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FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

ANNUAL REPORT 2018

CONTENT

PREFACE

APPLICATION-ORIENTED RESEARCH, RELIABLE DEVELOPMENT

Dear Friends and Partners of Fraunhofer IZM, dear Readers!

In 2017, Fraunhofer IZM has once again kept up with the times and, with innovative future-relevant applications such as autonomous systems, robotics, 5G, wearable electronics, and the Internet of Things, has laid important foundation stones for the future. Focus topics such as the miniaturization of highly complex systems and multifunctionality directly within systems were advanced further; system reliability for accurate lifecycle forecasts was improved, as were process and product monitoring. Breakthroughs were also made within environmentally friendly and resource-efficient product manufacture on wafer- and and panel-level. It remains our goal to determine application aspects from the very beginning in order to guarantee a quick and unhindered transfer to our industrial partners.

Let's take a look at a few outstanding developments and project results:

- Very successful advances in technologies for conformable electronics were made last year. It is our goal to provide new and cost-effective technologies for highly robust and reshapeable electronic systems. Significant progress was made particularly for electronics on textile carriers and thermoplastic systems. The assemblies developed have already passed a few tests with flying colors: To take one example, textile electronic systems were stretched in a linear direction by ten percent 100,000 times without failing.
- Within the MicroMole project, an integrated sensor system was developed that can measure the pH value and the conductivity of water. The sensor system harvests the energy it requires from the ambient temperature by means of a specially developed thermal harvester. As part of the project, a specific housing was developed for use in sewerage systems, and a prototype thereof was built.
- Within the ASTROSE project, we made a significant step in 2017 towards advanced market maturity for the construction of a client server architecture. The result – a finished prototype of the energy-independent and cable-free earth fault sensoring system – can be viewed in our Berlin showroom.

In addition, 2017 was another year in which we had a wide range of special highlights to celebrate. One of these was launch of the Research Fab Microelectronics Germany, in which Fraunhofer IZM has positioned itself as the main driver behind the Technology Park Heterointegration.

The end of the year saw the Panel Level Packaging Symposium. Renowned industrial partners from around the world came to Berlin to make use of our know-how when it comes to transferring fan-out panel level technology into industrial processes.

The opening of our founders' garage »Start-a-Factory«, in September 2017, also made waves. Hall 16 in the Berlin district of Wedding is now home to an optimized environment for developing prototypes. The environment is tailor made to meet the needs of inventors and start-ups.

In addition to the research successes, however, we also have structural improvements at Fraunhofer IZM to mention. Thanks to the newly formed MGE department (Marketing and Business Development), we will continue to be able to optimize contact with our customers in the future. Significant measures were also taken at our Berlin and Dresden locations to expand our infrastructure. The power laboratory was extended, a new sensor-system laboratory was built, and central media supplies were secured.

Our successes in research and cooperation are also reflected in the figures: At more than 30 million euros, 2017 had the highest operating budget in the Institute's history, a rise equally shown in the increasing number of employees. Looking both back and forward, I feel confident in saying that Fraunhofer IZM is still on a growth path.

I am particularly looking forward to 2018, as this year the Institute will celebrate its 25th birthday. To mark the occasion, an international symposium and an official function will take place in the fall. Furthermore, there will also be a comprehensive offering of workshops and a lot of new and challenging projects and technical innovations.

Before I sign off, I would like to thank all our partners in industry and research, our sponsors from the federal and state governments, and our lead project partners for their loyal collaboration.

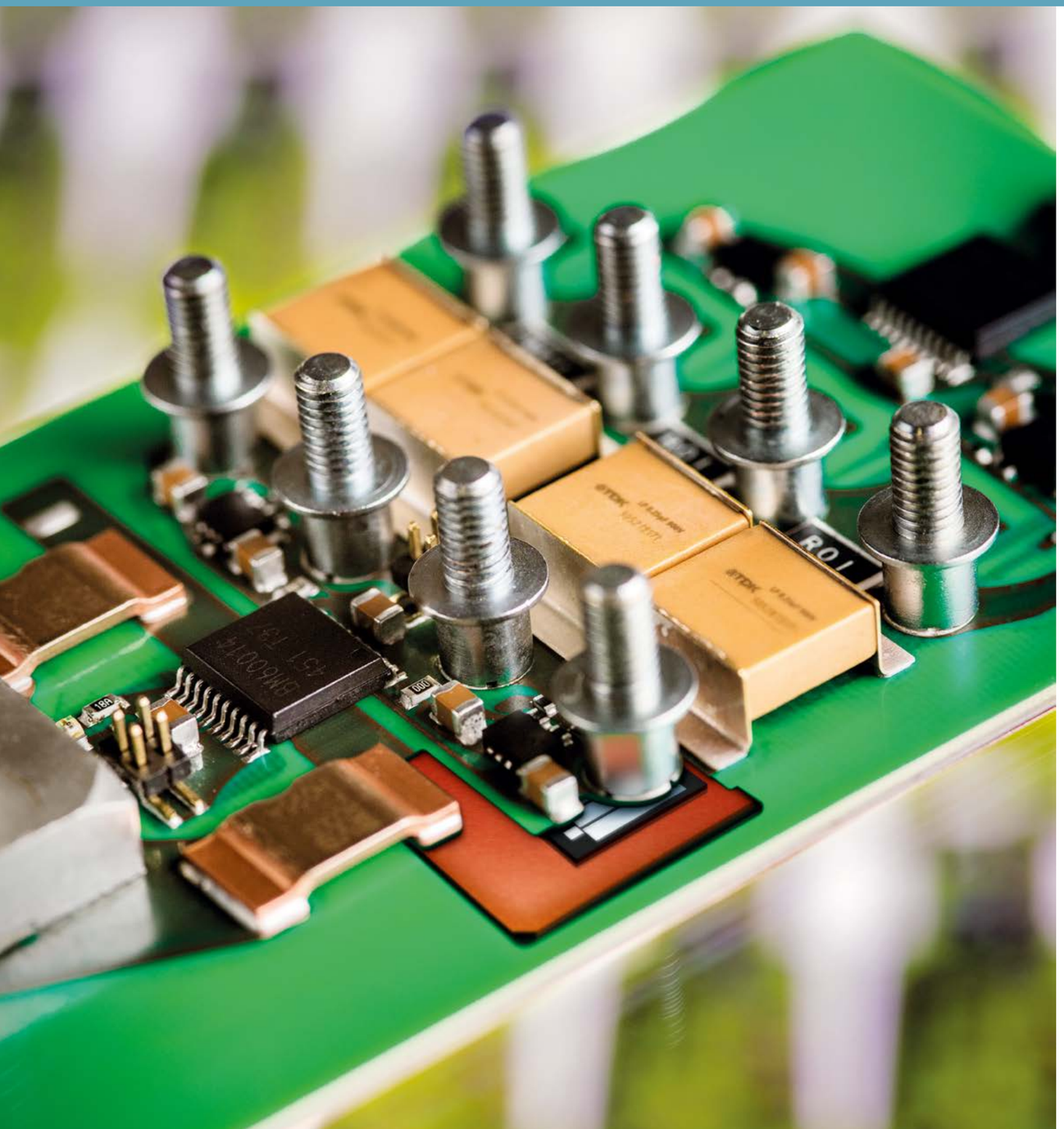
Particular thanks go to our staff. It is thanks to their dedication, their outstanding results, and their enjoyment of their work that the Institute is able to write so many success stories.

