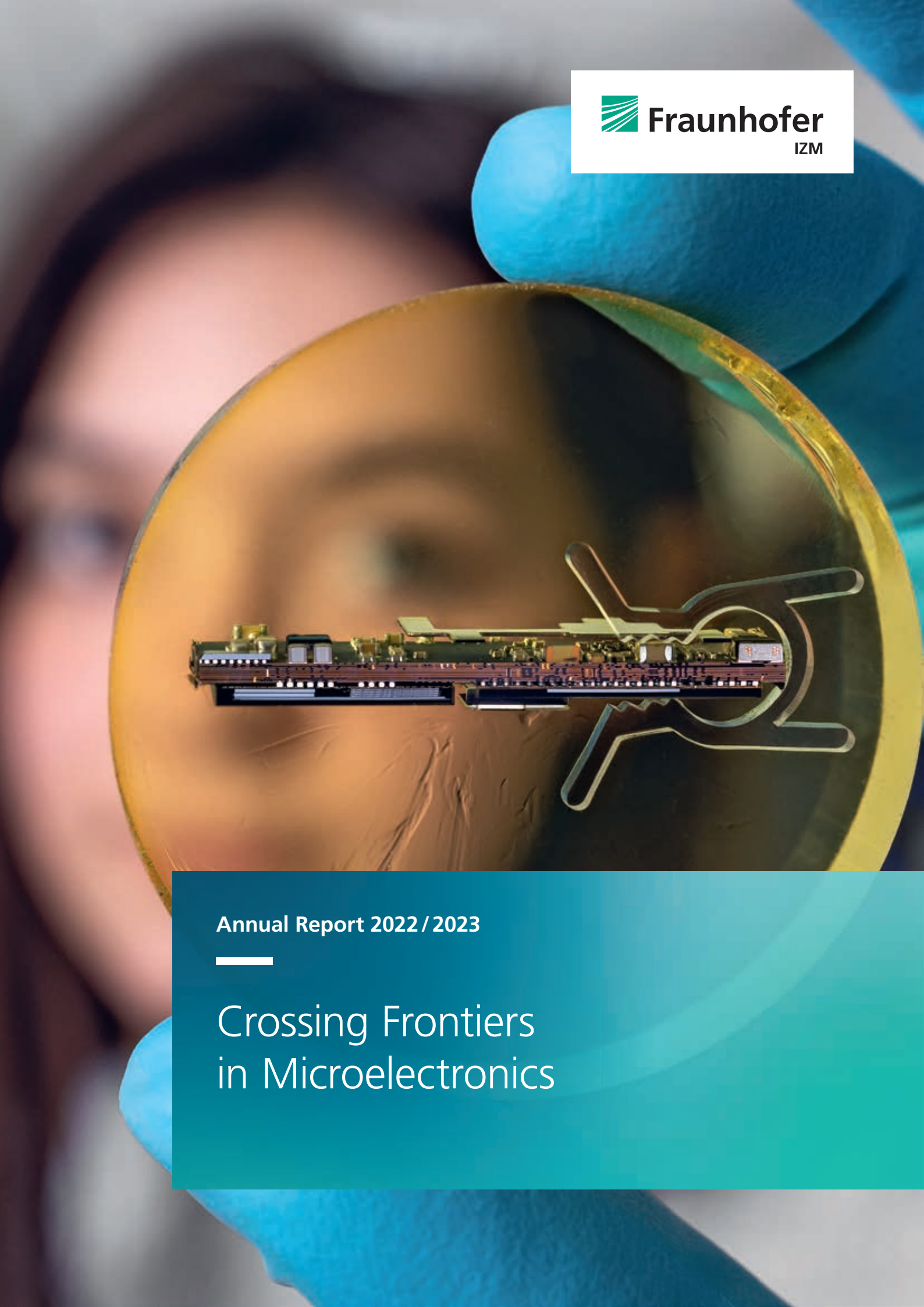


Fraunhofer IZM

Annual Report 2022 / 2023

Crossing Frontiers in Microelectronics

Annual Report 2022/2023

Crossing Frontiers in Microelectronics

»With 30 years of experience Fraunhofer IZM is constantly pushing the boundaries of what was thought technically feasible.«

Prof. Martin Schneider-Ramelow
Director of Fraunhofer IZM

Content

Preface

Dear Readers and Friends of Fraunhofer IZM!

There is talk of a new era in Europe, and we are feeling the changes in our lives: The current multicrisis of a global pandemic, the return of war in Europe, the energy crisis, and rampant inflation are affecting all of us. Our times call for resilience, and they need us to rethink where we stand. As one of the leading research organizations in the field of system integration and reliable microelectronics, we can do our part and use the knowledge and expertise of today to shape a better world of tomorrow with smarter, more powerful, and more durable electronic systems.

With our three decades of experience and constantly growing pool of expertise, we at Fraunhofer IZM are pushing the boundaries of what was thought technically feasible and are continuing to innovate electronics packaging technologies. High performance packaging is one key focus of our current work, using technologies like hybrid bonding, chiplets, or active interposers. The resulting high-performance packages will be used in high performance computing or quantum and neuromorphic computing e. g. for AI. Work at Fraunhofer IZM also contributes to other prime topics of our times, including 5G/6G, GreenICT, trustworthy electronics, or bioelectronics, and we continue to offer practice-oriented, industry-driven solutions for our clients and partners.

The last year has seen many highlights:

- Together with our research partners from across Europe and other Fraunhofer Institutes, IZM-ASSID has been contributing to a platform for producing AI hardware prototypes.
- The ability to make trustworthy electronics is one of the most pressing challenges in the hardware industry. Fraunhofer IZM has been working on this in several projects, including promising results in the use of wafer level packaging for trustworthy complex systems.
- Our 6G Research and Innovation Cluster (6G-Ric) and several other projects on 6G communication have been doing foundational work for the next generation of mobile communication.
- As part of the GreenICT @ FMD project, we have established a center of competence for resource-conscious ICT together with our partners.
- Through our Research Fab Microelectronics Germany, Fraunhofer IZM has been part of a Germany-wide cooperation venture on quantum and neuromorphic computing.
- We have been able to launch our Quantum Packaging Lab for photonic quantum integration technologies.

These and other fundamental achievements have only been possible due to the intensive and close cooperation with our partner universities, the Technical Universities of Berlin and Dresden, the BTU Cottbus-Senftenberg, and the Technical University of Delft. Every year, these partnerships are getting stronger and producing more shared progress and successes. Several newly launched DFG-funded projects were set up to intensify the link between the fundamental research done at the Research Center for Microperipheric Technologies at the TU Berlin and the applied research at our Institute.

Cooperative work in our research network is also starting to bear fruit at our other sites: The new Center for Advanced CMOS & Heterointegration Saxony is home to the close cooperation between our Dresden site IZM-ASSID and Fraunhofer IPMS-CNT on a better value chain for 300 mm wafers in CMOS production and packaging. This not only promises the more efficient and economical production of wafers, but also means the leap from innovative technologies to industry standard. Our work with the BTU Cottbus-Senftenberg on the iCampµs II is also going strong: The funding project for the innovation campus is already delivering promising results in microsensor technology, such as radar-driven monitoring of medical data. We are also expanding our Cottbus site for RF sensors and high-speed systems. One great piece of news here is the appointment in February 2023 of Ivan Ndip to the chair of antenna and RF system integration.

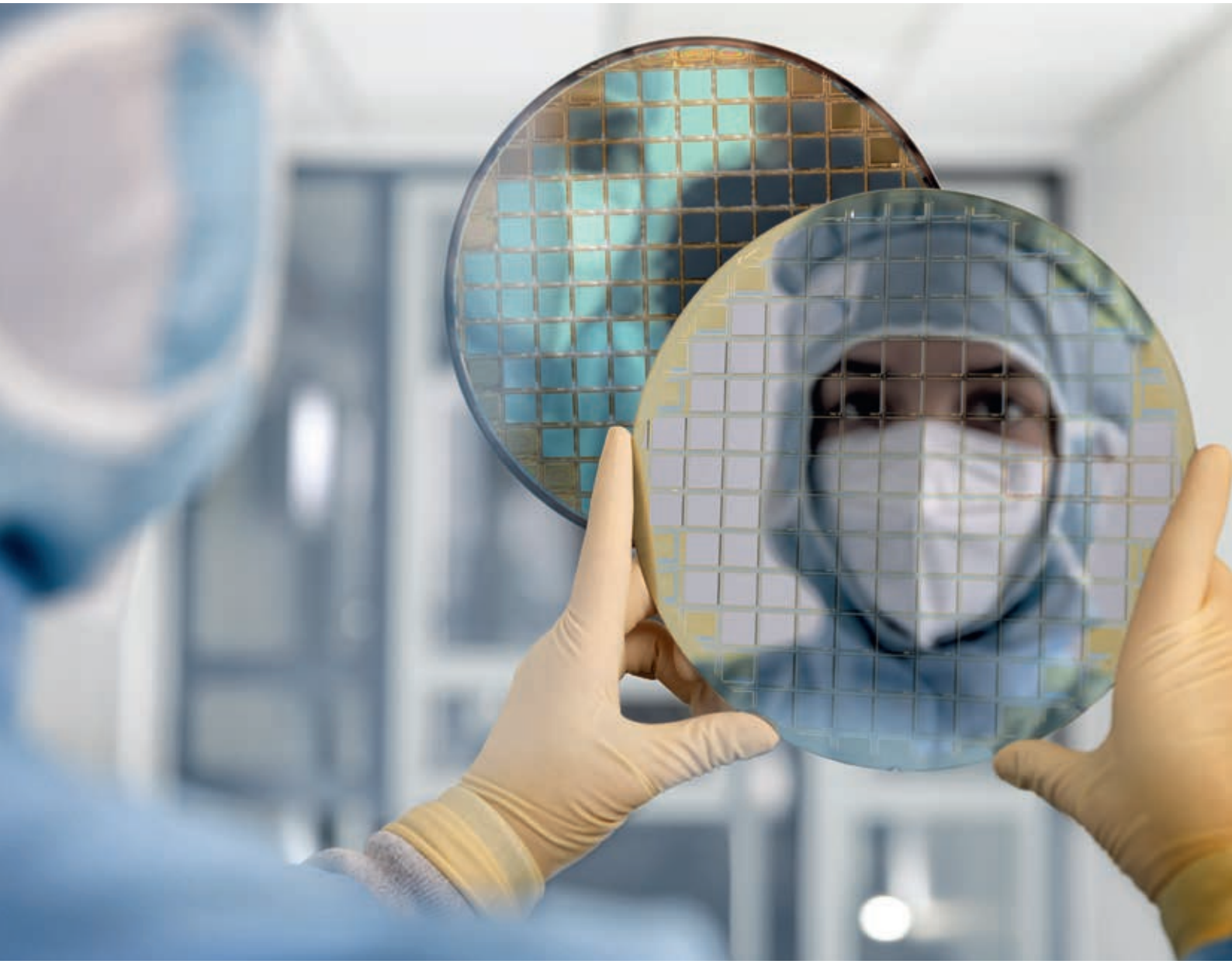
Another topic that is very close to my heart is the great work done to support young talent with our expertise and resources. I consider it our mission to promote scientific training for the microtechnologists of the future and training in non-technical jobs as well. We are also establishing master's and doctoral dissertation supervision as a key part of the work of our Institute. In this respect, the Young Research Talent Class »WOMEN IN SCIENCE« program is particularly important for us: It gives better professional opportunities to female researchers, improves female representation at our Institute, and helps overcome ingrained inequalities. For their idea, the colleagues behind this initiative were given the BestChance Award 2022 of the Fraunhofer Society.

The trend continues: the successful work of 2022 is again reflected in the hard facts and figures of our operational results. The 430 people at our three sites have all contributed to operational earnings of €15.2 million, bringing the operating budget of Fraunhofer IZM to a record amount of around €40 million.

This is why my thanks go first and foremost to our people for their excellent work: I thank each and every one of you for your great ideas, your exceptional passion, and your unfailing commitment! I also owe thanks to our partners in research and industry, our supporters in federal and state government, and our project sponsors. Together, we can be the engines of innovations that will help overcome today's many crises and spark more interest in the technologies of tomorrow.

I hope you enjoy and are inspired by 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 430 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 startups 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.

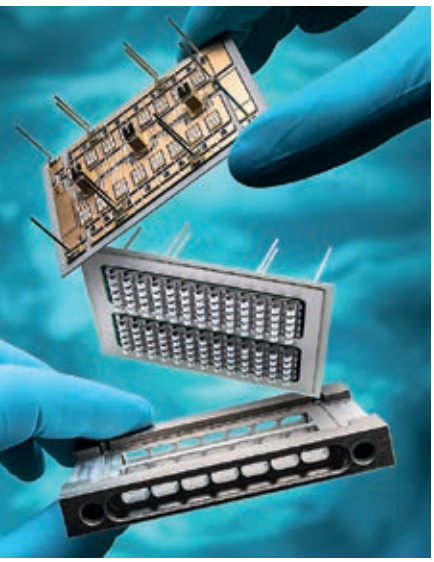
Contract research

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:

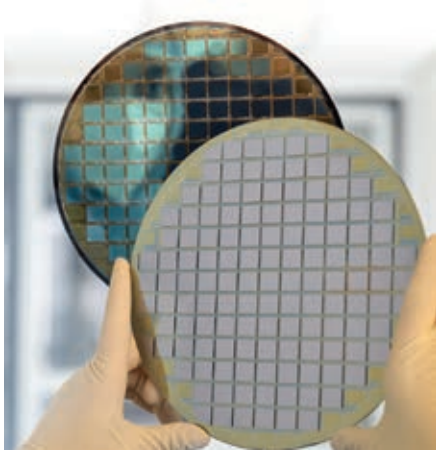
- 3D integration including Cu-TSV and wafer tacking
- Thin wafer processing and integrationtechnology
- Heterogeneous Integration
- Wafer-level packaging, fine-pitch bumping and interconnect technologies
- Hermetic MEMS and sensor packaging
- High density flip-chip assembly
- Sensor development and integration
- 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 and 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.



