potential partners in Europe and overseas.

The next pages will look back at a selection of the events hosted by Fraunhofer IZM or attended by our colleagues in 2021. There is a surprising number of workshops and seminars run by us compared to other years. And eventually, we also had events that could be held in person, such as the Girls' Day in August 2021. For the new year, we are all hoping for more of the same again.

Events

Much to discuss at the Ecodesign Learning Factory

Online seminars through the Corona crisis

The series of online expert sessions »Advanced Packaging: Simulation, Technology, and Reliability« introduced Fraunhofer IZM and many aspects of its technological work to new audiences. The events were an opportunity to showcase the latest research and opportunities for new applications or developments in industry or in joint projects. Every 45-minute session from January to May 2021 was joined by more than 100 interested participants from worldwide industry, science, and the economy. Topics included green electronics, reliability assessments, and panel-level packaging.

»IZM Photonics: IN GLASS WE TRUST«: Successful acquisition with digital expert sessions

The IZM group »Optical Interconnection Technologies« continued the digital expert sessions in 2021, with an online meeting every three months given over to a specific topic each under the umbrella topic of »IZM Photonics: IN GLASS WE TRUST«. In the brief sessions, the speakers showed the many capabilities of glass for photonic packaging and how they could be put to use by the participants in their industries or in joint projects with Fraunhofer IZM. The pre-recorded talks were also a hot on social media, with the session hosted by Dr. Wojciech Lewoczko-Adamczyk viewed several thousand times on YouTube.

Ecodesign Learning Factory – Circular Service Design

This two-day workshop explored means to envision and build the circular services of the future. Using diverse methods from fields like system thinking, service design, or speculative design, the participants were invited to work on a fictional scenario, define challenges, and find solutions for a specific industry. Intended for designers, industry professionals, product developers, environmental managers, business developers, and marketing experts, the workshop was facilitated by applied environmental scientists from the Technical University of Berlin and Fraunhofer IZM as well as design professionals from Fjord Berlin. 2021 saw two workshops, one online format in March, followed by a live event in September.

Sensor+Test as a press event

On May 4–6, 2021, Fraunhofer IZM took part in the online Sensor+Test 2021 expo as representative of the Research Fab Microelectronics Germany. Sensor+Test is considered one of the world's leading events in sensorics, measuring, and testing technologies. Participants could discover the Institute's entire portfolio in the

field of sensor systems, which brings together unique expertise along the entire value chain, from materials and processes, to system design, sensor system development, product integration, and sensor (system) qualification and reliability.

Electromagnetic compatibility for connected wireless systems

At the European EMC+SIPI 2021 symposium on August 4, 2021, Fraunhofer IZM teamed up with the University of Paderborn and KU Leuven for a workshop tutorial on »EMC for Emergent Wireless Systems«. The event focused on viable solutions for electromagnetic interference when using interconnected wireless systems or IWS. Such interferences are one of the principal hidden challenges for wireless connections and only become more critical when it comes to applications that demand particular reliability or safety, especially when moving to higher frequencies. The tutorial explored how more reliable and safer IWS can be made faster, but at still competitive prices, with a look at case studies in the field.

Panel Level Packaging Consortium 2.0

In 2016, Fraunhofer IZM teamed up with a group of industry leaders from Europe, the US, and Japan to develop the fundamental processes for new panel level packaging technologies that are ready to transition to industrial-scale high-volume production.

With the second consortium launched for 2020–2022, this focus has shifted to die placement and embedding technology for ultra-fine-line wiring down to 2 µm lines and space with a potential move to 1 µm. As such, migration effects and ways to exploit the migration limits of fine line wiring have become areas of interest for the consortium. The annual meet-up on August 18, 2021, brought together participants from all over the world for a two-day virtual event.

Events organized by Fraunhofer IZM (Selection)

Expert-Session-Series: Advanced Packaging: Simulation, Technology and Reliability	January until May, online
Workshop-Series: IZM Photonics: IN GLASS WE TRUST	February/May/August, online
Industry Working Group: System Reliability of Packaging and Interconnection Technologies	February/May/October, Berlin
Workshop: Ecodesign Learning Factory – Circular Service Design	March, online September, Berlin
PolyCE-Consortium Workshop: Circular Product Development – The Secrets to Design for and from Recycling	April, online
Industry Working Group: Compliance and Environmental Management in the Electronics Industry	April, online
Panel Level Packaging Consortium 2.0	August, online
5G User Forum	August, online
Launch of the Textile Prototyping Lab	September, Berlin
Webinar: Introduction to Multi-project Fan-out Wafer Level Packaging for EUROPRACTICE	October, online
Workshop: Reliability of Electronic Systems	November, online
eHarsh-Seminar	December, online