I would like to wish all of you some forward-thinking inspiration, promising cooperation ideas, and plenty of fun reading our annual report.

Yours sincerely,

Prof. Klaus-Dieter Lang

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.

Over 360 institute staff are dedicated to developing these adapted system integration technologies on wafer-, chip-, and board-level. Research at Fraunhofer IZM means designing more reliable electronics and making reliable lifetime predictions.

Working together with Fraunhofer IZM

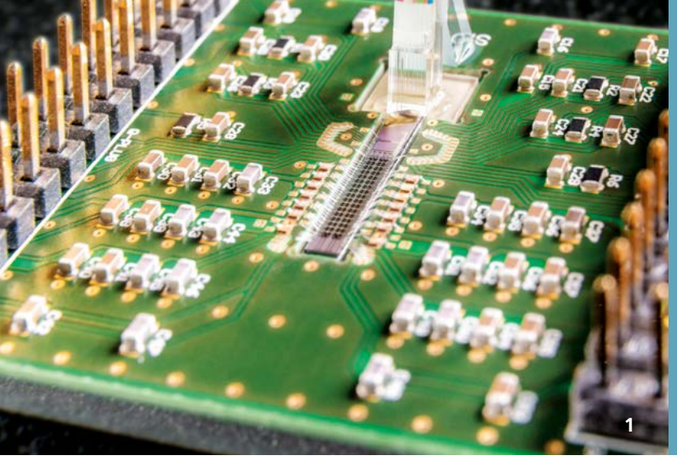
Fraunhofer IZM's research results are highly relevant to industries such as the automotive industry, medical engineering, industrial electronics and even lighting and textiles. Semiconductor manufacturers and suppliers of related materials, machines and equipment, but also small companies and start-ups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

Contract research

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

Project funding

Some development challenges require pre-competitive research. In these cases, teaming up with companies and research institutes and public funding support is more effective than operating solo. The institute cooperates closely with numerous universities, including the Technische Universität Berlin and the Berlin University of Applied Sciences (HTW), to ensure that the preparation for future cooperation with industry is optimal.



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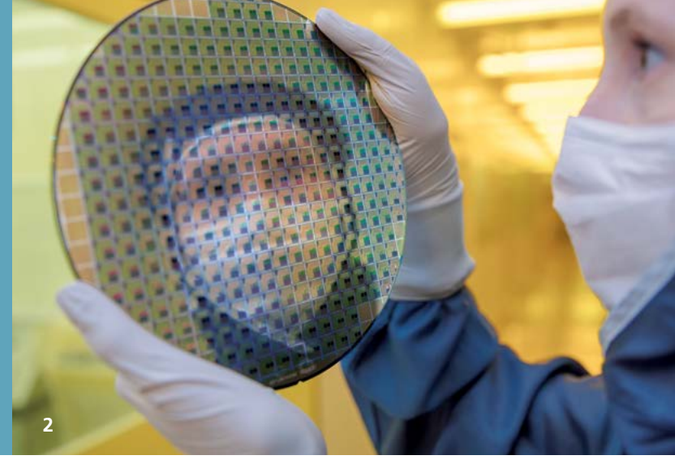

SYSTEM INTEGRATION & INTERCONNECTION TECHNOLOGIES

The department »System Integration and Interconnection Technologies« (SIIT) has more than 150 staff working on the development of processes and materials for interconnection technologies on board-, module-, and package-level, and the integration of electrical, optical and power electronic components and systems. Our spectrum of services, ranging from consultation to process developments right through to technological system solutions, covers every aspect of developing complex microsystem electronics.

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

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

The department meets the challenges of electronic and photonic packaging by combining system development with advanced interconnection technologies. As part of this, we develop packaging solutions in the cutting-edge areas of high-reliability power electronics and photonic modules, large-area panel manufacturing and conformable electronics.

We have the following aims:

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

WAFER LEVEL SYSTEM INTEGRATION

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

- 3D integration
- Wafer-level packaging and fine-pitch bumping
- Hermetic MEMS and sensor packaging
- High density assembly
- Sensor development and integration
- Hybrid photonic integration

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. Both technology lines are particularly equipped for production-related and industry-compatible development and processing (ISO 9001 certified management system).

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)
- Application-specific Cu-TSV integration: via middle, via last, backside TSV
- Cu-TSV interposer with multi- layer RDL and micro cavities
- Glass interposer with TGV
- High-density interconnect formation micro bump or pillar (Cu, SnAg, CuSn, Au, AuSn)
- Pre-assembly (thinning, thin wafer handling, singulation)
- 3D assembly (D2D, D2W, W2W)
- 3D wafer-level stacking
- Wafer bonding (adhesive, soldering, direct)
- Direct bond interconnects (DBI) – W2W (12")
- Micro sensors
- MEMS packaging (hermetic)

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

1 *Evaluation board with optical and electrical coupling to a SiGe chip containing integrated IQ modulators for optical telecom with 100 Gbps and faster (Project SPeeD, in cooperation with ADVA and IHP)*

2 *Back-end of line processing on CMOS wafer*

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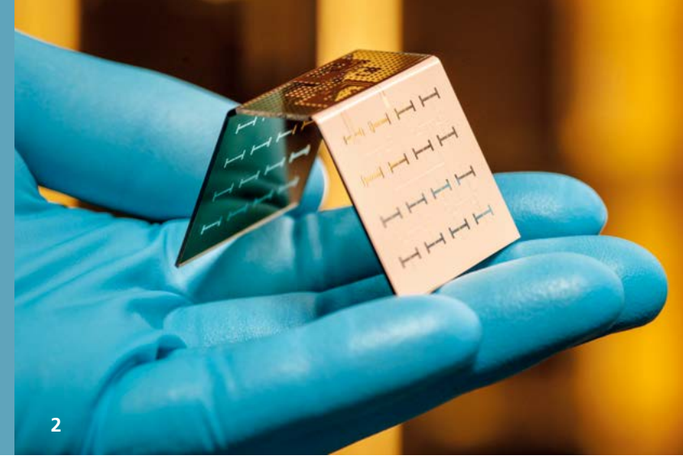


ENVIRONMENTAL & RELIABILITY ENGINEERING

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

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

The European Commission's Waste Electrical and Electronic Equipment (WEEE) directive intends to reduce the amount of electronic waste and to improve recycling and reuse in response to the loss of valuable resources in this growing waste stream.

More and more companies are acknowledging this situation's challenge for all of society. The concept of the Circular Economy is moving this debate increasingly to the question of how enterprises can reinvent their business with ecologically sound products and services. Fraunhofer IZM is supplying independent support and expertise for this transition. Recent research and studies by the department have investigated important aspects in the area, such as the environmental cost balance regarding energy and resource consumption in microelectronics production or assessing product design based on principles of robustness and longevity required for circular economy business models.