Wafer-level hermetic capping / vacuum sealing by AuSn wafer bonding of IR imaging sensor

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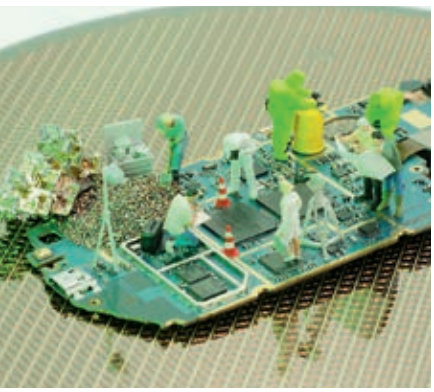
Environmental & Reliability Engineering



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

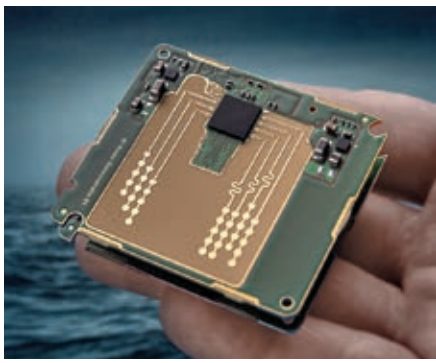
The department »RF & Smart Sensor Systems« is concerned with the research, development and industrial application of wireless sensor and communication systems. The focus of our work is on 5G and 6G communication systems, radar sensor technology and as well as wireless sensor nodes. The greatest challenge in terms of research and development and the defining criteria are large bandwidths high robustness and a commitment to maximum energy efficiency. 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 codesign) 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



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

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Highlight

High-End Performance Packaging – A New Paradigm for Electronics integration

Erik Jung

Advanced packaging technologies like flip-chip integration, wafer-level CSPs, or ICs embedded in the substrate play a crucial role in modern electronics manufacturing. As demand for faster and more efficient computers and other electronic devices continues to surge, innovative packaging solutions are becoming increasingly sought after. Industry and research have responded to the market's call with new techniques and novel architectures like chiplet designs or heterogeneous integration, all of which promise more powerful systems at lower costs. A related trend sees the move away from passive system carriers (i. e. interposers or high-end substrates) to system designs that give the carriers an active role in supplying some of the functionality of the system.

The advent of chiplet architectures has paved the way for this and continues to influence the direction of travel. Chiplets are tiny chip units that can work monolithically or be combined to provide the systems' functions, contributing with unique flexibility to the idea of a system-on-chip. Each chiplet is designed to have a separate and independent function and to be combined with other chiplets for a custom solution for each given application. The concept is extremely flexible and scalable – in the system's design and its production – and reduces both the time-to-market and the cost of developing innovative products.

The advantages of the chiplet architecture are evident: By breaking down the old, monolithic single-chip design into smaller, more versatile components, designers can enjoy the benefits of established, tested technologies while working on novel, innovative components. This makes the design process faster and leaner, makes success with the »first silicon« more likely, and reduces production costs with better utilization and better yields with the 300 mm wafer substrates.

1 Multi-chip stack connected by microbumps

2 High-density panel-level integration (435 x 610 mm²)

3 High-density flip-chip microbumps with a 3 µm pitch at 1.5 µm diameter

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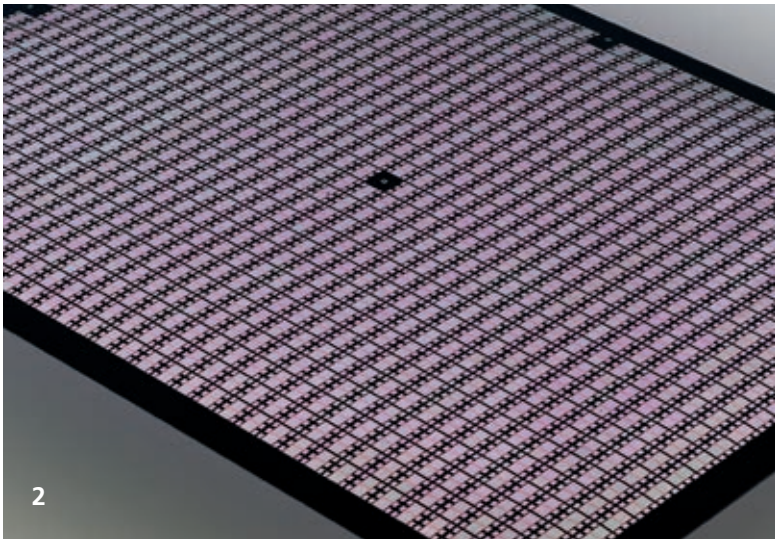

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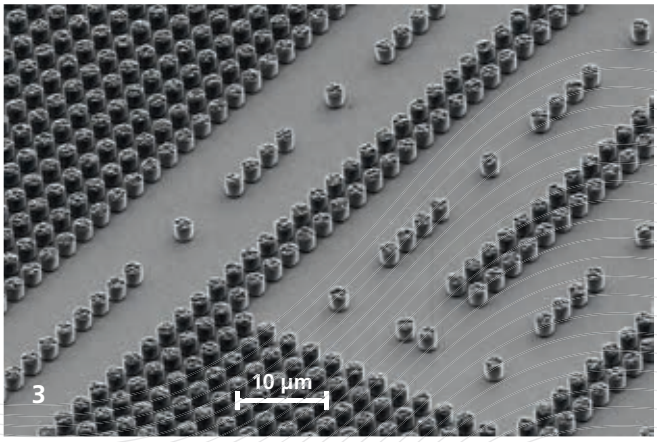
Fraunhofer IZM was quick to realize the potential of these trends and to pursue the idea of a top-down »disaggregated system«, banking on the Institute's extensive knowhow in advanced packaging. The Institute recognized the need for processing standards that would be accepted in the industry and became the first organization in Europe to forego specific R&D processes in favor of hybrid bonding combined with through silicon vias (TSVs), which has now been established as the standard approach across the industry.

Fraunhofer IZM has been behind many of the advances in micro-bumping for flip-chip integration with extremely dense contacts, as are now used in chip stacking. This has been part of the Institute's innovation strategy for a full three decades, making this packaging toolbox the natural choice when testing the chiplet paradigm, which already arranges the front-end architecture in separate, IP-centric hardware units, for high-performance systems.

A trend towards heterogeneous integration is accompanying this new architectural paradigm from the digital domain. Using the chiplet architecture adds substantially to the technological options, including the ability to integrate several technologies, like logic controllers, memory, analogue functions, or sensors, to a single chip-sized (sub) system. The end product is a highly versatile module with greater performance and better energy efficiency. Even further up the value chain in packaging, innovative approaches are complementing the concept of High-End Performance Packaging (HEPP). This HEPP approach to electronics integration is being powered by the availability of substrateless fan-out packaging, which allows extreme circuit and contact densities at large panel sizes, with active interposers and functional properties inherent to the geometry (e. g. directional antennas, integrated cooling). It charts a clear path towards meaningful heterointegration.

The next generation of systems will benefit substantially from these innovations and push the boundaries for sophisticated applications like edge AI, autonomous functions, ubiquitous services and more. At the same time, the systems will be less of a burden on resources and go some way towards the vision of a greener and environmentally fairer society. High-end packaging will become a mainstay of technological innovation in the electronics industry and an engine for the next revolution in electronic systems. IZM is ready and prepared to actively support and power these game-changing innovations.



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Highlight
Microintegration for Quantum Computing at Fraunhofer IZM

Wojciech Lewoczko-Adamczyk, Hermann Oppermann, Andrej Stranz

The quantum challenge

As futuristic as the term still sounds, quantum technology has been part of our everyday experience for more than half a century already. Semiconductor components, lasers or the atomic clock, all belong to the first generation of quantum technology. In the latter two cases, we are dealing with a whole set of quantum particles: lasers emit millions and millions of perfectly correlated photons, and atomic clocks use highly precise spectroscopy to read the quantum state of a macroscopic ensemble of atoms.

Recent technical progress has enabled the systematic manipulation of individual quantum bits (qubits). In conventional digital computing, a bit can only have one of two states: 0 or 1 at the same time. In contrast a qubit can exist in any combination of the basic states simultaneously. This state is called superposition and its experimental realization, together with quantum entanglement, has sparked the second quantum revolution. The doors are wide open for new quantum applications in communication, simulation, computing, or sensor technology.

The problem is that qubits are notoriously fragile and short-lived. The amount of information carried by a qubit will soon be lost because of interference with the environment. For instance, superconducting qubits or single photon detectors only work at cryogenic temperatures of lower than 4 K or even down to the milli-Kelvin range. For nuclear or ionic qubits the quantum particles have to be placed in an ultra-high vacuum and reliably encapsulated to avoid collisions with residual gas molecules.

For this purpose Fraunhofer IZM is innovating packaging technologies for quantum electronics and photonics on two fronts: with packaging and interconnection solutions that work at extremely low temperatures and with miniaturized vacuum packages that can be scaled up for industrial production.

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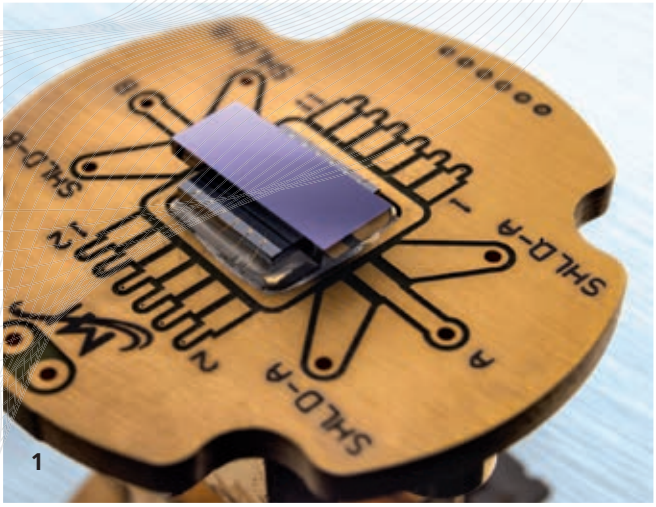

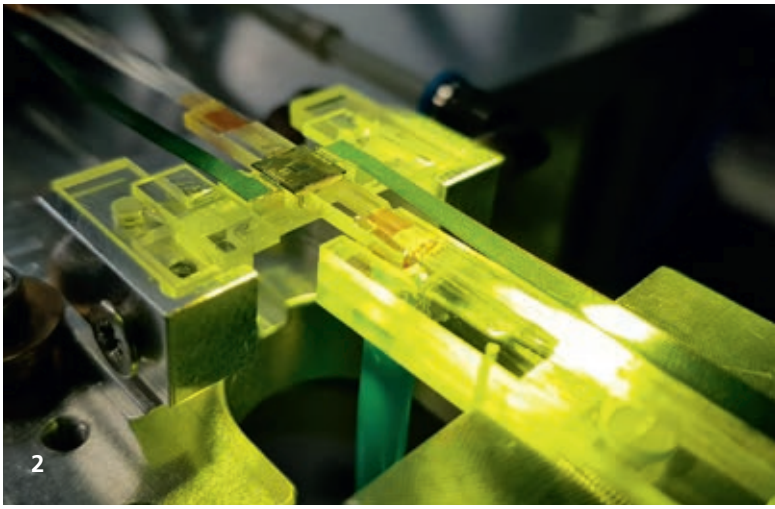

Interconnection and packaging technologies at extremely low temperatures

The electrical signals that are used to manipulate Qubits operate at frequencies of several GHz. The high frequency range requires the flip-chip assembly on interposers to achieve high performance devices. However, heat is dissipated during energy conversion at electrical resistance or by polarization losses in the interposers and flip-chip connections. This heat can cause the information in the qubits to get lost, so Fraunhofer IZM is working on superconducting interposer circuits based on niobium and niobium nitride to reduce the amount of dissipated heat from interconnects. For flip-chip assembly we use superconducting indium bumps, well established in our electroplating technology, to deal with temperature induced mechanical stress resulting from the temperature change between regular room temperature and the cryogenic environments. The proposed superconducting interposer chips can be characterized using a special testing setup at cryogenic temperatures of less than 4 K. Values like transition temperature (temperature at which the metals change from normal resistance state to the superconductive state), the critical current density, or the critical magnetic field strength at which superconductivity breaks down, are measured.

Interconnection and packaging technologies for hermetic packages

Ultra-high vacuum chambers are used when working with nuclear or ionic qubits, but their sheer size and hunger for energy makes them not immediately suitable for use in portable devices like quantum sensors or quantum computers.

At Fraunhofer IZM, work is under way on industrial and economical processes for the production of passive, miniaturized vacuum packages. The secret ingredient: Glass. The Institute has many years of experience with technical glass and its use in opto-electronic systems and can draw on a range of facilities for producing hermetically sealed connections, e. g. by laser soldering or welding of metallized glass or anodic bonding. Functionality of the package can be improved further by including e. g. optical waveguides and electronic vias into the transparent substrate (system-in-package) or by integrating and connecting photonic integrated circuits (PICs). Existing processes for the burying of waveguides in glass are currently being adapted to work with visible or near-IR light.

Fraunhofer IZM's capabilities

The institute is combining excellent technical facilities with long-standing expertise to develop reliable packaging solutions for the challenging field of quantum electronics and photonics. This will serve to bridge remaining technological gaps to advance the vision of the second quantum revolution to become actual industrial reality.

1 Chip layout for quantum computers' readout electronics on a cryo testbed

2 Hermetic opto-electronic package for photonic quantum computing with ultra-cold atoms (®Fraunhofer IZM, Quantum Source Labs Ltd.)

Highlight
Center of Competence Green ICT @ FMD

Nils F. Nissen

Energy efficiency, a climate neutrality, and a genuinely circular economy of raw materials and finished products: This vision will determine the technical developments in the information and communication technology (ICT) of the near and far future. It brings new requirements for technologies and products that the global ICT industry is tackling with the Green ICT initiative.

The Germany Ministry of Education and Research has been supporting applied research in this vast field as both an issue of general concern and as a technical research objective on its own. The Green ICT @ FMD funding initiative, launched in the fall of 2022, represents the next step in the federal government's climate protection efforts in the form of a dedicated Green ICT Center of Competence, headed by the Research Fab Microelectronics Germany (FMD). The Center of Competence is bringing together the whole spectrum of applied Green ICT electronics research in Germany for easier access by market actors. Three headline issues of particular relevance for industry partners in Germany and Europe were identified. They serve to cluster the many activities in the field: »Sensor-Edge-Cloud Systems«, »Communication Infrastructure«, and the materials and processes for »Resource Efficient Microelectronics Production«.

The environmental specialists of Fraunhofer IZM have a leading role in preparing and running this initiative. With their competence in lifecycle assessments (LCA) and environmentally optimized technologies (ecodesign), they represent the scientific backbone of the entire project. Ecological potential has to be quantifiable with more accuracy, since Green ICT and ecodesign solutions are subject to many factors and variables, and no single technology can promise a green outcome in every use case or scenario.