Launch of the Textile Prototyping Lab at Fraunhofer IZM

A two-wheeled charity challenge

The two cycling enthusiasts Ulf Oestermann (Fraunhofer IZM) and Carsten Homeyer (SAP) returned for a second time to the Nicola Werner Challenge. On September 11, 2021, they and thirty likeminded athletes assembled on Berlin's Alexanderplatz to start their marathon effort and collect donations for cancer research. Under a rainy and overcast Berlin sky, they still managed to ride for more than 100 kilometers before ending the challenge at the famous Victory Column. In total, they collected €1900 in donations for the German Cancer Research Center.

Stadtradeln – Cycling against climate change

Racking up as many kilometers as possible as a cycling team over a period of 21 days – that was the challenge accepted by 55 Fraunhofer IZM employees in September 2021. They swapped cars and trains for more self-propelled means of transport and covered no less than 16181 km, winning them a very respectable 28th place in the competitive ranking. »Stadtradeln« is a Germany-wide initiative that wants to get people out of their routines and onto their bikes: 80 percent of all German households own bikes, but rarely use them. What better occasion than doing so for a team effort? Every cycled kilometer can be tracked in a dedicated app, and routes can be recorded for later (anonymous) analysis by the Technical University of Dresden. The findings can be used by local authorities to optimize their cycling infrastructure and slowly improve the situation of cyclists in Germany.

SEMI Packaging Technology Seminar

On September 28–29, 2021, the SEMI Packaging Technology Seminar took place in Hof (Upper Franconia). Here, experts from the fields of semiconductor packaging, assembly, test manufacturing and design met to discuss and find solutions for the challenges facing the semiconductor industry, such as disruptions in the supply chain. Fraunhofer IZM presented recent research developments at the concurrent exhibition and IZM Group Leader Tanja Braun shared her insights on "Fan-Out WL/PL Packaging – a European Perspective for Advanced Packaging".

Launching the Textile Prototyping Lab

Fraunhofer IZM and the Weißensee Academy of Art in Berlin opened a unique open innovation lab for prototyping textile electronics. Fitted with the latest in high-tech equipment and machines, the Textile Prototyping Lab (TPL) can turn e-textile visions into real fabrics and garments with its interdisciplinary team of scientists and artists. Visitors from research, industry, and public administration as well as financial supporters and representatives from fashion and textile start-ups were present for the launch on September 29, 2021. The event gave them a unique opportunity to discover the modular lab and technical facilities, with highlights including a live demonstration of the advanced embroidering machines, cutter plotters, laminators, and a special 3D printer. All visitors could get their own designs and logos printed as a memento of the TPL's launch.

Changing of the guard: A farewell to Professor Klaus-Dieter Lang

His colleagues know and appreciate him as a celebrated expert for electronics system integration and specialist for durable chip connections. Having kept Fraunhofer IZM on a steady course to success over his years at the helm, Professor Klaus-Dieter Lang formally took his leave at a farewell barbecue party in mid-September. »People say: You should leave while it's still fun.« Klaus-Dieter Lang cannot see how this applies to him: »Applied research is always fun, and nowhere more so than in innovative microelectronics and microsystems technology.« After completing a much-celebrated thesis, he set up not one, but several organizations dedicated to his field of work, was appointed to the Chair of Nano-Interconnect Technologies at the Technical University of Berlin, became an active contributor at countless committees and research bodies, and doubled the commercial revenue of Fraunhofer IZM almost in passing.

Professor Klaus-Dieter Lang hands over the reins to his successor as Director of the Institute, Professor Martin Schneider-Ramelow in the presence of Department Leader Harald Pötter (left to right)

What does 6G mean for packaging?

At the 54th International IMAPS Symposium on October 11, 2021, no fewer than six speakers from Fraunhofer IZM addressed the question of »What does 6G mean for packaging?« in a special online workshop.

In his opening statements on »The leap from 5 to 6G«, Dr. Dr. Ivan Ndip looked at the key differences between 5G and 6G in terms of the requirements and challenges when packaging such systems. Technologies for a cost-optimized production of HF modules and a low-loss packaging concept using glass substrates and through-glass vias were surveyed by Dr. Tanja Braun and Markus Wöhrmann, before Dr. Hermann Oppermann took on the technical challenges of dense optical and electrical connections, caused in parts by the seemingly incompatible requirements of optimized HF transmissions and thermal management.