In parallel, a fundamental shift is under way in reliability management in the application sectors. Existing reliability and qualification standards need to be revised to keep pace with the challenges of the future. As a prominent example, the rise of electric and increasingly autonomous cars determines a considerable extension in the active lifetimes of certain vehicle components, which demands a more sophisticated analytical approach. Changing usage scenarios and the introduction of new component and packaging technologies mean a shift regarding the relevant fault mechanisms. While the past focus was mostly on thermomechanical stresses – which will remain a relevant force – more attention needs to be paid to slow-working effects like electrochemical or thermal degradation.

Fraunhofer IZM has already completed intensive work in a number of projects in the area, and is continuously equipping laboratories with cutting-edge facilities for the purpose. The Institute's services range from planning application-centric reliability tests, conducting various stress tests, analyzing and modeling the resultant fault mechanisms to lifetime predictions and design optimization with simulation tools.

RF & SMART SENSOR SYSTEMS

Self-sufficient sensor technology, radar sensors, 5G mobile radio or 60 GHz communication systems – despite great differences at first glance, research and development of all these applications share many similarities. All have to meet the fundamental requirements of any wireless networking technology, including large bandwidth, ruggedness, safety and energy efficiency. Additional functional gains are expected from controllable antennas. System design is assuming an ever-greater role in these technologies: tight integration of circuit design with technology development (hardware package codesign) is becoming as essential as hardware software code design. For this reason, the department has always sought to draw on the broad technological know-how of Fraunhofer IZM as a whole, in addition to delivering cutting edge expertise in firmware and software development. In particular, we focus on:

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

The combination of practical know-how gained in a wide variety of projects, state-of-the-art equipment, a sophisticated grasp of modeling tools and a systematic approach characterize the work of the department.

A particular specialty is RF systems. Material and structure characterization of high frequency-related assembly and connection technology in terms of high-frequency properties has vast potential, and we have translated this into a comprehensive, scientifically rigorous design approach, known as M3 (methodology, modeling, measures). The latter allows meeting the individual requirements of customized design in a relatively short time, i.e. without expensive and time-consuming iterations. Beyond purely functional optimizations, the approach facilitates multi-criteria optimization of electrical, optical, technological and economic parameters, so that the best performance for each application can be achieved. M3 is applied in the design of innovative high-frequency systems up to 110 GHz and sensor systems for harsh operating conditions in various research and industrial projects.

All our research and development relies on the department's cutting-edge technology and infrastructure. For example, in the HF laboratory, non-destructive determination of dielectric material parameters is available. Test structures can be measured up to 220 GHz. A screen cabin allows the 3D characterization of antenna modules. In the microelectronics laboratory, autarkic sensor nodes can be assessed and placed into operation. For the manufacture of micro batteries, a 10-meter-long battery development and assembly line with a precision screen printer, substrate bonding device and microfluidic electrolyte filling device is available. The entire assembly process of a battery is carried out under argon boxes in pure gas conditions.

1 *High-purity ABS obtained through the CreaSolv process (CloseWEEE-project)*

2 *24 GHz-radar frontend on glass substrate, connected with flexible PCB*

BUSINESS UNITS & INDUSTRY SECTORS

FRAUNHOFER – A STRONG NETWORK

Fraunhofer-Gesellschaft
The Fraunhofer-Gesellschaft is the leading organization for applied research in Europe. Its research activities are conducted by 72 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 25,000, who work with an annual research budget totaling 2.3 billion euros. Of this sum, almost 2 billion euros is generated through contract research. Around 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

Fraunhofer Group for Microelectronics
The Fraunhofer Group for Microelectronics, founded in 1996, is the leading European R&D service provider for smart systems. It combines the long-term experience and expertise of currently 17 Fraunhofer institutes with a total of more than 3,000 employees and a combined budget of roughly 439 million euros, of which industry accounts for 53 percent.

The core competences are in the following areas design for smart systems, semiconductor-based technologies, power electronics and system technologies for energy supply, sensors and sensor systems, system integration technologies, RF and communication technologies, as well as quality and reliability.

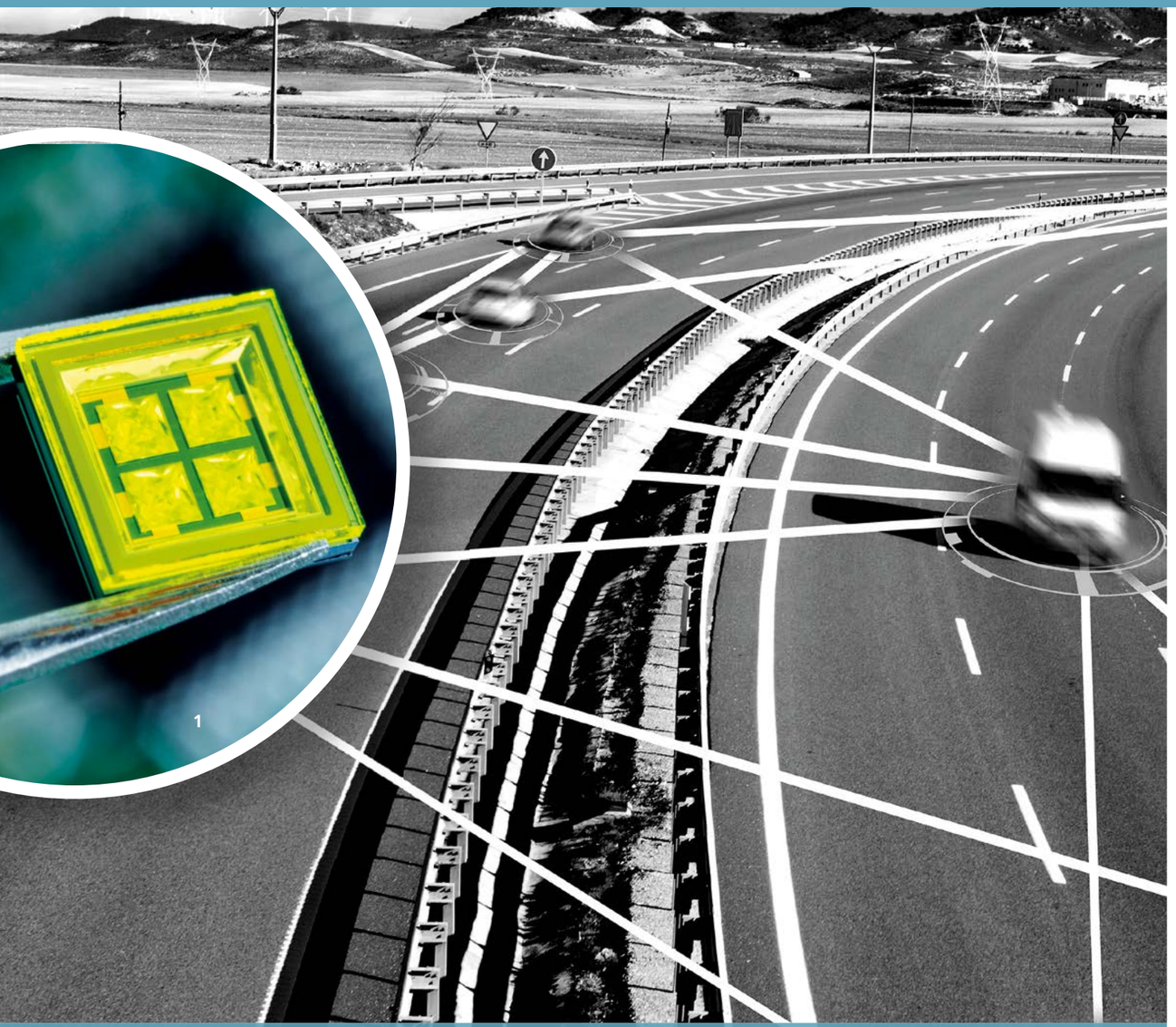
Research Fab Microelectronics Germany
Since April 2017, eleven institutes within the Fraunhofer Group for Microelectronics (among them Fraunhofer IZM) and two Leibniz-institutes (FBH and IHP) with more than 2,000 scientists have been working together in the Research Fab Microelectronics Germany (FMD). The cooperation is already the world's largest cross-location pool for microelectronics with a variety of competencies and facilities that is unique in the world. FMD bridges the gap between basic research and customer-specific product development and brings together the technological skills of Fraunhofer and Leibniz in a common technology pool. For the modernization and extension of their equipment the 13 research facilities receive around 350 million euros from the Federal Ministry of Education and Research.