All units of Fraunhofer IZM are bringing their specific competences to bear in this context: Resource efficient technologies and system designs are generated for use as reference solutions. Existing laboratory facilities are being expanded to include the means for the synchronized monitoring of performance and energy consumption. Workflows and new datasets are being developed for a

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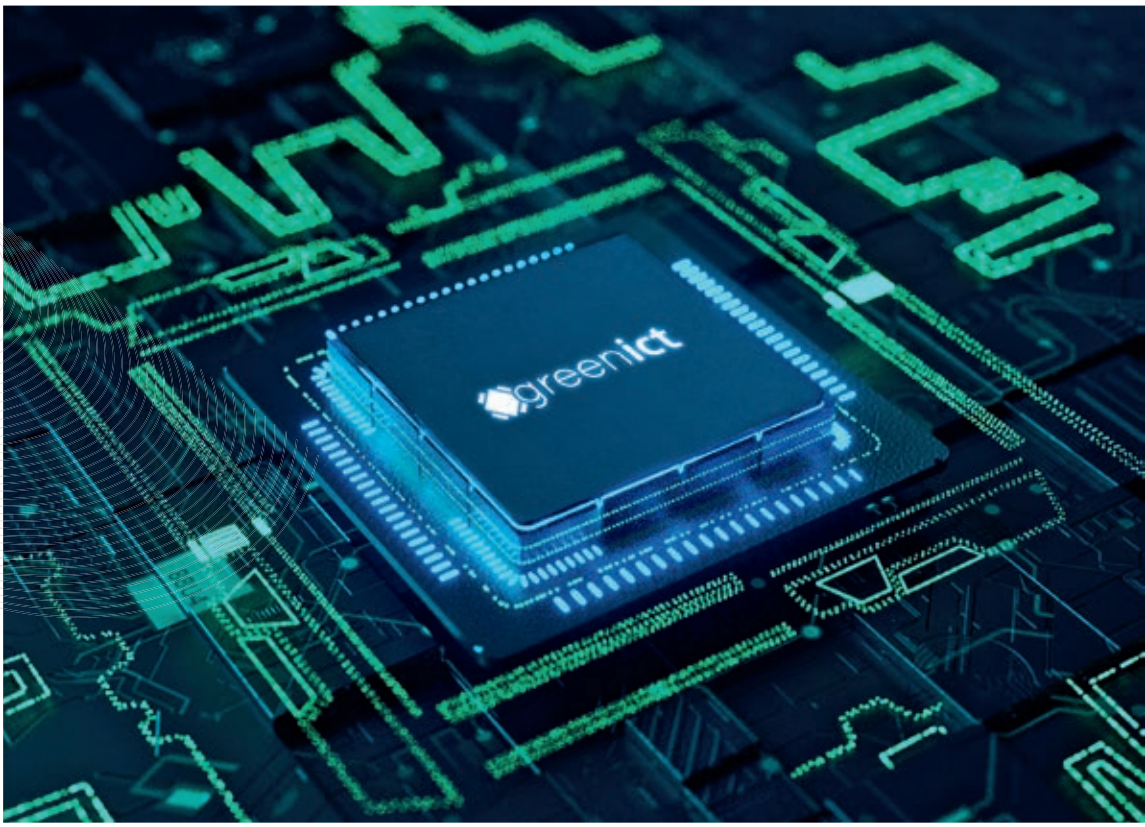


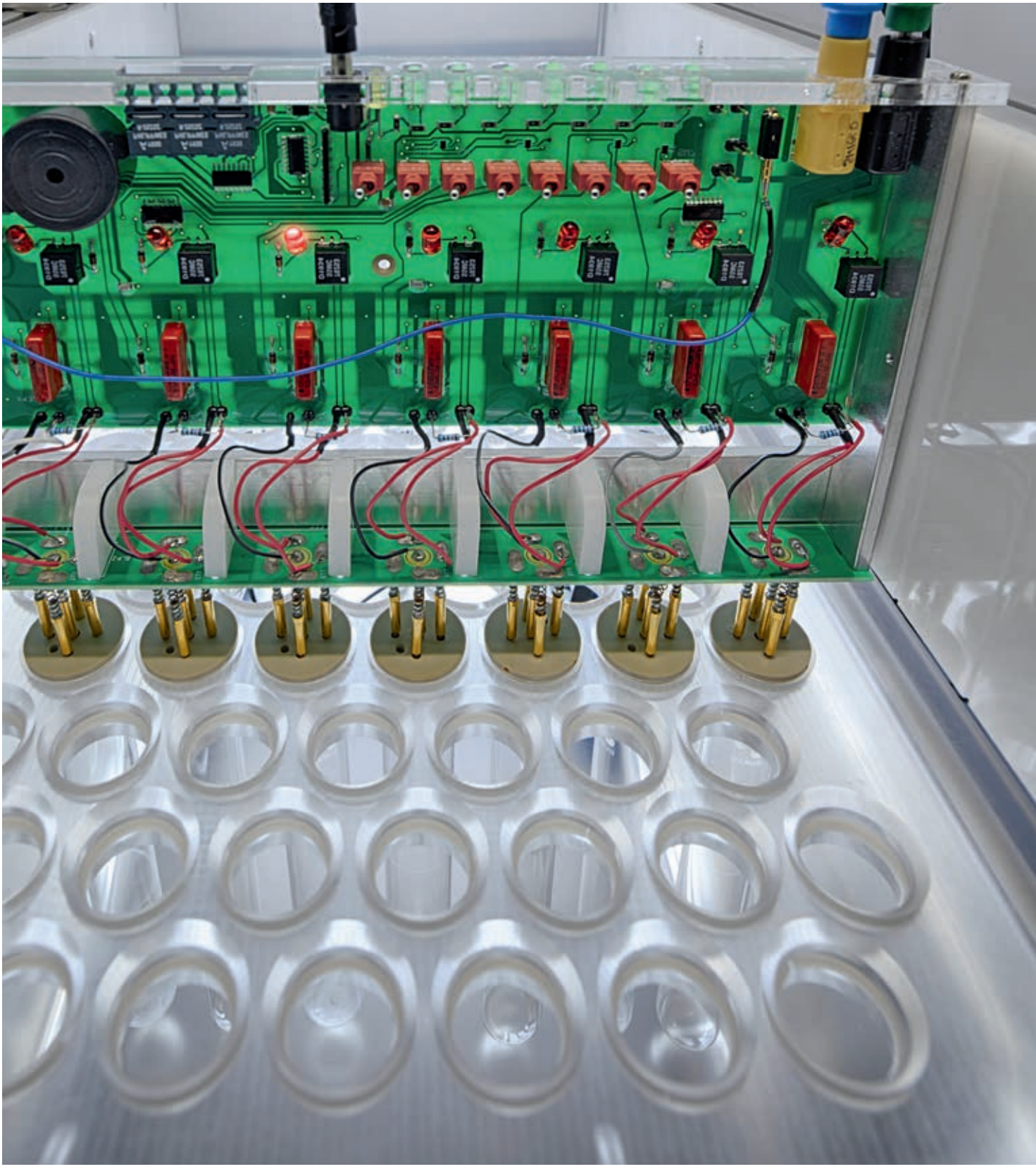
With support from the Germany Ministry of Education and Research a dedicated Green ICT Center of Competence is set up, headed by the Research Fab Microelectronics Germany (FMD)

faster eco-assessment in the decisive phases when developing new technologies or products. The core topic for Fraunhofer IZM will naturally be the eco-assessment and optimization of advanced packaging technologies.

The added range of Green ICT services include the many technologies for photonic ICT that are available at Fraunhofer IZM. Photonic ICT systems promise substantial energy savings by being able to transmit large amounts of data with less loss and at higher speeds. Considerable, but not insurmountable technical challenges remain, for which the planned work will provide an invaluable basis. Another focus issue will be the system design of sensor networks and of high-performance wireless systems operating at high frequencies (5G/6G). For the energy and resource-efficient design of such sensor or communication systems, everything from the systems' architecture or the orchestration of their components to their load-responsive operation needs to be considered. This calls for intensive interdisciplinary cooperation when designing and simulating such systems as well as for multifunctional test setups that can cover all relevant parameters at the same time.

As part of the paradigm shift energy efficiency during use is not the only environmental concern for microelectronics. The environmental burden during ICT production also needs to be addressed, and Fraunhofer IZM can already contribute knowledge about a range of manufacturing approaches for eco comparisons, including environmentally relevant cleanroom processes that are not part of advanced packaging.

The Green ICT @ FMD initiative is turning energy and resource efficiency from a topic of general concern into an integral part of all technological development for microelectronics across the Fraunhofer Society, with Fraunhofer IZM taking and expanding its lead in this important field.



Test stand to determine the long-term stability of implantable devices' encapsulation layers

World Leader in Applied Research

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. Roughly 30,000 employees, predominantly scientists and engineers, work with an annual research budget of approx. €3 billion. Fraunhofer generates about €2.5 billion of this from contract research.

Research Fab Microelectronics Germany

In 2017, Fraunhofer IZM became part of the Research Fab Microelectronics Germany, also known as the FMD or Forschungsfabrik Mikroelektronik Deutschland. The FMD is a cooperation venture of the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP. It is the go-to place for all issues concerning microelectronics and nanoelectronics in Germany and across Europe. With more than 4500 professionals affiliated with the FMD, it is one of the world's largest cooperations of its nature in the field of research and development.

Not one, but two major new projects were launched by the FMD in 2022. The »Green ICT @ FMD« project will spend the next three and a half years on establishing a center of competence for resource-conscious ICT across its various locations. In December, this was followed by »FMD-QNC«, the ambitious project to bring together and consolidate the microelectronics R&D capabilities for quantum and neuromorphic computing in Germany. A Germany-wide microelectronics academy will be formed in the next three years for the »Green ICT @ FMD« and »FMD-QNC« initiatives.

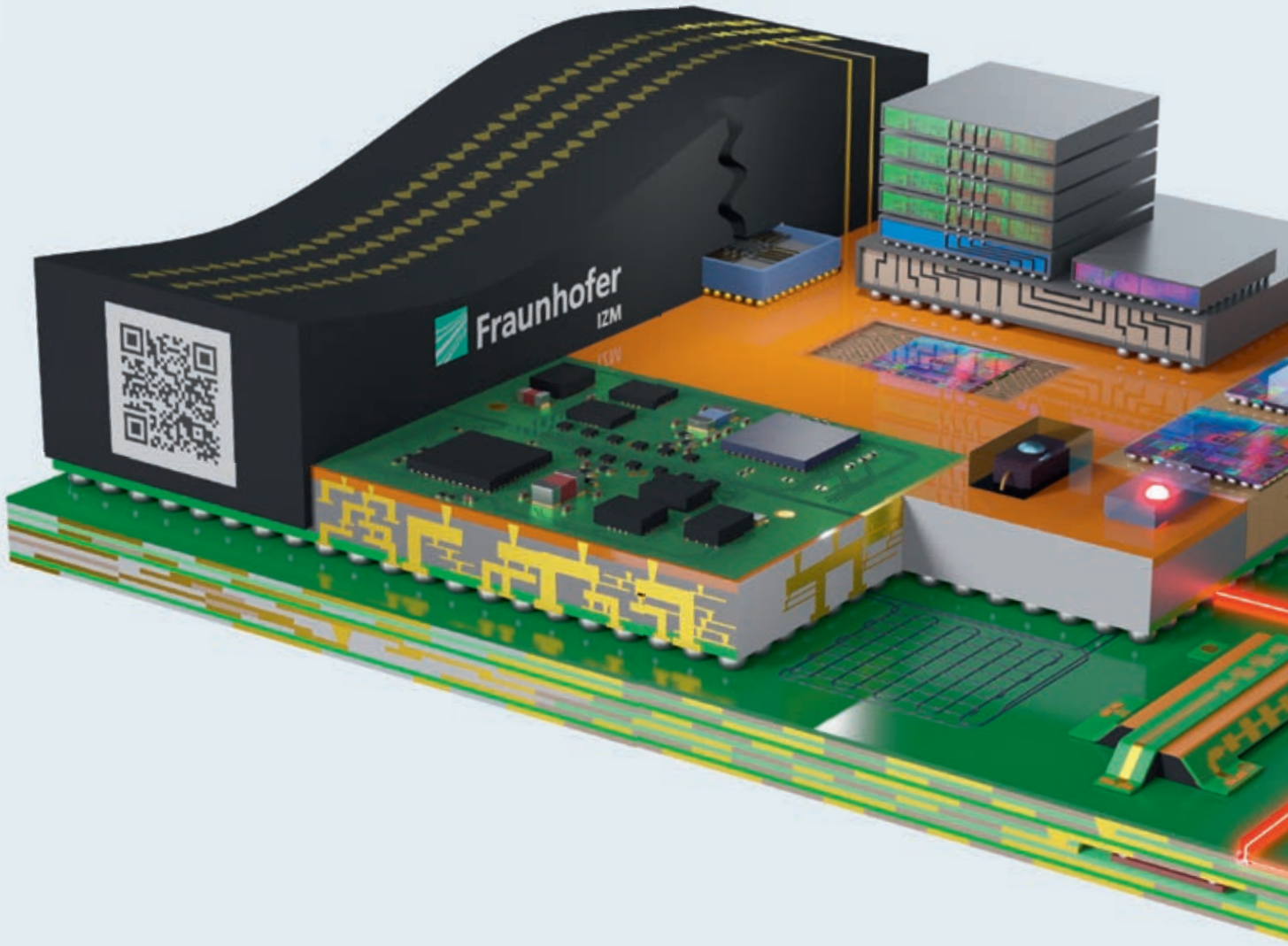
2022 also saw the essential groundwork being done at FMD for the technological foundations of the »European Chips Act«, introduced with the mission to keep Germany and Europe as a whole key actors in the global microelectronics value chain.

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.

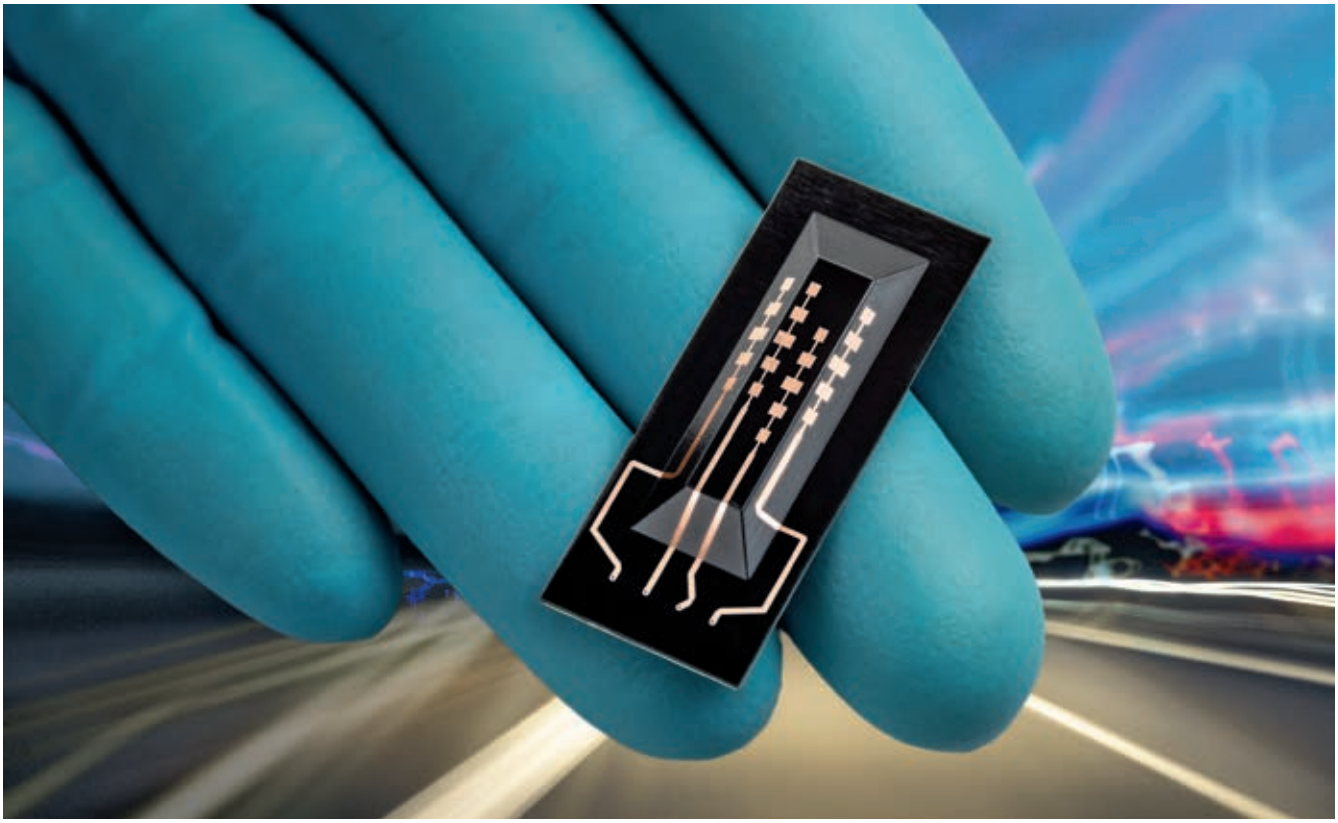
The »Berlin Center for Digital Transformation« is a collaborative venture involving the four Berlin-based Fraunhofer institutes FOKUS, HHI, IPK und IZM. Its work focuses on technologies and solutions that advance increasing digitalization and networking in all areas of life.