Dr. Hans Walter then looked at how the properties of HF laminates change with age. In his final talk, Dr. Tolga Tekin spoke about the use of photonic technologies for massive communication applications and next-generation computing.

Events with Fraunhofer IZM participation (Selection)

Sensor+Test 2021	May, online
Semi Packaging Technology Seminar	September, Hof
Berlin/Brandenburg Photonic Days	October, hybrid
IMAPS 2021	October, online
MikroSystemTechnik Congress 2021	November, Ludwigsburg
IPC E-Textiles 2021 Virtual World Tour	November, online
Productronica 2021	November, Munich

Micro-Macro: The tiny structures of the GlaRA radar sensor made easier to see for the MST Congress

EUROPRACTICE Webinar: Multi-project fan-out wafer level packaging

For their special webinar on October 28, 2021, Dr. Tanja Braun and Markus Wöhrmann of Fraunhofer IZM gave the participants an insight into multi-project fan-out wafer level packaging with a look at the basics of the technology and more recent trends and applications. Multi-project wafer processing is common practice for faster and more economical prototyping in the semiconductor industry, and it is now being tried out with fan-out wafer level packaging. The technology is particularly promising for high-frequency applications.

Returning to the MST Convention

The largest German-language electronics and microsystems convention returned to Ludwigsburg for its ninth edition from November 8-10, 2021. At the joint exhibit of the Research Fab Microelectronics Germany (FMD), Fraunhofer IZM and six other Fraunhofer institutes active in microelectronics enjoyed the long-awaited return of personal meetings and get-together with the attendees. Around 500 visitors had a chance to discover e.g. the GlaRA, an economical radar sensor for a range of industrial applications, developed and constructed with funding support from the Federal Ministry of Education and Research.

»Drones for Logistics« workshop bundling Fraunhofer competences

Every two years, experts from all over the world meet at Productronica in Munich to get the lowdown on new trends and innovations in the electronics sector, and Fraunhofer IZM was out in force in November 2021 for a talk and dedicated workshop series on »Drones for Logistics«. Fraunhofer IZM's contribution was all about radar systems to help logistics drones navigate indoor spaces. The project brings together the expertise of four Fraunhofer Institutes IZM, FHR, FKIE, and IML with their shared system development effort.

Reliability of electronic systems

On November 17 and 18, 2021, the Fraunhofer IZM's Environmental and Reliability Engineering unit hosted the »Reliability of Electronic Systems« workshop, covering the topic in its many diverse aspects like methods for system assessments, stress impacts, and resulting failure mechanisms, empirical data and physics used in failure modelling, the systematics of FE simulation, the handling of reliability characteristics and parameters, and the means for assuring reliability by condition monitoring.

Online seminar eHarsh

No fewer than eight Fraunhofer Institutes have pooled their competences in sensors, microelectronics, assembly technologies, PCB design, laser applications, and reliability analytics in a special joint consortium. Its mission: To develop and provide a technology platform for sensor systems for use in extremely harsh environments. The online seminar »eHarsh« on December 1, 2021, included talks and live demonstrations of the current R&D progress at Fraunhofer IZM and its seven consortium partners.

Fraunhofer IZM chosen as one of Berlin's iconic Zukunftsorte

Chosen in early 2022, Fraunhofer IZM is the proud representative of the Humboldthain Technology Park as one of the Zukunftsorte, the eleven locations in Berlin where the world of tomorrow is being forged today. Under the motto »Future is when the bees return«, two weeks in March were given over to the »Sens4Bee« project, with 146 citylight pillars and 237 public video stations broadcasting the message a full sixty times each day. The campaign was taken up on all social media channels and sparked a live debate across the Twitter community. This gave applied research its due presence alongside the more conventional adverts for products and services that litter the landmarks, traffic hubs, and public spaces of Germany's capital.

Promoting Young Talents at Fraunhofer IZM

Talented young scientists and researchers are the future of our industry. Fraunhofer IZM has been committed to supporting and harnessing this talent – and benefitting in turn from it – for more than 20 years. The Institute offers combined academic and vocational training to attract and recruit the brightest young minds. In 2021, two trained microtechnologists were once again rewarded with an employment contract for their excellent performance. Three additional microtechnologists in training have started their apprenticeships at Fraunhofer IZM, joined by an apprentice in the new qualification course as surface coating technician.