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

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

With its core competencies, Fraunhofer IZM can offer innovative process and technology solutions for a wide range of sectors, covering the entire value-creation chain from the material to product application. The main business units are found in the sectors automotive & transportation, medical engineering, industrial electronics, ICT, and semiconductors. The following pages offer an overview of the services offered to the different sectors.

AUTOMOTIVE AND TRANSPORTATION



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.

Conformable electronics facilitate innovative product design for car interior

3D conformable electronic systems have attracted considerable attention. Conformable electronics will not only save weight and volume in known applications – e. g. automotive. They will also allow completely new functionalities and systemic changes.

For rigid conformable systems two technologies are currently in the focus: Thermoforming and injection molding. The feasibility of both approaches has been shown with different materials and material combinations. While Fraunhofer IZM already has extensive experience in the application of TPU with Cu tracks for conformable electronics, the material portfolio is currently expanded by dedicated conductive screen printing pastes for thermoforming and new substrate materials – e. g. PC, PET and PMMA. The forming process is optimized by applying innovative heating tiles for more homogeneous strain distribution.

Hermetic wafer level packaging of LEDs

Within the project HeraKLED, hermetically sealed high-performance LEDs, that are especially suited for harsh environments, were developed by using ceramic converters and novel packaging technologies. The main task of Fraunhofer IZM was the assembly of the LED packages. On an interposer wafer, LEDs were placed on the top side and the interconnects to the circuit board on the bottom side. Both sides were connected via TSVs. The frame wafer was then bonded to the interposer wafers. Afterwards, the ceramic converters (realized by Fraunhofer IKTS) could be bonded to the packages. The hermeticity of the LED packages was successfully demonstrated.

Chip-scale packaging for SiC power semiconductors

New power semiconductors allow for a significant efficiency increase in power conversion. However, classic semiconductor packaging limits the benefits due to parasitic electromagnetic effects.

The most promising solution of the ones developed at Fraunhofer IZM is the Power CSP (chip-scale package). It is a minimum package with interfaces on the top and bottom sides, which can easily be adapted to assemblies modeled on classical power packages. At the same time, there is large potential for low inductive assembly. This technology will be pursued as the central strategy in power electronics packaging at Fraunhofer IZM in the coming years.

Services:

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

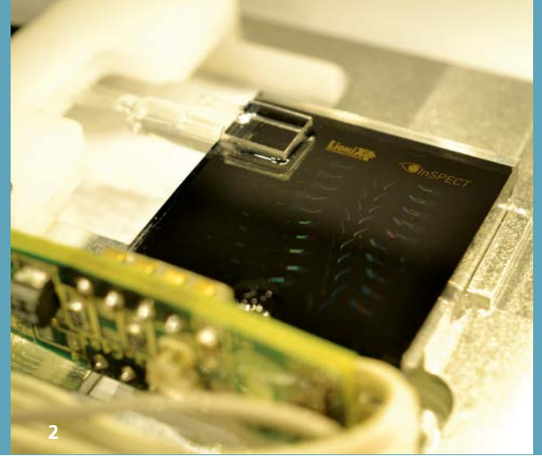
- Power electronics
- Sensor and actuator technology
- Reliability management and assurance
- Robust design

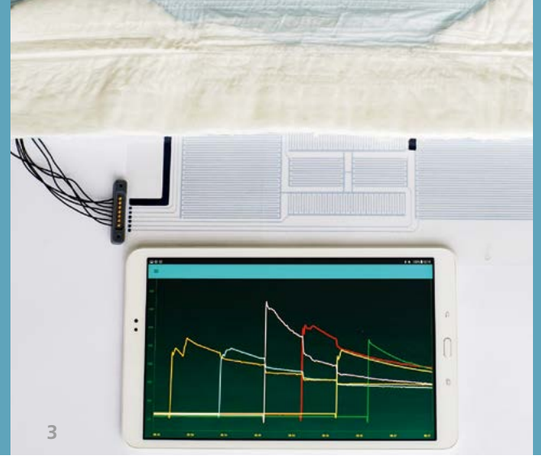
1 200 mm wafer-level LED package

2 Thermoformed printed circuit board with LEDs surface mounted prior to forming

3 Cross section of a power chip-scale package with embedded SiC power MOSFETs

MEDICAL ENGINEERING





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.

Packaging for a nano spectrometer

There is a growing demand for high accuracy, real-time, and miniaturized image-guided tissue sensing systems to identify cancer cells. Fraunhofer IZM has developed an integrated visible-to-NIR spectrometer coupled to a »photonic needle« as an alternative for the voluminous and expensive broadband spectrometers. Fraunhofer IZM realized advanced packaging design and optical interconnection for multi-mode to multi-channel single-mode fiber coupling. Such next-generation photonic integrated circuit (PIC) nano-spectrometers in combination with photonic needles for biopsy can drastically reduce costs of oncology screening and provide fast treatment for patients.

Printable battery separator for lithium-ion micro batteries

Extremely small batteries, such as are required for future medical applications, cannot be encapsulated using metal housings (button cells). Instead, processes derived from semiconductor and MEMS manufacturing are being used.

Whereas in button cells a porous polymer foil is put between anode and cathode as a separator, the common processing of anode and cathode requires the structured deposition of the separator. To this end, a microdispensable, printable separator was developed consisting of silica nanofibers and a polymer binder. The ionic conductivity of the 30 µm separator layer is comparable to conventional separators. With a current of 2 C, more than 80 percent of the nominal capacity can still be taken. The cyclability is similar to that of comparable batteries. Micro batteries with an active area of 6x8 mm^2 and a capacity of 0.8 mAh were manufactured.

Low-cost wireless moisture detection

The concept comprises a low-cost moisture monitoring system in incontinence materials allowing a personalized detection of moisture events and leakage rates within elderly care. The moisture detection is performed by low-cost biocompatible polymeric printed sensors arranged as sensor arrays. The system also features a small (<8 cm^2) re-useable read-out clip and a low-power microcontroller with advanced power management and »Bluetooth Low Energy« for an energy-efficient wireless communication, multiple device connection and automatic re-connection. The printing process is fully scalable and allows a direct sensor print onto the diaper bottom-substrate. A WiFi connectivity also enables BigData mining and analysis.