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



3D-radar-MIMO-antenna for ±90° object detection

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.

Reflecting aging processes in digital twins

Artificial intelligence is constantly improving the self-validation of electronics systems with novel hybrid models. In the SesiM project, test vehicles were equipped with functional structures for automotive and rail applications, and hybrid models developed in both open source and commercial software environments. The resulting grey box models allow the systems to be modelled down to their assembly and interconnect technology. For the DIREKT project (»Digital Life Cycles of (Hybrid) Electric Engine Systems«), the IZM team applied the same approach to aeronautical power electronics. Digital fingerprints of mechatronic assemblies are constantly being refined to form true digital twins.

Substrate embedding for power modules

Power modules equipped with wide band gap semiconductors like SiC and GaN are attracting increasing attention, due to the superior functionality of these materials and considerable potential for automotive, aerospace, and energy grid applications. Power modules in particular benefit from optimized electrical properties, heat management, robustness, or miniaturization in general. By embedding power semiconductors, sizes can be reduced substantially, electrical and thermal performance improved, and reliability optimized. Printed circuit board technologies are used to embed bare dies in a PCB polymer laminate material, yielding considerable benefits in terms of reliability, volume reduction, and electrical performance.

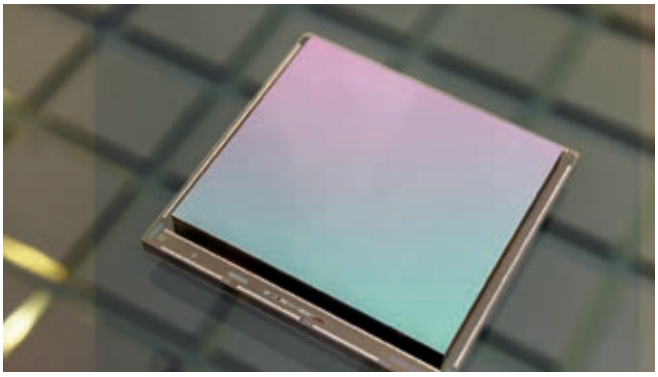
3D substrates for highly integrated communication modules

Fraunhofer IZM successfully uses the third dimension for the construction of highly integrated microsystems. In the design of 3D radar antennas as a special form of 3D electronic modules and the production of organic 3D circuit carriers, this meant particular attention to robustness and geometric stability over time, two key requirements of industry. This can be achieved by means of mold technology, which is used worldwide as a standard encapsulation process for electronic packages. In the KoRRund and KI-Radar projects, completed in 2022, high-precision 3D antennas were produced with an integrated shielding layer by direct metallization on the molding compound and by back-injection of the RF substrates.

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

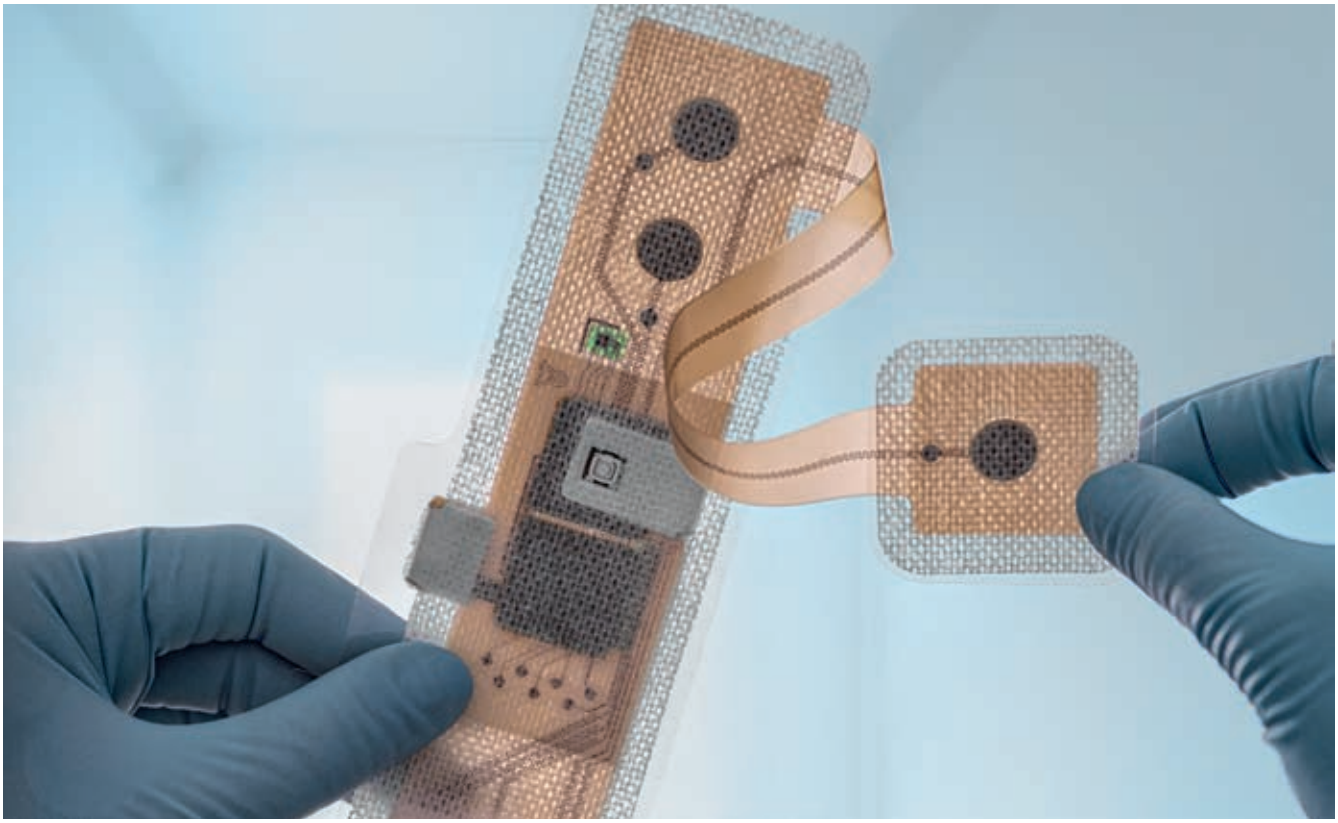
On the EU's ECSEL project APPLAUSE, Fraunhofer IZM developed wafer processes for the hermetic vacuum packaging of large MEMS-based pixel arrays (bolometers) as a core part of an infrared thermal sensor for automotive safety. The devices were hermetically sealed by wafer bonding, using Gold-tin (AuSn) bond rings to join an optical cap onto the sensor and ensure its reliable encapsulation and compatibility in later processing. Both cap and sensor device wafers were specifically prepared for wafer bonding, which enables the simultaneous hermetical sealing of more than 120 sensors on a 200 mm wafer. After dedicated dicing to access the IOs, the sensors were separated for the next integration steps.

360° surveillance of cars allows early identification of obstacles approaching from the side



Wafer-level hermetic vacuum encapsulation by AuSn wafer bonding of a MEMS-based IR imaging sensor

Medical Engineering



Multisensor patch (ECG, PPG, impedance, pneumography, movement) on TPU

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.

A photonic quantum and neuromorphic platform for communications and security applications

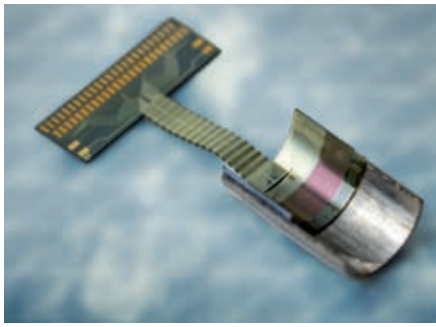
As electronics fabrication technology is coming up against the physical limits, new paradigms are being explored that satisfy the increasing hunger for computing power, e. g. neuromorphic or quantum computing. The EU-funded »PROMETHEUS« project is developing a platform fit for both of those fields. Such a platform requires the co-integration of waveguides, phase shifters, photodiodes, and lasers as well as the packaging and the necessary circuitry to control and use them in practice. Fraunhofer IZM focuses on the design of the electrical interconnects, testing of the fabricated devices, and the assembly and evaluation of the platform.

Smallest batteries for sensor networks

Networks of tiny sensors depend on decentralized energy sources in the form of batteries for wireless data transmission. Based on established technologies for silicon wafer processing, an industrial research partnership is pursuing ways to produce rechargeable li-ion micro batteries with lateral dimensions of less than 1 mm. An automated dispensing process introduces the electro-chemical active materials in the batteries. The finished batteries have a hermetic, corrosion-proof metal encapsulation with a total thickness of < 500 µm. These immensely miniaturized accumulators can be integrated in sensor systems by chip stacking and wire bonding from the top side.

Faster help for people in need of care – Radar technology for tracking movement in space

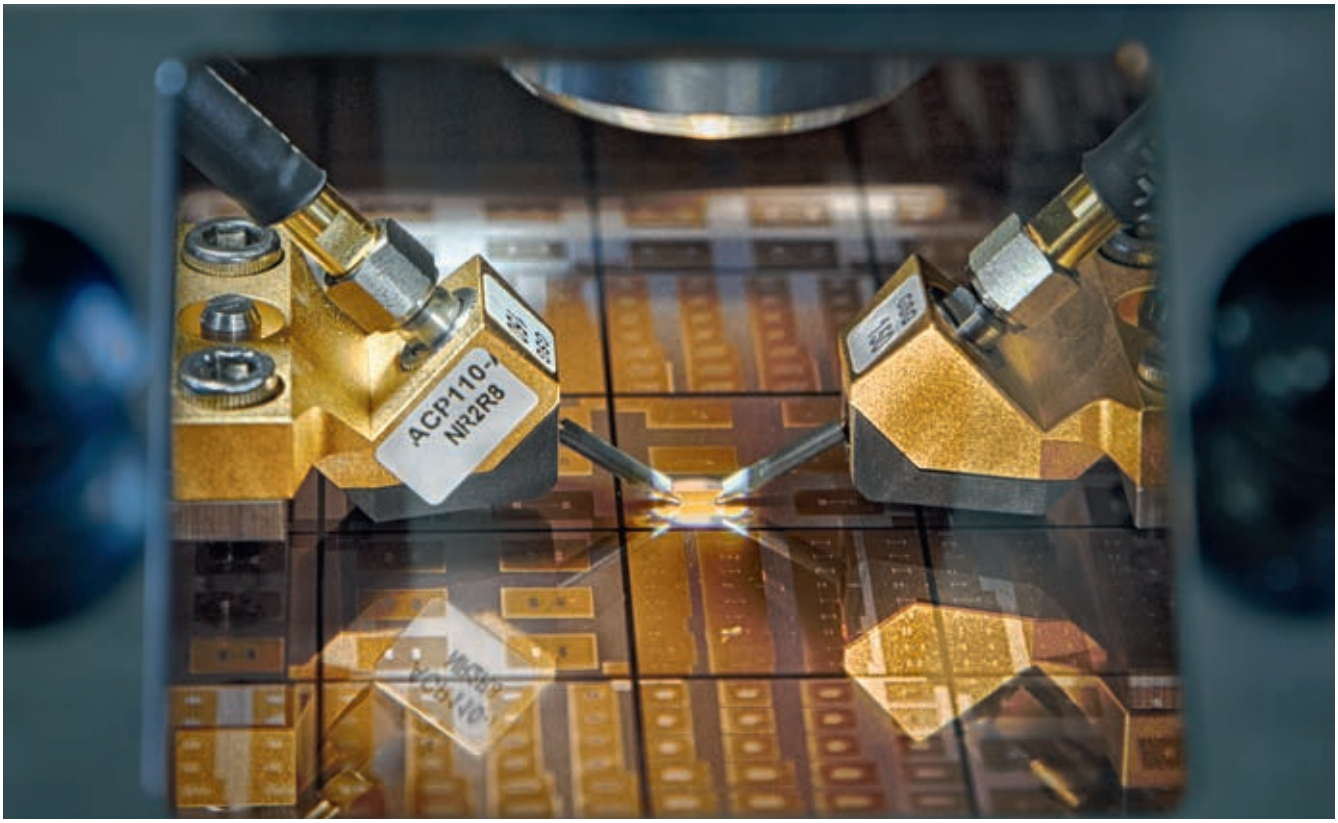
The ability to lead healthy and self-determined lives for longer is becoming more and more urgent as the population ages. Working with partners from science and industry, a radar system was developed that records and evaluates the movement profiles of people in an indoor setting and can notify caregivers where needed, while maintaining privacy. To detect movements, a MIMO radar was miniaturized and integrated into an LED ceiling light developed at Fraunhofer IZM. 360° coverage of the room is achieved by fusing the data from 4 radar modules, and critical motion profiles are created by artificial intelligence algorithms. An angular resolution of 12° enables the tracking of more than 30 persons in a room of up to 150 m².



Implantable nerve cuff – with its bioelectronics lab Fraunhofer IZM is very well equipped for technological developments in the area of medical technology

Polyurethane ceiling unit equipped with four radar modules

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.

Innovative flexible sensor arrays for low emission air traffic

In order to produce lower emission aircraft, European aircraft manufacturers need a high-resolution measurement set-up to determine dynamic pressure fluctuations below the turbulent boundary layer (TBL) on their aircrafts' fuselage. For this purpose, bare-die MEMS microphones with through-silicon vias are soldered onto PI substrates and then laminated into pre-structured TPU. The flexible sensor arrays manufactured in this way have a thickness < 1 mm and can be mounted on curved surfaces without affecting the ability to measure pressure fluctuations in the TBL.