The institute also offers internships to give young people an insight into the training and study opportunities for scientific (MINT) professions.

Even with the pandemic restrictions still in force, there was considerable demand for internships in 2021. Four school internship places were made available in the Fraunhofer IZM laboratories as well as a special internship as part of the EnterTechnik project, intended to give young, technology-minded women an opportunity to get valuable experience and insights in diverse organizations and enterprises and assist them in their career choices.

Voluntary ecological year – In pursuit of sustainability

The Environmental Engineering (ERE) department at Fraunhofer IZM offers young people an opportunity to complete a voluntary ecological year under Germany's voluntary service scheme. As electronics are becoming ubiquitous in modern life, the ERE specialists are exploring the environmental side of these technologies and developing concepts for more eco-friendly and energy-efficient systems and components. In 2021, Fraunhofer IZM welcomed two volunteers for their ecological year.

Girls' Day 2021 – A close encounter with microelectronics

After the Corona pandemic forced a year's interruption, 2021 saw the return of the Girls' Day: Twelve visitors from the Gabriele-von-Bülow-Gymnasium came to Fraunhofer IZM to get a live and close-up experience of the exciting world of microelectronics. The day started with a brief introduction to the world and terminology of electronics as well as the Fraunhofer IZM's areas of research. They could discover new sensors, circuit boards, and other exhibits and see in the showroom how and where these systems are used in practice. After a quick quiz, the group then went for a tour of the cleanroom facilities, with the ninth-grade students donning the full uniform for a real sense of the exciting work of Fraunhofer IZM's researchers. The visitors enjoyed the hands-on tour and had lots of questions for their guides. After a group photo in the full kit, it was time for them to get to work: Connecting circuits, calculating resistances, or getting LEDs to light up correctly.

The feedback at the end of the day spoke for itself: »There were so many different things to discover on the day, and it was great to be able to see the cleanroom from the inside«, as Josephine, one of the visitors, summed up the experience on behalf of her fellow Girls' Day visitors.

Hands-on time

Inspecting wafers in the full cleanroom outfit

Facts & Figures

Fraunhofer IZM in Facts and Figures

Financial situation

2021 represented a year of successful growth for Fraunhofer IZM. The previous years' investments in the Institute's facilities and equipment were used effectively to expand its research and development services for commercial partners. Revenue from German and international enterprises and industry associations increased by a full 11.1 percent to €16 million. This enabled Fraunhofer IZM to cover 41.6 percent of its expenditure with revenue from external commissions. Publicly funded projects amounted to €13.5 in project volume, representing a 13.5 percent growth over the previous year.

At a full €38.5 million, the revenue of Fraunhofer IZM grew by 2.4 percent. Fraunhofer IZM covered 79.8 percent of its operating budget for 2021 from external proceeds. In total, projects of a volume of €29.5 million were made possible with external funding.

Hardware and equipment

In 2021, a total of €1.5 million of the Institute's own funds were invested in replacement and refurbishment projects. These assets were used to upgrade the facilities of Fraunhofer IZM in several targeted areas and to increase the efficiency of the existing equipment.

A further €2.0 million were used for minor construction works. These included individual improvements and adjustments to the facilities to expand the capacities of Fraunhofer IZM and comply with new health and safety requirements.

With the support of the State of Berlin, construction started on the Berlin Quantum Packaging Labs, with a total of €3.4 million in funding. The development of the Bio Sense Labs was similarly supported with an additional €0.9 million in funding from the State of Berlin.

People development

The personnel situation remained stable on account of the good commercial performance of the institute. A total of 298 people were employed at the Fraunhofer IZM sites at Berlin, Cottbus, and Dresden/Moritzburg.

Fraunhofer IZM offers students an opportunity to combine their academic work with practical research in the offices and laboratories of the Institute. At the end of 2021, 132 interns, bachelor and master students, and student assistants enjoyed these opportunities at Fraunhofer IZM.

Fraunhofer IZM is also committed to vocational education. In 2021, eight apprentices were in training as microtechnologists or office management assistants.

Fraunhofer IZM in 2021

Budget	38.5 million euros
External revenue	29.5 million euros (79.8 percent of total turnover)
Sites	Berlin, Cottbus und Dresden/Moritzburg
Laboratories	> 8,000 m²
Staff	438 (including 132 student assistants, master students, interns and 8 apprentices)

Awards

Lars Böttcher wins 2021 Research Award for new chip embedding technologies

For over two decades, Lars Böttcher has helped electronic systems become smaller, more reliable, and better at handling high frequencies through his work on embedding chips in circuit boards. With his team and many industry partners, he has brought the former niche technology into the mainstream and paved its way into exciting new applications in the automotive sector, medical technology, or even consumer electronics. In recognition of these efforts, he was chosen as the recipient of the 2021 Fraunhofer IZM Research Award.