Services:

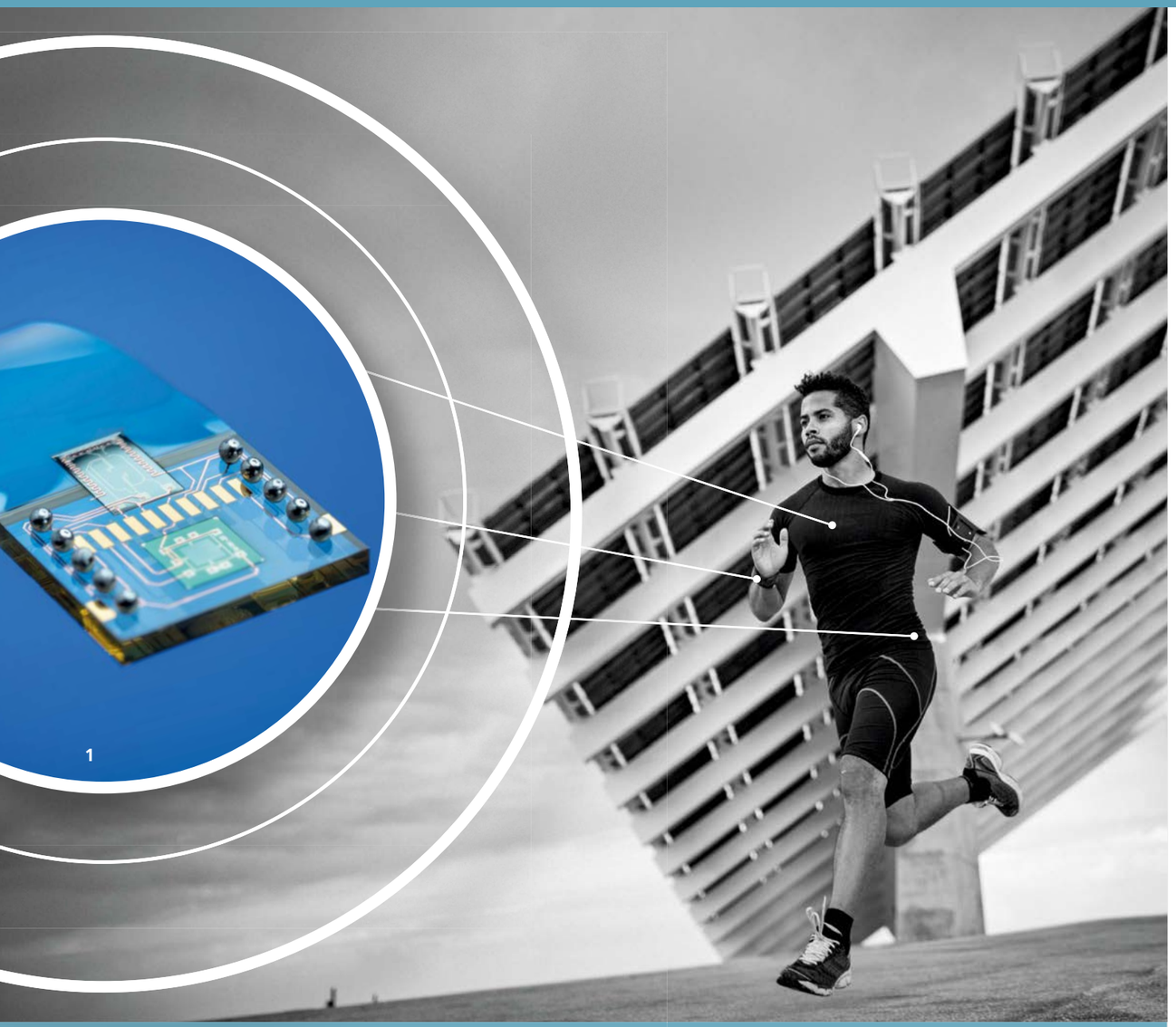
- Packaging and reliability analyses for miniaturized medical devices/implants
- Lab-on-substrate for patient-oriented laboratory diagnostics
- Improved functionalities for smart prostheses
- Wearables for medical use
- Textile- and structure-integrated electronics functionalities to support the digitization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

1 *Textile-integrated multi-sensor system to monitor the posture*

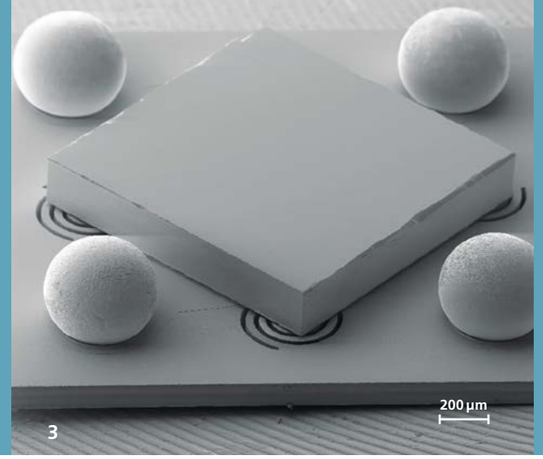
2 *Assembled nano-spectrometer, developed in the project InSPECT within the EU-Program Horizon 2020*

3 *Wireless moisture detection in incontinence materials via low-cost polymeric printed sensors and low power microcontroller*

SEMICONDUCTORS



This business unit has a focus on the integration and development of new sensors. Besides that 3D integration allows the realization of complex, heterogeneous system-in-package (SiP) solutions. Fraunhofer IZM offers its customers a closed implementation chain – from concept, process development, and characterization to reliability validation and prototyping of new sensors, hermetic sensor packages, and 3D systems. All processes necessary to the realization of sensors and wafer-level packages are available, including the formation of through-silicon vias (TSVs).



Camera components for high-performance X-ray laser
The »European XFEL«, the world's most powerful X-ray laser, allows the decoding of the three-dimensional structure of biomolecules and the analysis of synthetic materials. Here, an X-ray camera is required, for which Fraunhofer IZM has realized adaptive gain integrating pixel detector (AGIPD) modules. Electronic components on a silicon wafer were provided with µm solder balls. 16 electronic AGIPD-readout ASICS (200 x 200 µm pixel size, 65,536 pixel / module) were bonded to the 11 × 3 cm² X-ray sensitive silicon sensor chip. This makes it the largest detector modules realized at Fraunhofer IZM up to date.

Wafer-level packages for server-applications
Within the existing cooperation with the company Coinbau, a special chip-size wafer-level package (CS-WLP) for high performance computing applications was developed. Also, for the first time, a WLP for GlobalFoundries' 22 nm FDSOI technology could be realized.

Main technological challenges were the uniform distribution of the operating voltage over the entire chip area without a significant voltage drop as well as the realization of a cost-efficient solution for the chip size packaging, taking into account the later use as a server in constant operation. In a pilot production, chips with a high yield were successfully realized that met the customer's performance expectations.

Stress compensating silicon substrate for the assembly of sensitive sensors
MEMS sensors like accelerometers are sensitive to mechanical stress that can severely affect their performance. At Fraunhofer IZM, a system assembly technology was developed, that allows an effective mechanical decoupling of the MEMS elements in the sensor from the organic substrate. Silicon dies with continuously etched planar spring structures, redistribution and pads were manufactured and used as interposer between the sensor and substrate. Each interconnect of the MEMS is located at the center of one spring structure on the interposer and is linked to a large solder ball which connects the substrate. The technology was successfully demonstrated with a pressure sensor from Austria Microsystems.