Fine-pitch interconnection technology with nanowire-based Cu / Cu interconnects

Fraunhofer IZM ASSID and NanoWired GmbH are working together to develop a new fine-pitch interconnect technology for 300 mm wafers based on Cu nanowires. The influence of lithography, electroplating, and bonding on the interconnect quality is investigated in the joint Fraunhofer-funded »NanoInt« project. The technology is a potential alternative to hybrid bonding, since the demanding CMP processing with its complex requirements for wafer surface planarity are eliminated. The Cu pads include a forest of Cu nanowires (Ø: 400 nm, length: approx. 5 µm). The interconnect is bonded at room temperature and can be strengthened by annealing. This technology was shown to work for 55 µm pitches and is currently being scaled up to a 10 µm pitch.

Testing of chemicals for wet processing in Cu-RDL-modules

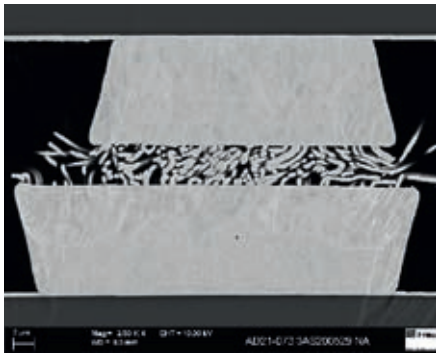
In an industrial cooperation venture, three different chemicals for removing photoresists were tested and investigated with a view to their performance in etching Cu-seeds. The chosen test wafer featured a RDL mask for 300 mm wafer with 10 µm line and 20 µm space as critical dimensions. All three chemicals were tested at different processing temperatures, with and without plasma ash treatment. All tested chemicals showed comparable results. The lowest Cu removal rate was found in the case of SVC-14 stripper, which is more environmentally friendly compared to standard solvents.

Microbumps for new 300 mm calibration wafer

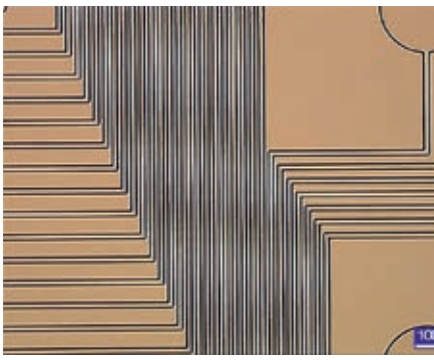
Fraunhofer IZM-ASSID realized a 300 mm calibration wafer for the next metrology tool generation of an industrial partner in Asia. The microbumps had a total Cu/Ni/SnAg stack height of 15 µm with a diameter of 13 µm to match the coming smaller-scale applications in packaging. The project included successful solder reflow, reliable bump adhesion on alumina pads, and more uniform heights over the wafer as a whole.

Project STXMOD – Interposer for HPC applications

Complex calculations like climate models or machine learning algorithms require computing power in the exascale range. This calls for special accelerator cards with fast memory modules and special processors as well as high-speed data buses. In the STXMOD project, a particularly energy-efficient stencil processing ASIC and high-bandwidth memory (HBM memory) are integrated on a silicon interposer to form a processor module for such accelerator cards. At Fraunhofer IZM, the signal and power integrity of the routing on the interposers is investigated. In addition, investigations are being carried out on components with a total of more than 8,000 microbumps for assembly, underfilling, and overmolding.

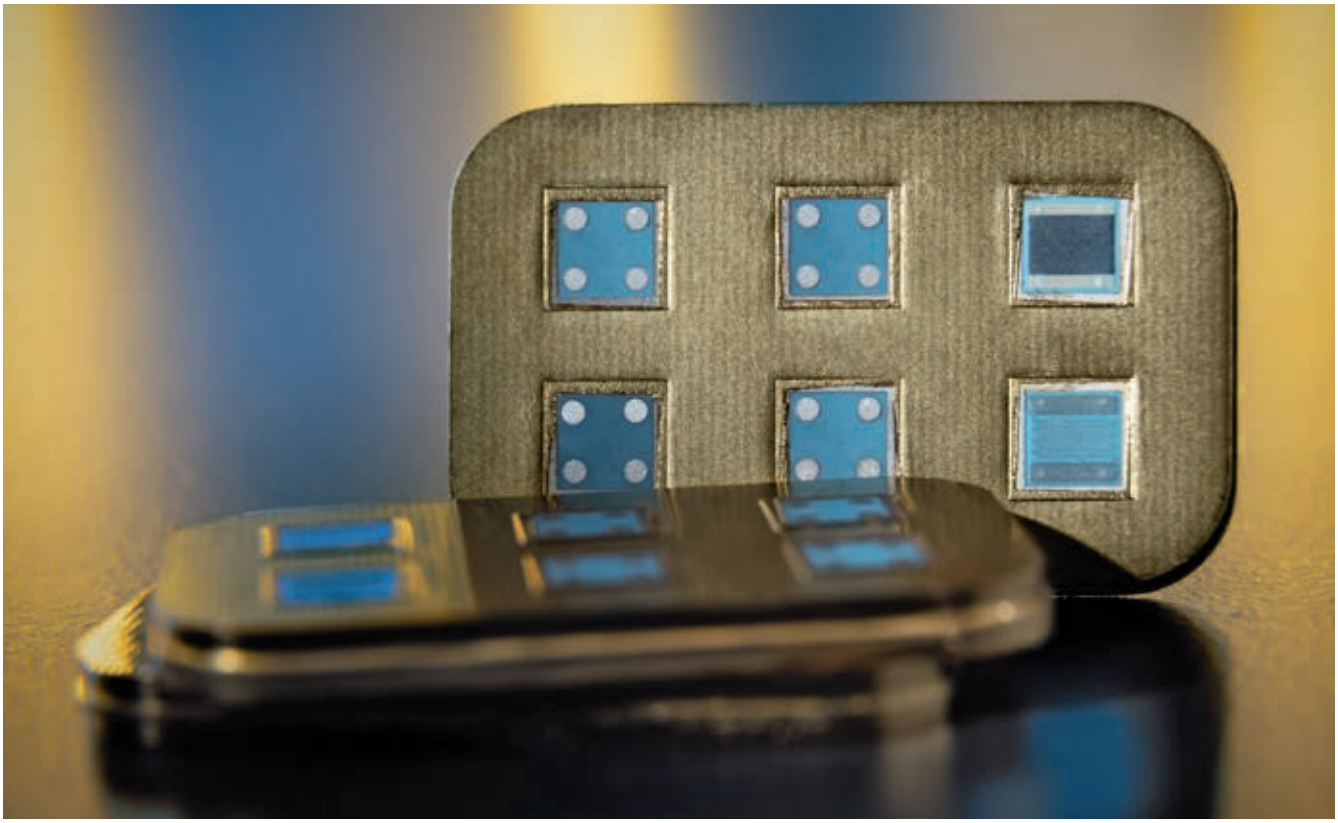


Micro structure of a bonded Cu / Cu nanowire contact



Microscopic investigation of Cu-RDL structures after the etching process

Industrial Electronics



Fully hermetically encapsulated module with embedded high temperature stable ASICs and capacitors in novel PCB laminate

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.

Edge computing replaces the cloud

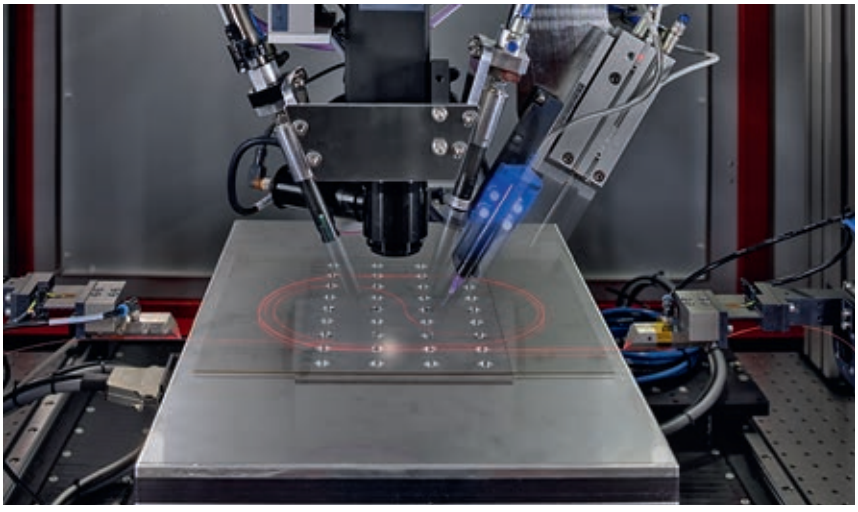
Fraunhofer IZM and its partners from iCampus have developed and implemented a powerful sensor fusion kit for AI-based edge computing as part of the Fortune project. This allows complex signals to be acquired and correlated from different sources, such as microphone or ultra-sonic arrays. The choice of AI-based evaluation algorithms is intended to enable responsive, condition-based maintenance in manufacturing, construction, and transport, in real time and on the move. In particular, Fraunhofer IZM is contributing its expertise in circuit development, power supply via Power over Ethernet (PoE), and the industrial design of communication interfaces and housings. The project is sponsored by the Federal Ministry of Education and Research (BMBF).

Chiplet assembly as a fundamental technology for high performance computing

Chiplet technology is currently being discussed as one of the most important building blocks for future high-performance computing systems. The advantages of chiplets lie their ability to optimize yield through the use of smaller individual chips, improve security through distributed manufacturing/split manufacturing, and optimize cost efficiency by being able to source chiplets from favored foundries. Building on Fraunhofer IZM's existing packaging know-how, comprehensive research work is being carried out in the BMBF-financed CeCaS project, which was launched at the end of 2022, with IFX, Conti, Bosch, Swissbit, and Nanotest among others. It focuses on the system design of central car server chiplet modules on organic interposers, with Fraunhofer IZM's work concentrating on flip chip assembly processes, including the underfilling, and collaborative work on digital twins for CeCaS modules to improve reliability through meaningful manufacturing data.

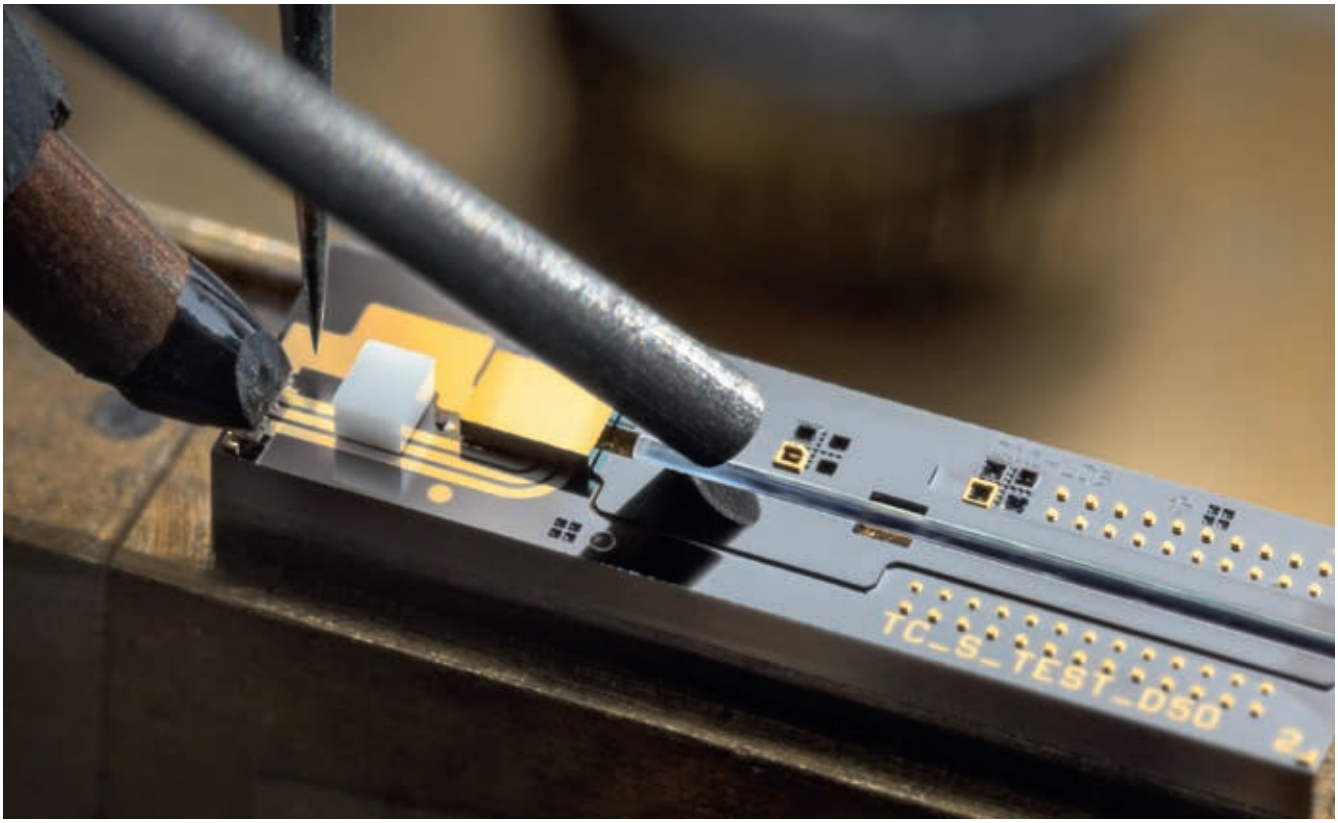
Serial production of large and ultra-thin chips

A new approach for the double-sided processing and assembly of ultra-thin functional wafer/dies (chips) has been successfully developed at Fraunhofer IZM-ASSID. Its innovation lies in the novel handling concept, which allows the application of the process flow on standard tools for 8" to 12" wafers. Changes to the die assembly process in particular respond to the requirements of ultra-thin single dies, e. g. intrinsic stresses in the dies themselves. The process adapted to the new requirements of ultra-thin silicon device wafers and the additional development of a specific assembly process allow the dependable serial production of customer-specific SiPs and have already been implemented in a customer's supply chain.



Measurement of glass integrated waveguides

Information and Communication



Characterization of a 3D Silicon optical bench module passively assembled, including flip-chip InP laser with 3D stoppers

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.

3D passive alignment for photonic applications

As part of the EU-funded APPLAUSE project, Fraunhofer IZM realized 3D substrates as optical benches, specifically a 3D silicon optical bench for the passive alignment of single mode fibers to laser sources for optical transceivers. This requires the accurate placement of all components along a common axis without powering any electronic components (as is done with conventional active alignment) for more cost-effective assembly. A high topography substrate was conceived to enable the precise flip-chip assembly of a laser system using mechanical stoppers, including RF routing lines and flip-chip bumps, and the precise mounting of free space optics to the single mode fiber, clamped in a v-groove.

eSIM beats SIM cards in the eco stakes

Embedded SIMs (eSIM) are an increasingly popular option and have begun to replace traditional SIM cards. A comparative life cycle evaluation was conducted for Giesecke+-Devrient in accordance with the ISO 14040/44 standard and revealed that eSIMs are also the preferred option from an environmental standpoint. The assessment covered the raw materials used in the production as well as the manufacturing, logistics, data provision and transfer, and usage phases, down to the eventual disposal of the products. It also surveyed the components in the end user devices that support the SIM functionality. In sum, eSIMs cause 46 % less harmful emissions over their lives compared to conventional SIMs.