The new millennium had only just begun when the microsystems specialist Lars Böttcher recognized the immense potential of embedding technologies and began to research concepts for packaging chips in polymers at Berlin's Fraunhofer IZM.

The Fraunhofer Research Award has been given out for »exceptional research in the field of microelectronics, microsystems engineering, and packaging« for more than twenty years. It honours research excellence and, above all, the successful application of new research in industrial use. Lars Böttcher received his award in a formal event on June 23, 2022.

Dr. Tanja Braun receives the »Exceptional Technical Achievement Award« of the IEEE Electronics Packaging Society

On March 19, 2021 the IEEE Electronics Packaging Society (EPS) 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«.

The award is not only a recognition of Dr. Braun's exceptional work in the field of electronic packaging, but also shows that her technical contributions to the topic have struck a chord with the jury. The prize is awarded for pioneering contributions as well as leadership in fan-out wafer level packaging and the transition to panel level packaging. Dr. Braun´s extraordinary activities in this area encompass, among others, the establishment of the first international large-scale PLP reference line for R&D, as well as the initiation and organization of the Panel Level Consortium with 17 industry partners, which is currently in its second phase (PLC2.0).

IZM researchers win the Ralf Dahrendorf Prize for demonstrative solutions in sustainable electronics

As part of the sustainablySMART project, a team of researchers at Fraunhofer IZM have modeled the available sustainable alternatives, and how approaches from the recycling economy can be best applied to consumer goods. Their comprehensive approach has now won them the award for outstanding collaborative research at the European level and the associated scientific communication of the German Federal Ministry of Education and Research (BMBF).

Award-winning researchers:
Dr Tanja Braun and Lars Böttcher

The team made a significant contribution towards an understanding of the recycling economy with its European-level sustainablySMART project. The research focused primarily on mobile products such as smartphones and tablets that have been in daily use for a long time now, yet which leave a heavy ecological footprint. Using extended lifecycles obtained from innovative product designs, together with improved recycling and reprocessing concepts and greater resource efficiency, the team applied ideas from the recycling economy to ICT devices.

The researchers created alternative solutions and constructed sustainable electronic devices, including a modular smartphone concept, a locally manufactured tablet made from sustainable materials, concepts for reusing the electronic components of a smartphone in other devices, a collaborative dismantling robot for removing components, and much more.

Dr. Tanja Braun receives the »Sydney Stein Award«

At this year's IMAPS 2021 Conference Fraunhofer IZM's Dr. Tanja Braun received the »Sydney Stein Award« in recognition of not only her leadership in the microelectronics packaging industry, but also her significant technical contribution on an international level. The International Microelectronics and Packaging Society (IMAPS) is the largest society dedicated to the advancement and growth of microelectronics and electronics packaging technologies. Every year IMAPS honors various members with »Society Awards« for remarkable work.

Students at Fraunhofer IZM succeed with their bid for the Fraunhofer Communication Prize

The two Fraunhofer IZM students Olga Putsykina and Niklas Goll have taken a proud third place with their bid for this year's Fraunhofer Communication Prize with their digital edutainment idea. Their video shorts feature their tiny mascot, µ, explaining a complicated term from microelectronics in an easy-to-follow style to an audience that has already grown to 800 regular viewers. The concept thought up and presented regularly for the last year by the student duo themselves wowed more than a hundred PR managers at the Fraunhofer society in a tough competition with five other nominees in the category.

The Fraunhofer PR Network has been awarding the Communication Prize since 2005 to raise a flag for the importance of good science communication. It is awarded for original ideas, powerful campaigns, and creative projects that help spread knowhow from the academic domain into general society. The winners were celebrated at the PR strategy event on 11 November 2021.

Olga Putsykina and Niklas Goll – The creative minds behind the #µknowsbest format

Fraunhofer IZM named »Research Institute of the Year«

Fraunhofer IZM is happy and proud to receive 3DInCites award for the second time after 2018. Every year this award honors researchers and institutions for outstanding work in the field of hetero system integration of semiconductors.