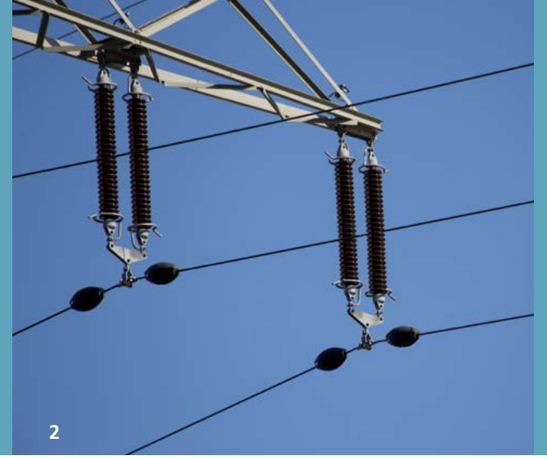
Services:
- TSV formation in CMOS wafers (via-middle, via-last)
- Reverse-side contacting (BS via-last) for sensors
- Silicon and glass interposers
- 3D assembly (die-to-wafer, wafer-to-wafer)
- 3D integration of optical connectors
- Hybrid 3D pixel detector modules
- Hermetically sealed MEMS packages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

1 *Embedded ultra-thin micro sensors for condition monitoring using rigid-flex technology*

2 *X-ray camera at XFEL/SPB line with modules assembled at Fraunhofer IZM © A. Allahgholi – CFEL*

3 *Pressure sensor flip-chip mounted on silicon substrate with through etched planar spring structures around each of the 4 flip-chip pads*

INDUSTRIAL ELECTRONICS



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In recent years Fraunhofer IZM's industrial electronics specialists have concentrated on the visionary concept of Industrie 4.0. Particular emphasis was placed on the work on cyber physical systems (CPS) and autonomous, specifically high-reliability radio sensors that record and process the relevant monitoring and/or video data on site and distribute it via standard interfaces when and where the user needs it. Industrie 4.0 means much more than CPS integration: Flexible access to monitoring data is particularly vital both for location-bound controlling and management processes and ERP systems and for on-demand access via mobile devices in inspection, maintenance, or repair scenarios.

Monitoring of power transmission lines
Real time processing of data by networked embedded systems and sensor networks is required for monitoring and control of critical infrastructure systems (electric power systems, water distribution systems). In order to handle the wealth of data, we have developed a flexible data management system based on client-server architecture. It comprises a base station, databases, data analytics, intranet/cloud services and connection to a control center by means of industry-standard protocols.

Sewage pipe monitoring
An energy self-sufficient sensor technology is being developed within the microMole project for the continuous monitoring of environmental parameters (such as pH and conductivity) in sewage systems. The technology comprises one or more sensor rings, on which waterproof functional modules are mounted. The modules communicate via a wired bus system, while the sensor rings communicate with each other wirelessly via radio. A continuously operating, low-energy sensor and an event-based sampling algorithm controls the parameters, triggering the sensor system as a whole when predefined limits are exceeded. Combined with the specially developed »low power« architecture, minimal static power is required. The microMole project is funded by the European Union's Horizon 2020 research and innovation program (no. 653626).

Power electronics in harsh environments
The reliability of power-electronic assemblies is gaining in importance all the time when it comes to satisfying the requirements of renewable energies. That is why Fraunhofer IZM, as part of the AMWind (Autonomous Monitoring of Wind turbines) project, is developing approaches to forecasting failure of off-short wind turbines in order to carry out maintenance in good time and to minimize down times. Within this project, the institute is collaborating with the companies M&P, Siemens, Infineon and WindMW GmbH who, as the owners, are providing a wind park with around 50 wind turbines, 8 km off the coast of Helgoland. This project is intended to determine electrical parameters that can allow conclusions to be drawn about the aging process of the devices within the wind turbines. Within the KorSikA project, particular attention is being paid to the reliability of the sintered silver connections within the power modules of the off-short wind turbines. The damage mechanisms that arise within marine conditions are being identified and, together with the project partners, preventive measures are being developed to help avoid failures caused by corrosion. The lessons learned from this project ought to improve the efficiency, the operational reliability, and the service life of wind turbines. Another aim is to reduce the costs of repair and service work off shore.

Services:

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

1 *High-temperature sensor für extrusion plant: SOI-Chip and housing*

2 *Monitoring of power transmission lines, project ASTROSE (funded by BMBF and BMWi)*

3 *Energy self-sufficient sensor system to monitor environmental parameters in sewage systems*

INFORMATION & COMMUNICATION

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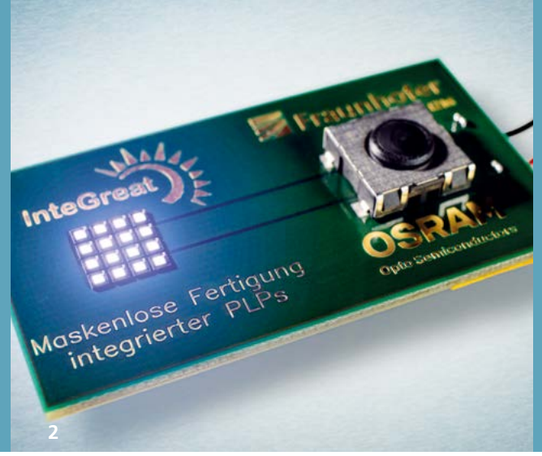

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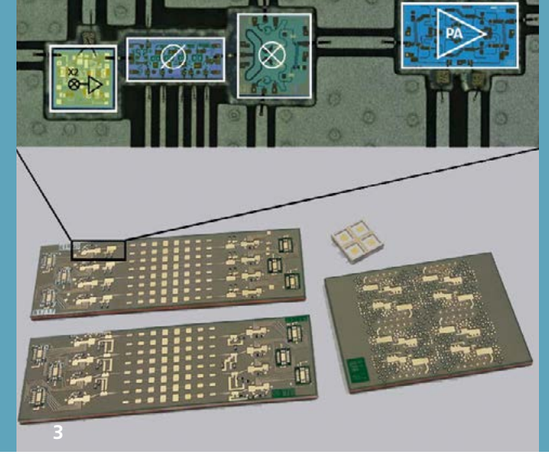

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The new era of increasing connectivity and digitalization creates new challenges for the design and construction of ICT systems: The efficient sharing and storing of data needs ever larger data centers and the means to transmit electric and optical 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.

Microfluidic interposer for dual side chip cooling for high performance computing

High performance processors are the backbone of data centers. Processor performance is mainly limited by heat removal efficiency. Conventional air-cooling concepts cannot achieve the needed considerable heat removal capacity. Within the European project CarrICool, Fraunhofer IZM has realized a system-in-package (SiP) with fluidic dual side chip cooling. To this end an innovative technology for the waterproof integration of fluidic micro channels together with TSVs for processor power and signaling. The fully assembled SiP-stack was bonded on laminate and housed by manifold which provided the external fluidic connectors as well. This double-sided cooling concept realized a heat dissipation of 692 W on a processor surface of 4 cm².