More awareness for carbon footprints among science communicators

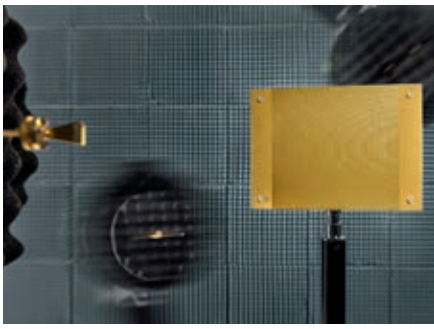
At the IFA 2022 expo in Berlin, Fraunhofer IZM showcased its research in sustainable electronics to the general public: The climate impact of smartphone production was made more immediately tangible in the form of a 35 kg backpack. Looking forward to the planned energy label for smartphones and tablet computers, which draws substantially on the work of IZM researchers, a survey offered important insights for the design of the label. In total, more than 600 attendees visited the exhibit to learn about eco assessments, critical materials, innovative ecodesign concepts, and the planned regulations. Several of the contents produced for the expo will be included in the tour that will take Fraunhofer IZM representatives to several repair café initiatives as part of the scope3transparent project.

Simulation of waveguides in glass

IZM researchers have built models to simulate both the ion exchange for the production of optical waveguides integrated in glass and the resulting optical properties to determine the appropriate process parameters for the intended optical properties. Both models are connected to each other and were written in Python (open source) and optimized to be efficiently usable for inverse photonic design. This will pave the way for optical components in glass that are superior to conventional optically integrated components.

Shaping the future

While the 5 G radio standard is still being rolled out, technologies for the next standard (6 G) are already being investigated on the 6 G RIC project. The increased bandwidth is offset by the higher free-space attenuation in the frequency bands used. Therefore, the radio waves are emitted in a directional manner for reasons of range. Fraunhofer IZM is researching intelligent reflective surfaces (IRS) that deflect these directional beams to the desired location. Such IRS are currently neither commercially available nor yet fully researched. To date, a static IRS prototype has been developed and measured at 150 GHz. The next step will be a switchable IRS.



Measurement of Intelligent Reflecting Surfaces (IRS) for 6G applications

Labs & Services

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 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. Production-ready machines facilitate the transition into industrial production.

- 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

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 microlense 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
- Fs writing processes and thermal ion exchange for integrated optics in glass

Quantum Lab

- 3D glass structuring with selective fs laser etching
- 2PP printing of microoptical interconnects / lenses
- Laser sealing for hermetic cavities (vacuum / gas)
- Automated coupling for quantum chips / PICs
- Characterization of optical fields (SNOM)

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
- Component and assembly qualification in acc. with AEC, IPC, JEDEC

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

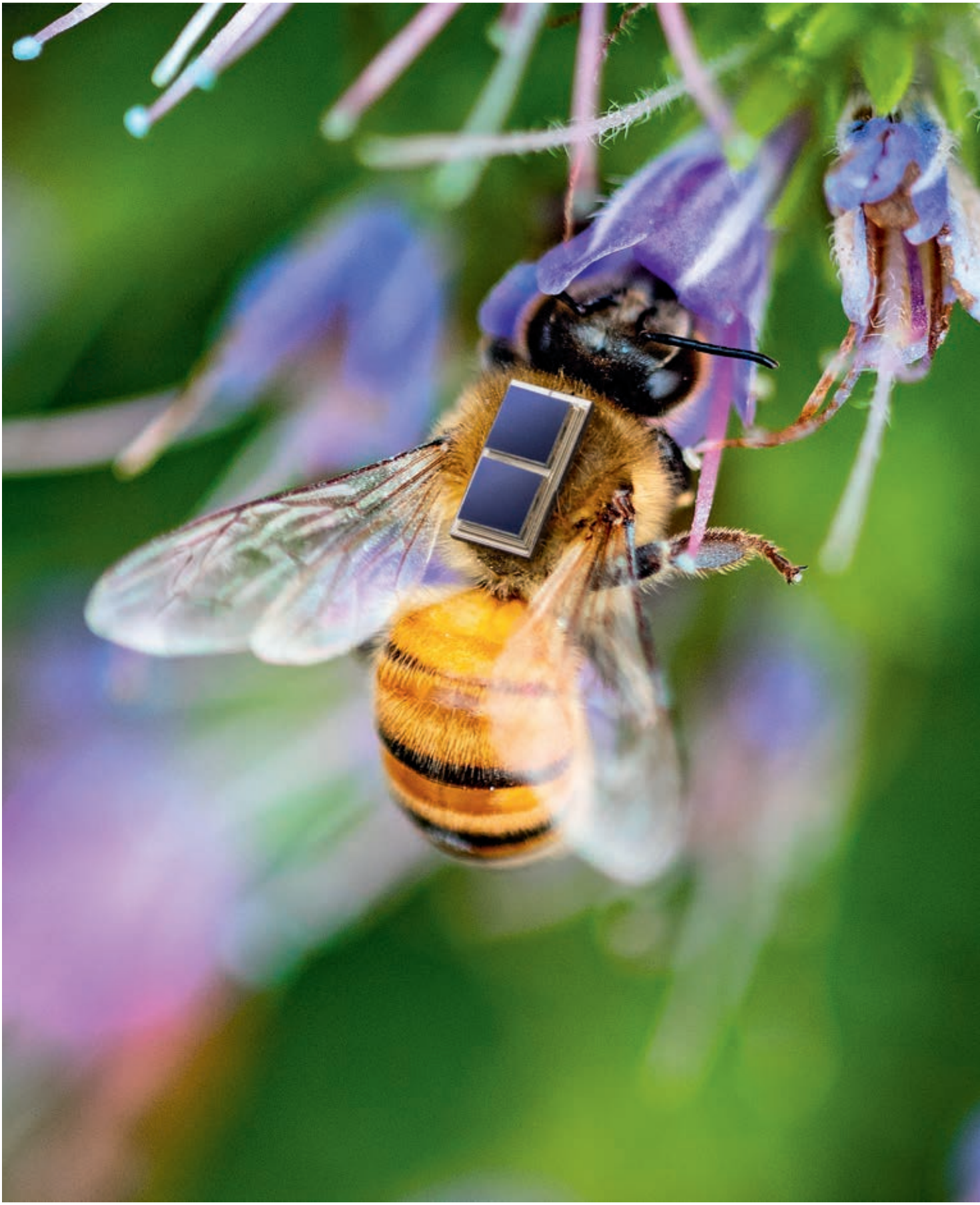
- Free-space measuring station up to 170 GHz, Fabry-Pérot resonators up to 140 GHz and THz system for HF material characterization
- Semi-automatic sample station with thermal chamber (-60 °C to 300 °C)
- EMC and test environment for wireless communication systems in the multi-gigabit and terabit-range
- 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



Events & Promoting Young Talents

In living color!

From San Francisco to Nuremberg or Nottingham – 2022 was the first year since 2019 that the microelectronics community could meet up again live and in person at expos, conferences, and workshops. Some restrictions and regulations still applied, but everybody was looking forward to meeting colleagues and business partners again for some much-needed face time.

Everything back to business as usual, then? Not quite. Some of the new formats tried out in response to the pandemic have proven so successful that they are here to stay in the events repertoire of Fraunhofer IZM. These include the one-hour expert sessions on individual technologies, which will still be offered online because of popular demand.

The next pages will highlight a selection of the events that Fraunhofer IZM has been able to host, contribute to, or attend in person. One special feature of 2022 is the many events created specifically for younger audiences.

The image shows our work for a different kind of young audience: Miniaturized batteries created by Fraunhofer IZM are powering a tiny sensor system that tracks the interactions between bees and can help unravel the causes of bee colony collapses.

The Sens4Bee project: Micro integration of solar cells, miniaturized batteries and sensors to investigate and monitor the well-being of bees and how it is influenced by the environment

Events

Official opening of the Center for Advanced CMOS & Hetero-integration Saxony in Dresden

Launch of the new Semiconductor Research Center in Dresden

7 June 2022 was the day that the Center for Advanced CMOS & Heterointegration Saxony formally opened its doors as a new beacon for semiconductor research in the international community. The Center is headed jointly by Dr. Manuela Junghähnel, Site Director of IZM-ASSID, and Dr. Wenke Weinreich, Deputy Director of Fraunhofer IPMS.

The combination of Fraunhofer IZM-ASSID and Fraunhofer IPMS, specifically the Center for Nanoelectronic Technologies CNT, means that two unique German research organizations focused on microelectronics are active in Saxony. They are Germany's only centers for applied microelectronics research in the field of 300 mm wafer industry standard equipment. Bundling their competences and forming the Center for Advanced CMOS & Heterointegration Saxony creates excellent new prospects for attracting semiconductor enterprises, companies using their systems, and material or technology suppliers to what is known as Silicon Saxony. Together, the two institutes can cover the entire value chain for 300 mm microelectronics, paving the way for more high-tech research into the technologies of tomorrow.

Fraunhofer IZM returns to the expo circuit

As the Corona pandemic began to have less of a hold on our lives over the course of 2022, Fraunhofer IZM finally had a chance to return to many of its usual trade fairs and exhibition slots. Highlights included the three major spring expos PCIM Europe, SMTconnect, and Sensor+Test, hosted in tandem from 10 to 12 May 2022 in Nuremberg. Organizers,

exhibitors, and attendees were all excited to be back in person and get a chance to see new electronics innovations and meet likeminded professionals in living color.

In September 2022, Fraunhofer IZM researchers used the prize money from the Ralf Dahrendorf Prize they had won the previous year to bring an interactive exhibit to IFA in Berlin that allowed visitors to go on a »sustainability safari«. It gave the participants an introduction to the various life cycle stages of a typical smartphone and included an info panel on the new energy label and the environmental impact of selected IT devices.

In the fall of 2022 Fraunhofer IZM also joined two Fraunhofer booths at the Smart Country Convention (SCCON 2022) in Berlin and the electronica expo in Munich. At the Berlin expo for e-government and smart cities, the institute's exhibit covered the recently completed flagship project ZEPOWEL, which saw nine Fraunhofer Institutes showing how sensor systems can operate with extremely minimal power or even completely autonomously and thus help reduce carbon emissions across Germany by up to 20 percent. In Munich, the Institute showcased recent developments in radar sensors, RF technology, and sensor packaging.

The Lord of the Line – Ulf Oestermann has been managing the »Future Packaging« line at SMTconnect for over a decade

Fraunhofer IZM was not only a frequent sight at technical expos. In late November, the Institute also came to the Berlin job fair Connecticum to get students, postgraduates and young professionals excited about a career in science.

Events organized by Fraunhofer IZM (Selection)

Expert Session Series: Advanced Flexible Circuits for Novel Applications	January – May, online
Workshop within the Project »E:Space«: Innovative E-textiles in the Context of New Work	April, Berlin
Opening of the Center for Advanced CMOS & Heterointegration Saxony	June, Dresden
4th Panel Level Packaging Symposium	September, Berlin
Conference: ESREF 2022	September, Berlin
Workshop: APPLAUSE Heterogeneous Integration Summer School	September, Berlin
Workshop: Reliability of Electronic Systems	November, online & Berlin
Public Hearing on »Digitization and Sustainability« in the German Bundestag	November, Berlin
Online Workshop: »Drone Technology in the Logistics Industry«	November, online
Online Session: IZM Photonics: In Optical Interconnects We Trust	December, online

Research prize recipient Lars Böttcher with IZM Director Prof. Martin Schneider-Ramelow and the head of the award jury, Dr. Nils F. Nissen

On your bike! IZM staff pedaling for a better climate

»Stadtradeln« is a German campaign to promote cycling as a key ingredient for a healthier climate and a happier life. Several years ago, cyclists from all sites of Fraunhofer IZM (Berlin, Dresden, Cottbus) started taking part in the challenge to collect as many miles as possible. They can form internal teams to add an element of intra-institute competition or simply enjoy the group outing that is part of every year's Stadtradeln. And whether they went for an ambitious cycling tour of Flanders or simply tried to beat their personal best going around Berlin: More and more Fraunhofer IZM colleagues have joined over the years – bringing the Institute's Stadtradeln team to 57 people in 2022 and clocking up an amazing 13,103 km.

Fraunhofer IZM Research Award

Fraunhofer IZM has been awarding its Research Prize for over two decades in recognition of »exceptional research achievements in the field of microelectronics, microsystems technology, and packaging« to champion research excellence and its translation into developments relevant for industry.

Six of the 57 IZM colleagues taking to their bikes for a better climate in 2022

The prize for 2021 went to Lars Böttcher for his work on embedding chips in circuit boards. The Corona restrictions meant that the actual award ceremony had to be postponed to 23 June 2022, when it could be handed over to the proud recipient in a gala event. After the official proceedings ended, sand artist Polina took the guests on a virtual tour of Lars Böttcher's work, imagining his research achievements in a sequence of images that she created in front of the live audience with her chosen medium: Sand.

4th Panel Level Packaging Symposium

In 2016, Fraunhofer IZM began cooperating with a group of leading industry partners from Europe, the United States, and Japan to develop the fundamental processes for new panel level packaging technologies that are being transitioned into full series production. The Institute and its 17 partners completed the second phase of this Panel Level Consortium (PLC 2.0) last year and marked this occasion with the first in-person get-together since the pandemic.

The final meeting of the Consortium on 7 September 2022 was followed by the 4th Panel Level Packaging Symposium, which saw experts from industry and research speaking about the status quo, recent advances, and the limitations of panel level packaging. After the talks, the more than seventy attendees were given an exclusive tour of the lab facilities of Fraunhofer IZM.

Celebrating a successful ESREF 2022

From 26 to 29 September 2022, Fraunhofer IZM hosted the 33rd European Symposium on Reliability of Electron Devices, Failure Physics and Analysis (ESREF) at the H4 Hotel Berlin Alexanderplatz. The focus of the international symposium was the recent developments and future prospects for quality and reliability management concerning the materials, components, and circuits in micro, nano, and optoelectronics. Three keynotes, three tutorials, four invited talks, a special workshop organized by the »Velektronik« project, and a Summer School meant an exciting

and rich schedule for the 320+ visitors from across the world. They had their pick of 84 lectures in 18 sessions as well as 30 poster exhibits. The attendees could use their breaks to visit the accompanying exhibition, where 21 well-known companies from the industry showed off their products and services. The conference also left lots of opportunities for networking, not just informally during the breaks, but also at the dedicated conference dinner in the attractive environs of the Wasserwerk.

Following ESREF, the APPLAUSE community of partners from industry and research conducted a summer school specifically for doctoral students. More than 30 young scientists joined the »APPLAUSE Heterogeneous Integration Summer School« for the many interesting classes.