Fraunhofer IZM has been named Institute of the Year for its pioneering research in panel level packaging. Within the »Panel Level Packaging Consortium 2.0« project, the institute has teamed up with industry-leading companies from various countries to develop PLP technologies that can also be used in industrial mass production. The second consortium is set to run until 2022 and focuses on die-placement and embedding technology for ultra-fine line wiring down to 2 µm line width and a potential of up to 1 µm.

Best Paper, Dissertations, Editorials

Best Paper

EMPC 2021 Best Paper Award goes to Elisabeth Kolbinger
For her paper on »Characterization of the Corrosion Behavior of Al-X Bond Wire«, IZM researcher Elisabeth was presented with the EMPC 2021's Best Paper Award alongside her colleagues Anne Groth, Stefan Wagner, and Martin Schneider-Ramelow. The European Microelectronics Packaging Conference (EMPC), held online from 13 to 16 September on account of the pandemic, is the largest European conference on microelectronic packaging and gives experts in the field a biennial chance to come together from all over the world.

In their paper, the IZM team investigated the corrosion behavior of Al-X bond wires in a comparison with three other aluminum wire types. Their question: Would Al-X bond wires be suitable for more rugged environments? Conventional mechanical and electrochemical methods were used to answer that question.

The electrochemical analysis revealed that Al-X bond wire is far less likely to corrode than the other tested wire types. The researchers' conclusion was that Ai-X bond wire is a proven contender for use under harsh environmental conditions.

Dissertations

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

Krüger, Michael
»Untersuchung der Linearität elektrischer Verbindungen zur frühzeitigen Erkennung von Degradationen«

Lykova, Maria
»Investigation of Cu-Cu Bonding for 2.5D and 3D System Integration Using Self-assembled Monolayer as Oxidation Inhibitor«

Schambeck, Simon
»Einfluss der Temperaturwechselbedingungen auf Fehlermechanismus und Lebensdauer von SnAgCu Lotverbindungen«

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

Tschoban, Christian
»Methoden zur Vorhersage der Impedanz und Abstrahlung von flächigen Spannungsversorgungsanlagen für High-Speed Anwendungen«

Yang, Hua
»Homogenization of Strain Gradient Continua: Constitutive Parameter Identification, Size Effects Analysis, and Brittle Fracture Propagation«

Editorials

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

Bioelectronic Medicine Journal
Giagka, V. (Associate Editor)

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)

Lectures

BTU Cottbus-Senftenberg

Prof. Dr. M. Jaeger-Erben
- Social Sciences and the Environment
- Sociology
- Pre-semester preparatory course (Propädeutikum)

German University in Cairo

Dr. T. Tekin
- Sensor Technology

University of Applied Sciences for Engineering and Economics in Berlin

M. Bäuscher
- BioMEMS

M. Hubl
- Bionics

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

Dr. T. Tekin
- Nanotechnology

Dr. H. Walter
- Materials in Microsystem Technology

Technical University of Berlin

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

Dr. J. Köszegi
- Design, Simulation and Reliability of Microsystems (I)
- High-frequency Measurement Techniques for Microelectronic Packaging

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
- Neurostimulation

Dresden University of Technology

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

Cooperation with Universities (Selection)

Some of Fraunhofers university partners

Aalto University, Finland
Aalborg University, Denmark
AGH University of Science and Technology, Poland
Binghampton University, USA
Delft University of Technology, Netherlands
Eindhoven University of Technology, Netherlands
KU Leuven, Belgium
Michigan State University, USA
Tohoku University, Japan
University of Tokyo, Japan
University of Zurich, Switzerland
University of Quebec in Trois-Rivières, Canada
University College London, Great Britain
University of Utah, USA

Berlin University of the Arts
Bielefeld University
Chemnitz University of Technology
Heidelberg University
Humboldt University of Berlin
Technische Hochschule Ingolstadt
Universität der Bundeswehr, Munich
University of Bonn
University of Erlangen-Nuremburg
University of Freiburg
University of Mainz
University of Rostock
Weißensee Academy of Art Berlin

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 the Technical University of Berlin

Ever since its foundation in 1993, Fraunhofer IZM has drawn a lot from its productive cooperation with the Research Center for Microperipheric Technologies at the Technical University of Berlin, forming one of the world's first research institutions for packaging and interconnection technologies in the 1990s. In 2021, Professor Martin Schneider-Ramelow followed in the footsteps of Professor Klaus-Dieter Lang to head not just Fraunhofer IZM, but also the Research Center for Microperipheric Technologies.