Material characterization for high-frequency applications

The layer structure of heterogeneously integrated system-in-package structures has to meet a wide variety of often conflicting requirements in terms of mechanical, thermal and electrical properties. The characterization of dielectric material properties provides important data for determining material selection. In a project to develop fan-out wafer-level packages, the dielectric properties of the used materials were determined over a wide frequency range of up to 100 GHz. A combination of resonator methods and planar resonators was used.

Fan-out-wafer- and panel-level packaging

Fan-out wafer level packaging (FOWLP) is one of the key packaging technologies for heterogeneous integration. Main advantages of FOWLP are the substrate-less ultrathin package, low thermal resistance, as well as high RF performance due to shortest interconnects in combination with direct IC connection by thin film RDL wiring. The technology is well suited for various applications, ranging from µController and sensor packaging with direct access to the sensing surface to communication, e. g. RF and mm-wave applications for 5G. From the manufacturing side a movement towards larger formats (e. g. panel level) yielding lower cost is noticeable, supported by IZM's Panel Level Packaging Consortium – a process related research initiative joining forces of 17 industrial partners. Exemplarily technology development and transfer from wafer to panel scale was successfully demonstrated for an SMD-compatible LED package within the BMBF-funded project InteGreat.

Assembly and interconnection concept for innovative Satcom antenna terminals (AVISAT)

In satellite communications, copper-core PCBs provide a cost-effective integration platform for controllable antennas with high bandwidth. Such printed circuit boards combine functional and thermal advantages. In cooperation with the companies IMST GmbH and HISATEC, using a GaAS IC for the satellite frequency bands 20 GHz/30 GHz (down/up-link bands) and the 60 GHz ISM band, we proved that the required power levels, bandwidths and heat spread and heat dissipation were achieved for the construction of controlled antennas.

Services

- Design of integrated, miniaturized, autonomous, and robust sensor systems and wireless networks
- Assembly of high-frequency systems and electro-optical components
- Optimization of processes and transfer of assembly technologies for highly integrated systems
- Reliability testing and service life forecasting
- Consulting and eco-design services for sustainable ICT products

1 *SiP with fluidic dual side chip cooling, developed in the EU-project CarrICool*

2 *Highly integrated LED-packages manufactured on panel-level (BMBF-project InteGreat)*

3 *KA-band-front-end for satellite communication*

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.

Process Modules:

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

Substrate Line

In the substrate area panel-size substrates with a size of 460 x 610 mm² can be prepared for resist and PCB lamination, solder resist and cover lays can be applied and developed after exposure.

In our bonding lab high-precision module assembly is carried out under inert gas. New equipment in the 480 m² cleanroom allows surface preparation for assembly at reduced bonding temperatures.

Our services include:

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

Mold Encapsulation Lab

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

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

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

Wire Bonding Lab

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

Soldering Lab

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

Photonics Lab

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

MATERIAL ANALYSIS

Moisture Lab

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

Long-term Testing and Reliability Lab

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

Power Lab

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

DESIGN

High Frequency Lab

- Electric and functional characterization of assembly technology and electronic modules for applications down into millimeter wave bands (220 GHZ)
- Dielectric material characterization 1 MHz up to 170 GHz
- Temperature-controlled on-wafer measuring stations
- Measuring station up to 80 GHz for antennas and antenna systems
- Measuring electrical properties of digital data transfer systems (up to 32 Gbit/s)
- Localising EMC-hot spots with near field probe up to 6 GHz

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)
- Assembly Lab for automatic flip-chip and die bonding on wafer level
- Electronics Condition Monitoring Lab (ECM) for functional tests of electronic systems under environmental stress
- Qualification and Test Center for Electronic Components (QPZ)
- Thermo-mechanical Reliability Lab
- Thermal & Environmental Analysis Lab

EVENTS

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EVENTS & WORKSHOPS

Opening a research platform for hardware startups
On September 22, the new laboratory complex »Start-a-Factory« was opened at Fraunhofer IZM. Around 160 guests from industry, research and politics came to the Berlin district of Wedding to find out about this leap towards smooth and cost-effective production.

At Start-a-Factory, IZM researchers are developing tailor-made solutions for reoccurring problems during product development. The goal is to create the Founders' Garage of tomorrow, with high-tech equipment tailored to the needs of young companies. Not only are development and production-related interfaces within the process chain identified, but the factors that influence the later production costs are also considered from the very beginning.

»From Package to Application« –
Technology Day at Fraunhofer IZM
September held a special treat for over 100 interested guests as Fraunhofer IZM, one of the world-leading institutions in advanced packaging, answered the question: Which package does my application need? The Technology Day focused on three application areas: Wireless Communication and Connectivity, Automotive & Transportation und Medical Technology and Sensors. The talks explained how different components, regardless of their application, can be brought together to serve an overall system. This appealed especially to engineers and technicians from development, construction and production in the automotive and supplier industries, including mechanical, electrical and medical engineering.

Pitching for Fraunhofer know-how
On December 6, Fraunhofer IZM opened its gates for Berlin's prolific startup scene. In cooperation with CUBE GmbH, the institute hosted an event that allowed new entrepreneurs, investors, and many other interested visitors a chance to meet and mingle: the »Founders' Garage«. Alongside the Director of Fraunhofer IZM, Klaus-Dieter Lang, Bernd Lietzau of the Senate Office of the Governing Mayor of Berlin, and CUBE Director Torsten Oelke welcomed the attendees to the day's event.

The networking breakfast put nine table captains from many enterprises and organizations, including Berlin Partner, Tektronix and Fraunhofer, in the spotlight to answer the many questions of the visitors. Guided tours took the participants to the IZM lab facilities, where they had a chance to see the potential and capabilities of Fraunhofer IZM. At the same time, three startups were given the opportunity to demonstrate their work to the attending crowd in the distinctive container facilities of Start-a-Factory. Another 25 startups attended the exhibition with their products and concepts at HALLE16 IZM Berlin.

A special highlight of the Founders' Garage was the series of three-minute pitches, in which twenty startups had three rounds to showcase their ideas to a rapt jury. The three strongest ideas won the opportunity to cooperate with Start-a-Factory at Fraunhofer IZM.

1 *Excited expectation at the opening of Start-a-Factory*

2 *Opening Start-a-Factory with the press of a button, from left to right: Guido Schlief (SAP Deutschland), Dr. Stefan Mengel (BMBF), Dr. Andreas Olmes (Hightech-Gründerfonds GmbH), Bernd Lietzau (Senate Chancellery), Prof. Georg Rosenfeld (Fraunhofer Board), Prof. Klaus-Dieter Lang (Fraunhofer IZM)*

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Official opening of the Fraunhofer »Center for Digital Transformation« in Berlin
On May 6, the Fraunhofer »Center for Digital Transformation« was officially opened in Berlin. The transfer center offers companies - from start-ups to large corporations and everything in between - comprehensive research and implementation expertise from a single source. By combining the expertise and know-how from four Fraunhofer institutes, it places a further milestone in Berlin's positioning as a leading city for digitization.

The Fraunhofer Society's transfer centers organise the unification of university and non-university research with business. The centers provide binding, consistent roadmaps for the partners involved in the areas of research and teaching, promotion of young talent, infrastructure, innovation and transfer. They are designed to develop scientific excellence, providing the economy and politics with social benefits, specifically for the Berlin region and Germany.