Online session series »Advanced Flexible Circuits for Novel Applications«

In the online sessions on »Advanced Flexible Circuits for Novel Applications«, Fraunhofer IZM presented its longstanding experience with flexible circuit boards and showcased the latest research results and cooperation opportunities. Six expert talks covered specific subjects like reliability, electronic textiles, miniaturized low-power IoT nodes, high-density thin film flex, conformable electronics, or radar systems. The sessions were met with great approval among attendees from industry, science, and politics. Altogether, around 350 people joined the 45-minute online sessions between January and May 2022.

Researchers from all over the world met at ESREF 2022 to discuss quality and reliability management in microelectronics

Events with Fraunhofer IZM participation (Selection)

SPIE Photonics West 2022	January, San Francisco (USA)
CIPS 2022	March, Berlin
Smart Systems Integration 2022	April, Grenoble (FR)
LASER World of PHOTONICS 2022	April, Munich
PCIM Europe 2022	May, Nuremberg
SMTconnect 2022	May, Nuremberg
SENSOR+TEST 2022	May, Nuremberg
NBT Berlin	May, Berlin
ECTC 2022	May, San Diego (USA)
embedded world 2022	June, Nuremberg
Techtextil 2022	June, Frankfurt/Main
IFA 2022	September, Berlin
ESTC 2022	September, Sibiu (RO)
InMotion	September, online & Weimar
Smart Country Convention 2022	October, Berlin
E-Textiles 2022	November, online & Nottingham (UK)
electronica 2022	November, Munich
connecticum 2022	November, Berlin

Online workshop »Drone Technology in the Logistics Industry«

Drones have left their beginnings as experimental designs or design studies behind them and have long since proven themselves as systems suitable for everyday use. For the next leap in development, the step must now be taken from basic drone technology to individual applications to holistically optimized system solutions.

On 30 November 2022, more than 30 members of the audience took part in an online workshop to learn about possible applications in logistics and their requirements for the technology. Fraunhofer IZM focused on presenting novel solution ideas for radar sensors and the fusion of sensor data in this workshop jointly organized with three other Fraunhofer institutes (FKIE, IFF, FHR).

Promoting Young Talents at Fraunhofer IZM

IZM researcher and green ICT expert Dr. Nils F. Nissen speaking in the Bundestag's Digital Affairs Committee

IZM expertise in the German Bundestag

On 28 November 2022, the German Bundestag's Digital Affairs Committee held a public hearing on the topic of »Digitization and Sustainability«. Joining the panel as an expert on Green ICT was Dr. Nils F. Nissen from Fraunhofer IZM. The hearing examined how ecological data centers and transmission networks are and what framework conditions are needed for climate-neutral data centers. The committee is also looking at the opportunities and challenges of data use, artificial intelligence, and software design for combating the climate crisis and ecological sustainability.

Seminar on the »Reliability of Electronic Systems«

Due to shorter development times and higher demands on electronic components and systems, reliability assessments are constantly gaining importance. Fraunhofer IZM's »Environmental and Reliability Engineering« department has many years of experience in this field. For the last four years, participants from industry have been introduced to the relevant methods and tools along the product development process in a two-day seminar.

The last »Reliability of Electronic Systems« seminar was held on 10 and 11 November 2022 and included four sessions as well as workshops and lab tours. No fewer than nine experts took part to navigate the 13 participants through the English language seminar – virtually and on-site.

For more than two decades, Fraunhofer IZM has been committed to investing into its future and inspiring young people for a life in science. To create more awareness of and generate interest in the work of the Institute, internship and training opportunities, and available places for a voluntary ecological year, Fraunhofer IZM took part in the 2022 Girls' Day, exhibited at the connecticum job fair, and took the ten, mostly teenage winners of INVENT a CHIP for an exclusive tour of its facilities. These and more job marketing activities meant that the Institute was flooded with requests for internships and apprenticeships.

Excellent opportunities for interns and trainees

No fewer than 27 school interns meant a record year for Fraunhofer IZM, not least due to the backlog of internships from the Corona years. In their internships, young people are introduced to the basics of electronics and get to know the work in the laboratories as well as the specific job profiles of microtechnologists, chemical lab technicians, or materials testers. Fraunhofer IZM is also active in Berlin's EnterTechnik project, which allows young women to experience work life at several organizations after school and discover different technical jobs. The Institute welcomed two interns interested in a microtechnologist career as part of that project.

Fraunhofer IZM also continues to promote dual vocational degrees: In 2022, two apprentices completed their training in microtechnologies and were immediately offered contracts to stay with the Institute. Three more apprentices have followed in their places, and Fraunhofer IZM has also agreed to supervise another apprentice as part of a joint training agreement. Since the Institute is

committed to excellence in vocational training, Fraunhofer IZM is also active in the proANH e. V. association and supports the High Technology Training and Education Network, set up to promote dual apprenticeship schemes in MINT fields in Germany's capital.

A voluntary ecological year at Fraunhofer IZM: It's all about sustainability

The »Environmental and Reliability Engineering« (ERE) unit of Fraunhofer IZM gives young people the opportunity to complete a voluntary ecological year at the Institute. As more and more aspects of modern life are governed by electronics, the unit is dedicated to the environmental side of microelectronics and works on concepts to improve the energy efficiency and environmental record of electronic systems or components. In 2022, Fraunhofer IZM welcomed two young volunteers for their year who had a chance to contribute to projects on energy efficiency in mobile communication and a circular economy for critical resources.

Hands-on microelectronics at the 2022 Girls' Day at Fraunhofer IZM

In 2000, the Berlin Chamber of Commerce initiated the School-Business Partnership initiative that has to date led to around 400 successful cooperation ventures. One of these started five years ago and is still going strong: The partnership with the Gabriele-von-Bülow Gymnasium. Fraunhofer IZM not only came to the school with an electronics DIY kit exhibit for the school's open day, it also opened its own doors to welcome twelve girls from the school for the 2022 Girls' Day.

With the recently relaxed Corona precautions, the Girls' Day allowed a close-up insight into the IZM labs and cleanrooms. The day started by bringing the attendees up to speed with the basic theory and main terms of microelectronics and the applications being researched at Fraunhofer IZM. The twelve participants could then take a close look at wafers, circuit boards, and other exhibits in the showroom and were excited to hear about the many areas these are used in.

The day's proceedings continued with a hands-on lab introduction, giving the visitors a first-hand experience of a day in the life of a microelectronics researcher, with several IZM researchers on hand to help the girls. They had an opportunity to lay out a circuit by themselves, to see a wafer being etched, and to experience the chemical lab from the inside. After lunch, the group was taken on a tour of the cleanroom facilities to learn how a low-particulate room is defined and what this means in practice when suiting up for work.

Before they received a small souvenir of their visit, the visitors had a chance for some quick feedback: »It was great to be able to do so much ourselves and to get a real insight into how you work at the Institute«, Mila said about her day at Fraunhofer IZM.

Every Girls' Day's highlight: A visit to the cleanroom

Facts & Figures

Fraunhofer IZM in Facts and Figures

Financial situation

2022 was a year of growth and consolidation for Fraunhofer IZM. The Institute managed to again increase its revenue, growing by 2.8 percent to €39.6 million. Over the year, Fraunhofer IZM covered 75.5 percent of its operating budget with third-party funds. All in all, externally funded projects increased to a volume of €29.9 million.

Public funding for projects increased to €14.7 million, representing an increase of 9.1 percent over the previous year. These public projects often produce new insights and expertise that can be built on and used in later commercial projects on industrial applications.

Earnings from work with domestic and industrial industry partners and associations remained stable at €15.2 million in 2022. This means that Fraunhofer IZM covered 38.3 percent of its operating costs with direct commercial projects.

Hardware investments

In 2022, €3.3 million of the Institute's assets were used for hardware replacement and maintenance investments. These were used to improve the facilities of Fraunhofer IZM with several targeted investments and to improve the efficiency of the established facilities.

A further million euros was spent on several smaller construction projects, introducing changes and specific improvements to optimize the performance of the Institute and comply with current health and safety requirements.

With the support of the State of Saxony, expansion work continued on the Dresden site of the Institute, with Fraunhofer IZM investing €2.6 million for the purpose in 2022. The aim of this project is to upgrade the research infrastructure in Saxony for 300 mm 3D wafer-level semiconductor integration as a development platform for hardware components and quantum computing applications.

Human resources

The positive trends in external funding mean that the workforce at all IZM sites in Berlin, Cottbus, and Dresden/Moritzburg could be increased to 301 people.

Fraunhofer IZM offers students many opportunities to combine their degree courses with applied scientific work in the offices and laboratories of Fraunhofer IZM. At the end of 2022, 121 student interns, bachelor and master dissertation researchers, and undergraduate assistants were placed at Fraunhofer IZM.

Fraunhofer IZM is committed to offering vocational training to young people. In 2022, eight apprentices were in training as microtechnologists, surface coating specialists, and office management assistants.

Fraunhofer IZM in 2022

Budget	39.6 million euros
External revenue	29.9 million euros (75.5 percent of total turnover)
Sites	Berlin, Cottbus and Dresden/Moritzburg
Laboratories	> 8,000 m²
Staff	430 (including 121 student assistants, master students, interns and 8 apprentices)

Awards

Alireza Rezaei honored at the PCB Design Awards

The Electronics Design and Manufacturing Association (FED) presented the PCB Design Awards 2022 for the sixth time at its annual conference in Potsdam, Germany. The award, sponsored by the FED, recognizes PCB designers for outstanding work every two years. A panel of six experts judges the designs in terms of technical merit, manufacturability and documentation.

Our IZM colleague Alireza Rezaei took 2nd place in the »3D/Component Design« category for his work on the Fraunhofer lead project ZEPOWEL (Towards Zero Power Electronics). In this project, nine Fraunhofer institutes successfully demonstrated how sensor systems can consume extremely little power or function completely autonomously, thus saving up to 20 percent of carbon dioxide emissions nationwide.

IZM researcher Alireza Rezaei (left) receiving the PCB Design Award in Potsdam

IZM Communication Prize awarded to Manuel Bäuscher

Alongside the Research Award presented at the ceremony on 23 June 2022, Fraunhofer IZM has awarded its first communication prize in recognition of special achievements in communicating the Institute's work to the wider public. The prize's first recipient is Manuel Bäuscher, a researcher whose exceptional work in publicizing the work of Fraunhofer IZM won in the »Demonstrator« category. Bäuscher and his team developed a graphene oxide quick test for a range of biomarkers in blood samples. The exhibits and illustrations he produced for the GraphPOC project were praised for their creativity, persuasiveness and relevance for society.

iNEMI Project Leadership Awards for two projects with Fraunhofer IZM participation

At its annual Members' Council meeting in July 2022 the International Electronics Manufacturing Initiative (iNEMI) presented its first ever »Project Leadership Awards« to five selected projects. These projects stood out for achieving excellence in electronics manufacturing, outstanding technologies or results, or positive impact on the electronics manufacturing value chain and its ecosystem.

Among the five awards, no less than three Fraunhofer IZM employees from the »Environmental and Reliability Engineering« (ERE) department were involved in two of the honored projects. In the project »Eco-Design Best Practices for a Circular Electronics Economy« Karsten Schischke was part of a team that developed an interactive webinar series with recommendations for the transition to a circular economy. Furthermore, experience reports and innovative approaches in the field of eco-design were provided.

Saskia Huber and Olaf Wittler contributed their expertise in the field of deformation of materials, substrates, components and assemblies to the project »Package Warpage Prediction and Characterization, Phase 5«. Together with their team they furthered iNEMI's work on dynamic warpage of advanced packaging technologies by identifying the need for a model for shrinkage strain and then developing this model themselves.

The ESTC 2022 Best Paper Award goes to Steffen Bickel

This year's Electronics System Integration Technology Conference (ESTC 2022) brought 350 attendees from 28 countries to the central Romanian city of Sibiu from 13 to 15 September. Among them, our colleague Steffen Bickel, researcher at Fraunhofer IZM-ASSID in Dresden, won the Best Paper Award for his contribution on »Metallurgical Aspects and Joint Properties of Cu-Ni-In-Cu Fine-pitch Interconnects for 3D Integration«.

In his paper, he investigates the kinetic mechanisms at work during phase formation at the nickel indium border, a space of only a few micrometers in size that is critical for the creation of electrically and mechanically reliable interconnects. His insights are already being used for the production of intermetallic fine-pitch interconnects that show the potential and the limitations of the nickel barrier.

The ESTC is acknowledged as an important date in the calendars of researchers and industry representatives interested in the latest developments in packaging and interconnect technology. The biennial conference has been organized by the IEEE Electronics Packaging Society ever since 2006.

Prof. Martin Schneider-Ramelow, Christina Lopper and Dr. Michael Schiffer

Rolf Aschenbrenner honored with the IEEE Region 8 Award

As part of ESTC 2022, another award went to a member of the IZM team: Rolf Aschenbrenner, head of the »System Integration & Interconnection Technologies« department won the IEEE Region 8 Award in Sibiu in recognition of his excellent contribution to strengthening the impact and development of the EPS program. With the award, the hosts drew particular attention to Rolf Aschenbrenner's contributions in the field of electronic packaging and system integration in Europe in the form of his technical expertise, his contributions at international conferences, and his active presence in the communities in the field.

Fraunhofer IZM-ASSID awarded the Siemens Healthineers »Technology & Innovation« prize

Every year since 2017, Siemens Healthineers has been hosting the Global Supplier Day. At last year's event on 22 June, awards were given out by Siemens Healthineers for excellent suppliers as a sign of appreciation for strategic partners and key suppliers. The award for the »Technology & Innovation« category went to Fraunhofer IZM-ASSID for its many years of reliable cooperation with Siemens Healthineers and production of electronic components for power converters.

»BestChance« Award 2022 goes to Fraunhofer IZM

For their commitment to providing effective support for female students at Fraunhofer IZM, Christina Lopper and Michael Schiffer have been honored with the »BestChance« award for 2022. The award was presented on 8 November 2022 as part of the 17th networking day of the Equal Opportunities Representatives, again hosted in virtual form. Professor Albert Heuberger, Director of Fraunhofer IIS in Erlangen and speaker of the Microelectronics Association, praised the recipients of the award in his speech; the actual presentation of the €3,000 prize was taken over by Professor Martin Schneider-Ramelow, Director of Fraunhofer IZM, on site in Berlin.

Christina Lopper had recognized that women have long been underrepresented at all levels of the Fraunhofer IZM, prompting her to investigate the causes in conversations with students leaving the Institute. One of her findings was that many of the female students were missing a meaningful link between their practical work at the Institute and their study topics. They lacked prospects and were rarely spoken to about possible career opportunities and conditions. Christina Lopper also asked herself whether female students at the Institute should be more visible and more effectively employed as an important talent pool in times of constrained labor markets. Her idea was the creation of a dedicated support program for female students – Young Research Talent Class »Women in Science«, developed by Christina Lopper and Michael Schiffer and run by her ever since.