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 (D)
Ajinomoto Group	Tokyo (JP)
Amkor Technology, Inc.	Tempe, (AZ, USA)
AMO GmbH	St. Peter am Hart (AT)
ams AG	Premstätten (AT)
Amsterdam Scientific Instruments B.V.	Amstedam (NL)
ASM Pacific Technology Ltd.	Singapore (SG)
AT&S AG	Leoben (AT)
Atotech Deutschland GmbH	Berlin (D)
BASF SE	Ludwigshafen am Rhein (D)
Berliner Nanotest und Design GmbH	Berlin (D)
Boston Scientific Corporation	Marlborough, (MA, USA)
Brewer Science, Inc.	Rolla, (MO, USA)
CERN	Meyrin (CH)
Comelec s.r.l.	Ferriera di Buttigliera Alta (IT)
Corning Inc.	Corning, (NY, USA)
Daimler AG	Stuttgart (D)
DISCO Corporation	JP
DuPont de Nemours, Inc.	Wilmington, (DE, USA)
Dyconex AG	Bassersdorf (CH)
Evatec AG	Trübbach (CH)
Finisar Corporation	D, USA
FIRST SENSOR	Berlin (D)
Fujifilm Electronic Materials	EU, USA
GEFRAN S.p.A.	Provaglio d'Iseo (IT)
GlobalFoundries	Dresden (D)
IMASENIC Advanced Imaging S.L.	Barcelona (ES)
Intel Corporation	USA
Invensas / Xperi	Santa Clara, (CA, USA)
MED-EL GmbH	Innsbruck (AT)
Meta Platforms, Inc.	Menlo Park, (CA, USA)
Meltex Inc.	Tokyo (JP)
MENNEKES Elektrotechnik GmbH & Co. KG	Kirchhunden (D)
Merck KGaA	Darmstadt (D)
Multi Channel Systems MCS GmbH	Reutlingen (D)
Nagase ChemteX Corporation	Osaka (JP)
Nexperia	Nijmegen (NL)
OSYPKA AG	Rheinfelden (D)
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 (D)
Robert Bosch GmbH	Gerlingen (D)
Salvia BioElectronics B.V.	Eindhoven (NL)
Schaeffler AG	Herzogenaurach (D)
Schmoll Maschinen GmbH	Rödermark (D)
SwissGrid AG	Aarau (CH)
Semsysco GmbH	Salzburg (AT)
Shōwa Denkō K.K	Tokyo (JP)
SKW Associates, Inc.	Santa Clara, (CA, USA)
SLAC National Accelerator Laboratory	Menlo Park, (CA, USA)
STMicroelectronics N.V.	Amsterdam (NL)
Süss MicroTec SE	Garching, Munich (D)
Swissbit AG	Broschhofen (CH)
TEN Thüringer Energienetze GmbH & Co. KG	Erfurt (D)

Memberships (Selection)

AMA Fachverband Sensorik, Wissenschaftsrat	H. Pötter	Member
Cluster Optik BB, Photonik für Kommunikation und Sensorik	Dr. H. Schröder	Spokesman
Deutscher Verband für Schweißtechnik DVS	Prof. M. Schneider-Ramelow	Representative of Fraunhofer IZM
Deutscher Verband für Schweißtechnik DVS Arbeitsgruppe »Bonden«	Prof. M. Schneider-Ramelow	Chairman
ECPE Competence Centre	Prof. M. Schneider-Ramelow	Member
European Network High Performance Integrated Microwave Photonics	Dr. T. Tekin	German Representative
European Photonic Industrial Consortium (EPIC)	Dr. H. Schröder	Representative of Fraunhofer IZM
European Technology Platform on Smart Systems Integration (EPoSS)	H. Pötter	Member Executive Committee
FED Fachverband Elektronik-Design e.V.	Dr. N. F. Nissen	Member
Heterogeneous Integration Roadmap (HIR)	R. Aschenbrenner	Chair Technical Working Group SiP
IEEE Electronics Packaging Society	R. Aschenbrenner	Fellow
IEEE EPS TC Material & Processes	Dr. T. Braun	Member
IEEE EPS to Board of Governors	Dr. T. Braun	Region 8 Director
IMAPS International Microelectronics Assembly and Packaging Society	Prof. K.-D. Lang	Fellow
	Prof. M. Schneider-Ramelow	Fellow
IMAPS Deutschland	Prof. M. Schneider-Ramelow	President
IMAPS Signal/Power Integrity Committee	Dr. Dr. I. Ndip	Chair
IMAPS Executive Council	Dr. Dr. I. Ndip	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
Strategischer Arbeitskreis Silicon Germany	Prof. K.-D. Lang	Member
Wissenschaftlich-technischer Rat der Fraunhofer-Gesellschaft	Dr. M. Hampicke	Representative of Fraunhofer IZM