Best Paper, Dissertations, Editorials

Best Paper

Marius van Dijk honored with Outstanding Paper Award at EuroSimE 2022
Congratulations to our IZM colleague Marius van Dijk: For the paper »Numerical Simulation of Transient Thermomechanical Ageing Effects« he and his co-authors Saskia Huber, Hans Walter, Olaf Wittler and Martin Schneider-Ramelow were honored with the Outstanding Paper Award at this year's EuroSimE Conference. For the award-winning paper, van Dijk and his colleagues investigated aging effects in printed circuit boards used for 5G and radar applications. PCB samples were aged at 175°C and changes were diagnosed using material characterization techniques. Using finite element analysis, the IZM researchers developed a method to continuously describe the material changes, i.e. the aging process. This enables a more realistic assessment of reliability.

Lars Stagun wins the Best Presentation Award at the IMAPS Fall Conference
At this year's IMAPS Germany Fall Conference in Munich, Lars Stagun, research assistant at the Technical University of Berlin, was honored with the Best Presentation Award on 21 October 2022. Stagun received the award for his contribution on »Adhesive Bonding – Reliable Integration of Electronics Modules in Textiles« that investigated the means to integrate electronics in textile objects. For the evolution of smart textiles, Stagun and his colleagues from Fraunhofer IZM needed to achieve the robust integration of electronics in textile substrates. In his paper, Stagun explored the adhesive bonding technology that works without soldering or crimping for the mechanical and electrical integration of modules in fabrics in a single step.

Dissertations

Hofmann, Florian
»Circular Business Model – Notion of Sustainability, Organizational Transition Management, and Experimentation Capabilities«

Javaheri, Ehsan
»Qualification of the Instrumented Indentation Technique for the Parameter Identification of Welded Advanced High Strength Steels«

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

Mackowiak, Piotr
»Technologieentwicklung und Charakterisierung von Through SiC Vias (TSiCV)«

Masuzawa, Takashi
»Modeling of Stray Magnetic Couplings in Power Electronic Devices«

Popov, Mikhail
»Contact Mechanics and Dynamics of Frictional Systems under Oscillation«

Schmid, Maximilian
»Weiterentwicklung der transienten thermischen Analysen für Leistungs-Halbleiter«

Sirbu, Bogdan
»Hybrid Metallo-dielectric Grating Couplers for Unidirectional Excitation of SOI Waveguide Modes«

Sokolov, Aleksei
»On the Wave Nature of Thermal Transport in Low-dimensional Lattices: From the Atomistic to the Continuum Perspective«

Editorials

Bioelectronic Medicine Journal
Giagka, V. (Associate Editor)

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

Lectures

Aalborg University

Prof. Dr. Eckart Hoene
- Design of Modern Power Semiconductor Devices
- EMC in Power Electronics

BTU Cottbus-Senftenberg

Prof. Dr. M. Jaeger-Erben
- BTU4Future – Climate Protection and Sustainable Development
- Introduction to Technology and Environmental Sociology
- Interdisciplinary Foundations Course: The Scientific Method
- Sociology
- Sociology of Sustainable Development
- Transdisciplinary Sustainability Research

Delft University of Technology

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

Dresden University of Technology

Jun.-Prof. Dr. I. Panchenko
- 3D System Integration and 3D Technologies
- Micro-/Nanomaterials and Reliability Aspects (Practical Course)
- Micro-/Nanomaterials and Reliability Aspects (Lecture)
- Advanced Course: Packaging and Interconnection Technologies
- Materials and Reliability

German International University Berlin

Dr. T. Tekin
- Sensor Technology

Technical University of Berlin

Dr. P. Mackowiak
- Technologies and Materials for Microsystems Technology

Prof. Dr. W. H. Müller
- Hands-on Project to Finite Element Analysis (Project)
- Hands-on Project to Finite Element Analysis (Lecture)
- Kinematics and Dynamics
- Structural Engineering and Basic Strength of Materials

Dr. N. F. Nissen, Dr. A. Middendorf
- Ecodesign for Electronic Systems

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

Dr. O. Wittler, Dr. J. Jaeschke
- Reliability of Integrated Electronics Systems

University of Applied Sciences for Engineering and Economics in Berlin

M. Bäuscher, M. Hubl
- BioMEMS

M. Hubl
- Bionics

Dr. H. Walter
- Materials for Microsystems Technology

Cooperation with Universities (Selection)

Some of Fraunhofer IZM's university partners

Aalborg University, Denmark
Aalto University, Finland
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 College London, Great Britain
University of Quebec in Trois-Rivières, Canada
University of Tokyo, Japan
University of Utah, USA
University of Zurich, Switzerland

Berlin University of the Arts
Bielefeld University
Bundeswehr University Munich
Chemnitz University of Technology
Heidelberg University
Humboldt University of Berlin
Otto-von-Guericke University Magdeburg
Rhenish Friedrich Wilhelm University of Bonn
Technische Hochschule Ingolstadt
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 bring their innovative ability and competence in basic research to the table, Fraunhofer contributes excellence in applied research as well as outstanding technical infrastructure.

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. Since 2021, Professor Martin Schneider-Ramelow has been heading 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. Since February 2023 IZM department head Prof. Ivan Ndip has held the chair for for Antennas and Radio Frequency Systems Integration. 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 Fine-Techno USA Corporation	Cupertino, CA (USA)
Ajinomoto Group	JP, USA
Amkor Technology, Inc.	Tempe, AZ (USA)
AMO GmbH	St. Peter am Hart (AT)
ams AG	Premstätten (AT)
Amsterdam Scientific Instruments B.V.	Amsterdam (NL)
AnSem NV	BE
AT&S Austria Technologie & Systemtechnik AG	Leoben (AT)
AUDI AG	Ingolstadt (D)
Baker Hughes Inteq GmbH	Celle (D)
BASF SE	Ludwigshafen am Rhein (D)
Berliner Nanotest und Design GmbH	Berlin (D)
BMW AG	Munich (D)
Bosch Semiconductor Manufacturing	Dresden (D)
Brewer Science, Inc.	Rolla, Missouri (USA)
Carl Zeiss SMT GmbH	Jena (D)
CERN	Meyrin (CH)
Contag GmbH	Berlin (D)
Corning Inc.	Corning, NY (USA)
Delo GmbH	Windach (D)
DeltaHeat GmbH	Berlin (D)
DISCO Corporation	JP
DResearch	Berlin (D)
DuPont de Nemours, Inc.	Wilmington, DE (USA)
DuPont Electronics & Imaging	Marlborough, MA (USA)
DustPhotonics	IL
Evatec AG	Trübbach (CH)
FACEBOOK TECHNOLOGIES, LLC	Menlo Park, CA (USA)
FIRST SENSOR	Berlin (D)
Fujifilm Electronic Materials	EU, USA
GEFRAN S.p.A.	Provaglio d'Iseo (IT)
GLOBALFOUNFRIES INC.	Dresden (D)
Heraeus	Hanau (D)
IMASENIC Advanced Imaging S.L.	Barcelona (ES)
Intel Corporation	USA
KSG GmbH	Görnsdorf (D)
LTB GmbH	Radebeul (D)
Malvern PANalytical B.V.	Almelo (NL)
Meltex Inc.	Tokyo (JP)
MENNEKES Elektrotechnik GmbH & Co. KG	Kirchhunden (D)
Merck KGaA	Darmstadt (D)
Micro Systems Engineering GmbH	Berg (D)
Multi Channel Systems MCS GmbH	D
Nagase ChemteX Corporation	Osaka (JP)
Nexperia	Nijmegen (NL)
NEXT FUEL R&D LTD	Neve Yamin (IL)
NKG	JP
OSYPKA AG	D
Picosun Oy	Masala (FI)
Pilz GmbH & Co. KG	Hamburg (D)
Plath	Ostfildern (D)
POSIC S.A.	Colombier (CH)
RENA Technologies GmbH	Gütenbach (D)
Robert Bosch GmbH Zentrum für Forschung und Vorausentwicklung	Renningen (D)
Rolls-Royce Deutschland Ltd & Co KG	Cottbus (D)
Saltec GmbH	Salzhausen (D)
Schaeffler AG	Herzogenaurach (D)
Schlumberger	Paris (FR)
Schmoll Maschinen GmbH	Rödermark (D)
Semsysco GmbH	Salzburg (AT)
sensiBel AS	Oslo (NO)
Shōwa Denkō Materials Co. Ltd	Tokyo (JP)
Siemens AG	Berlin (D)
SLAC National Accelerator Laboratory	Menlo Park, CA (USA)
Süss MicroTec SE	Garching, München (D)
Swissbit Germany AG	Berlin (D), Broschhofen (CH)
TEN Thüringer Energienetze GmbH & Co. KG	Erfurt (D)
Texas Instruments	München (D), London (GB)
Thales	FR
The Chemours Company	Wilmington, DE (USA)
United Monolithic Semiconductors (UMS)	Villebon-sur-Yvette (FR)

Memberships (Selection)

AMA Fachverband Sensorik, Wissenschaftsrat	H. Pötter	Member
Cluster Optik BB, Photonik für Kommunikation und Sensorik	Dr. H. Schröder	Spokesman
Deutsche Keramische Gesellschaft	Dr. M. Junghähnel	Member
Deutscher Verband für Schweißtechnik DVS	Prof. Dr. M. Schneider-Ramelow	Representative of Fraunhofer IZM
Deutscher Verband für Schweißtechnik DVS Arbeitsgruppe »Bonden«	Prof. Dr. M. Schneider-Ramelow	Chairman
ECPE Competence Centre	Prof. Dr. M. Schneider-Ramelow	Member
EFDS – Europäische Forschungsgesellschaft Dünne Schichten e. V.	Dr. M. Junghähnel	Member
Wissenschaftlicher Beirat des EFDS	Dr. M. Junghähnel	Elected Member
Fachausschuss »Beschichtungstechnologien für optische und elektronische Funktionalisierung – FABF	Dr. M. Junghähnel	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, Board Member
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 Region 8 Program Director	Dr. T. Braun	Senior Member
IEEE EPS TC Material & Processes	Dr. T. Braun	Member
IEEE EPS to Board of Governors	Dr. T. Braun	Elected Member-at-Large
IMAPS International Microelectronics Assembly and Packaging Society	Prof. Dr. M. Schneider-Ramelow	Fellow
IMAPS Deutschland	Prof. Dr. M. Schneider-Ramelow	President
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International Conference on Coatings on Glass and Plastics (ICCG)	Dr. M. Junghähnel	Board Member
IVAM Fachgruppe Wearables	E. Jung	Technical Chair
Organic Electronics Saxony (OES)	J. Haberland, E. Jung	Representatives of Fraunhofer IZM
Photonics 21	Dr. R. Jordan	Board of Stakeholders
Photonics West Optical Interconnects Conference	Dr. H. Schröder	Chair
PLASMA GERMANY	Dr. M. Junghähnel	Elected Expert
SEMI ESiPAT Group	Dr. T. Braun	Member
Silicon Saxony e. V.	Dr. M. Junghähnel	Member
Strategischer Arbeitskreis Silicon Germany	Prof. Dr. M. Schneider-Ramelow	Member
Wissenschaftlich-technischer Rat der Fraunhofer-Gesellschaft	Dr. M. Hampicke	Representative of Fraunhofer IZM

Publications (Selection)

Bakhshaee Babaroud, N.; Palmar, M.; Velea, A. I.; Coletti, C.; Weingaertner, S.; Vos, F.; Serdijn, W. A.; Vollebregt, S.; Giagka, V.
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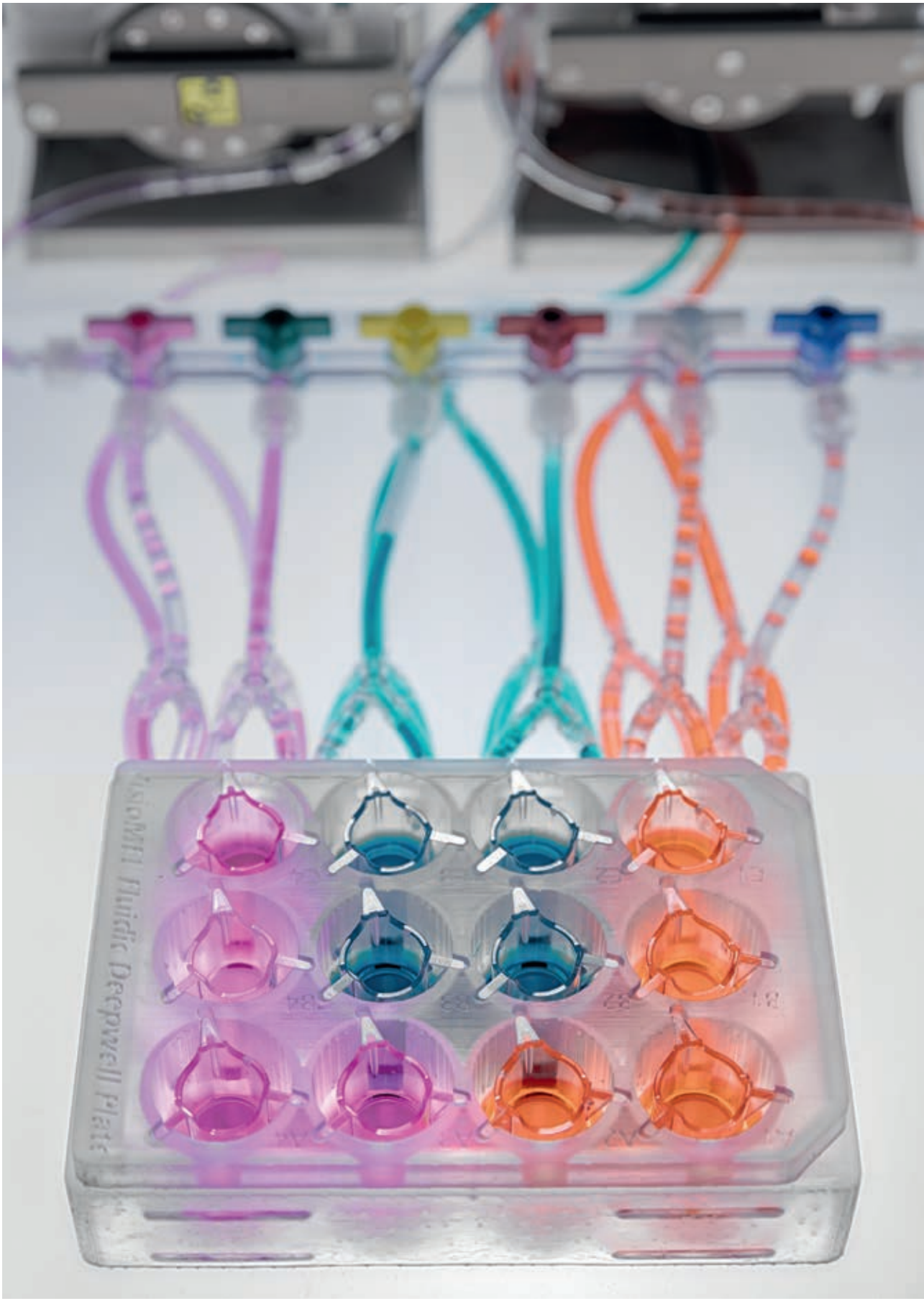
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