Publications (Selection)

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Investigation of the Long-term Adhesion and Barrier Properties of a PDMS-Parylene Stack with PECVD Ceramic Interlayers for the Conformal Encapsulation of Neural Implants
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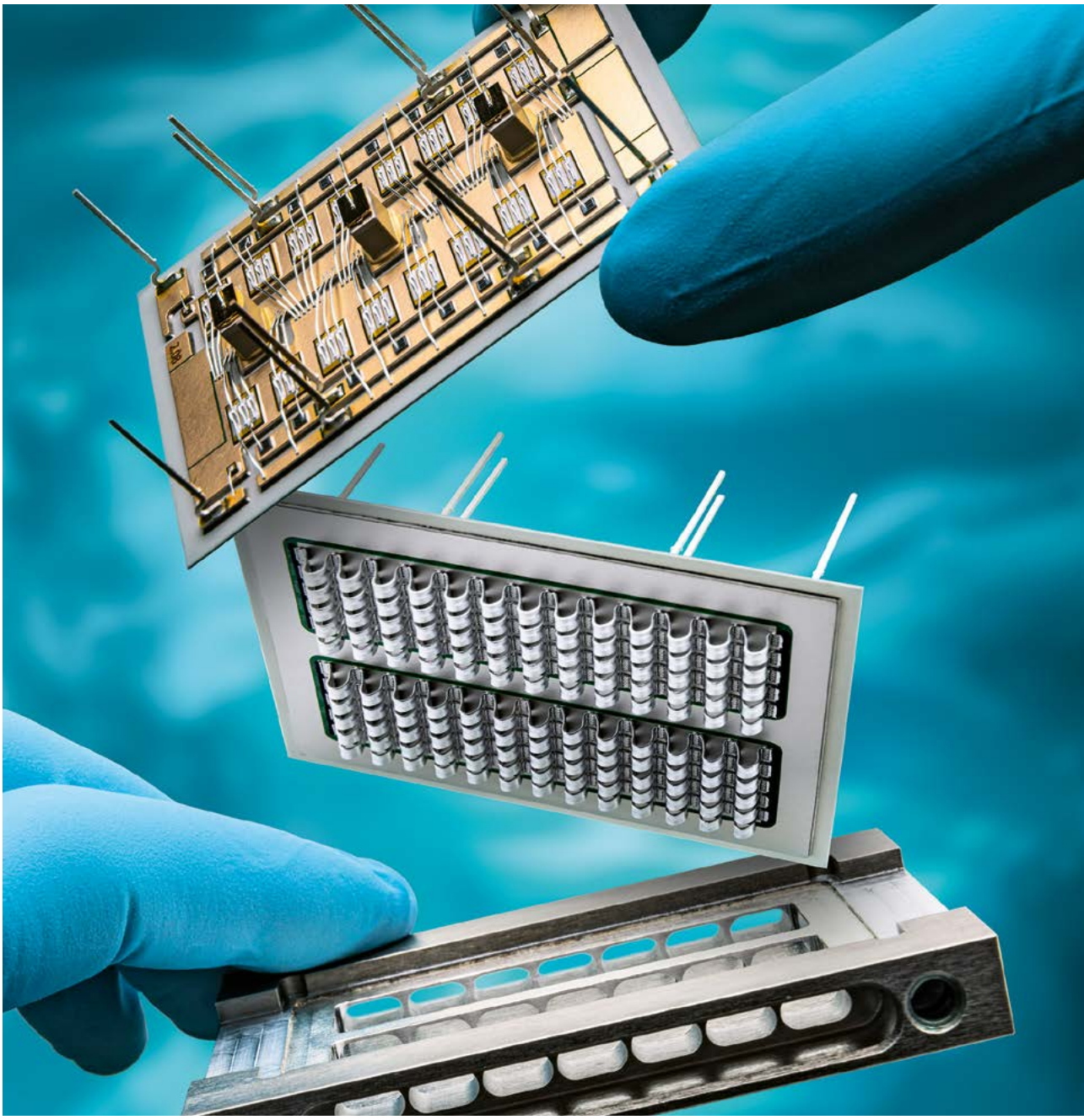

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