Unveiling the »Research Fab Microelectronics Germany« in Berlin and Brandenburg
A consortium of eleven Fraunhofer institutes from the society's Microelectronics Group and two institutes of the Leibniz Association have developed a novel concept for a nano- and microelectronics research factory. The ambition for this cross-regional initiative is to level up the quality of electronics research in Germany and establish a joint source for research services covering the entire innovation chain.

The two pairs of Leibniz and Fraunhofer institutes from Berlin and Brandenburg, including the Fraunhofer IZM, are pooling their expertise and resources in dedicated technology hubs, designed to promote immediate and efficient progress in promising new avenues of research. On July 6, the Ferdinand Braun Institute, the Leibniz Institute for Ultra-High Frequency Technology, opened its doors for the regional launch of the Research Fab in Berlin-Brandenburg. An opening address by the Federal Minister for Education and Research, Johanna Wanka, and statements of many representatives from science and politics accompanied the official unveiling of the sign for the new »Research Fab Microelectronics Germany«.

High-Tech from Berlin
At the beginning of November, more than 50 participants met up in the name of »High-Tech from Berlin« for a cooperation forum at Fraunhofer IZM, to discuss examples of small, medium and start-up sized companies collaborating within the field of microelectronics.

Fraunhofer IZM at trade shows	
SPIE Photonics West	February, San Francisco, USA
Smart Systems Integration	March, Cork, IRL
SMT Hybrid Packaging	May, Nuremberg
PCIM Europe	May, Nuremberg
TechTextil	May, Frankfurt
Sensor + Test	May, Nuremberg
ECTC	May - June, Florida, USA
SemiExpo Russia	June, Moscow, RUS
Laser	June, Munich
Semicon West	July, San Francisco, USA
Photonic Days BB	October, Berlin
ELIV	October, Munich
MST Congress	October, Munich
Productronica	November, Munich
Compamed	November, Düsseldorf
Semicon Japan	December, Tokyo, JPN

The guests were interested in the transfer partners such as the Berlin Fraunhofer Center for Digital Transformation, but also examined the technological concept of the new co-working space and high tech labs in Hall 16. The event was supported by OptecBB, Brandenburg Invest (WFBB) and Berlin Partner and gave a thorough insight into the region's current funding and cooperation programs.

Panel Level Packaging Symposium
Panel level packaging is seen as a promising candidate for extremely cost-effective manufacturing technology with high market potential. On November 29, around 100 company representatives from all over the world met at Fraunhofer IZM in Berlin to discuss this industrialization process. Experts from renowned technology partners such as INTEL, Amkor Technology, ASM, Hitachi Chemical, AT&S and Unimicron presented the current state of development in this area.

The International Panel Level Packaging Consortium, initiated by Fraunhofer IZM in 2016, pools the specialist resources of the partners and drives forward the industrialization process of panel level packaging.

AMA Workshop on energy self-sufficient radio sensors
Together with the Association for Sensor Technology and Measurement Technology (AMA), Fraunhofer IZM again held a workshop on energy self-sufficient wireless sensors for industry. The basics of manufacturing and application examples of such systems were presented and participants were provided opportunity to talk directly with the speakers and to discuss concrete applications.

User-Workshop for signal integrity
In a two-day workshop, theoretical and metrological aspects of signal integrity for data transmission of electrical high-speed bus systems, such as USB 3, PCI Express and SATA with data rates of several gigabit/s, were presented. In addition to basic topics from electromagnetic field theory and metrology, the workshop presented application-oriented questions about design support through simulation tools and measurement options for the validation of high-speed designs.

Workshop on micro batteries
Focusing on the current state of and trends in micro battery design and manufacturing, the workshop dealt with new materials for next-generation electrochemical storage, particularly solid-state lithium-metal batteries. Applications for the micro-test cell arrays developed at Fraunhofer IZM for combinatorial and high through-put testing in battery material research were also discussed. With 44 participants from 10 countries and 26 lectures, the workshop was a great success.

1 From left to right: Prof. Eckart Uhlmann (Fraunhofer IPK), Prof. Ina Schieferdecker, Prof. Manfred Hauswirth (Fraunhofer FOKUS), Prof. Reimund Neugebauer (Fraunhofer-Gesellschaft), Björn Böhning (Senate of Berlin), Prof. Thomas Wiegand (Fraunhofer HHI), Prof. Dr. Angela Ittel (TU Berlin), Prof. Klaus-Dieter Lang (Fraunhofer IZM)

2 From left to right: Prof. Martin Schell (Fraunhofer HHI), Prof. Klaus-Dieter Lang (Fraunhofer IZM), Prof. Günther Tränkle (FBH), Prof. Johanna Wanka (BMBF) and Dr. Ulrike Gutheil (MWFK Bradenburg) at the unveiling ceremony for the »Research Fab Microelectronics Germany«

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More women in science!
As part of the Fraunhofer Science Campus event in April, 80 undergraduates and postgraduates from the MINT subjects (Mathematics, Information, Science and Technology) visited the four Fraunhofer Institutes in Berlin. Fraunhofer IZM has joined forces with Fraunhofer FOKUS, IPK, and HHI to support the move towards more women in science and research.

At Fraunhofer IZM, the attendees were offered an exclusive insight into assembly and interconnection technologies used for electronic system integration. They visited the cleanroom facilities for an up close and personal experience of researchers at work. On top of the lab tours, the Science Campus event hosts several interesting seminars, lectures, and workshops, including talks on career opportunities at Fraunhofer IZM, ways into management and personal career coaching.

Selection of events organized by Fraunhofer IZM	
European 3D Summit	January, Grenoble
Colloquium: Cooperation Project Silicon Micro Sensors	February, Berlin
Workshop: EMC-compatible Design for Power Electronic Systems	April, Berlin
Workshop: Characterization of Dielectric Materials	April, Berlin
Workshop: EMC in Power Electronics	May, Berlin
Workshop: Conformable Electronics	May, Berlin
Seminar: Photonics in Data Centers	May, Berlin
Workshop: Reliability and Test of Robust Radio Sensor Systems	May, Berlin
Forum: 5G: Future Industrial Communication	June, Paderborn
Workshop: Reliability Management in Electronics	October, Berlin
Workshop: Next Generation Batteries	October, Berlin
AMA-Seminar: Autarke Funksensoren	November, Berlin
Panel Level Packaging Symposium: Status and Trends	November, Berlin

PROMOTING YOUNG TALENTS

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

New school partnership initiated
Fraunhofer IZM is looking forward to its new cooperation with Berlin's Gabriele von Bülow Gymnasium high school. In September, the school's headmistress, Heike Briesemeister, and Institute Director Professor Klaus-Dieter Lang came together to put their signatures to the cooperation agreement.

The participating students can follow their interests in school projects at Fraunhofer IZM, join a »mini research project« supervised by IZM professionals, enjoy additional opportunities on the Girls' Day and internships, and get a special invite for a tour of the Institute as part of the Long Night of the Sciences. The activities are offered alongside the biology, chemistry, and physics courses for year 7 and higher and are meant to stimulate an interest in working in the natural sciences.

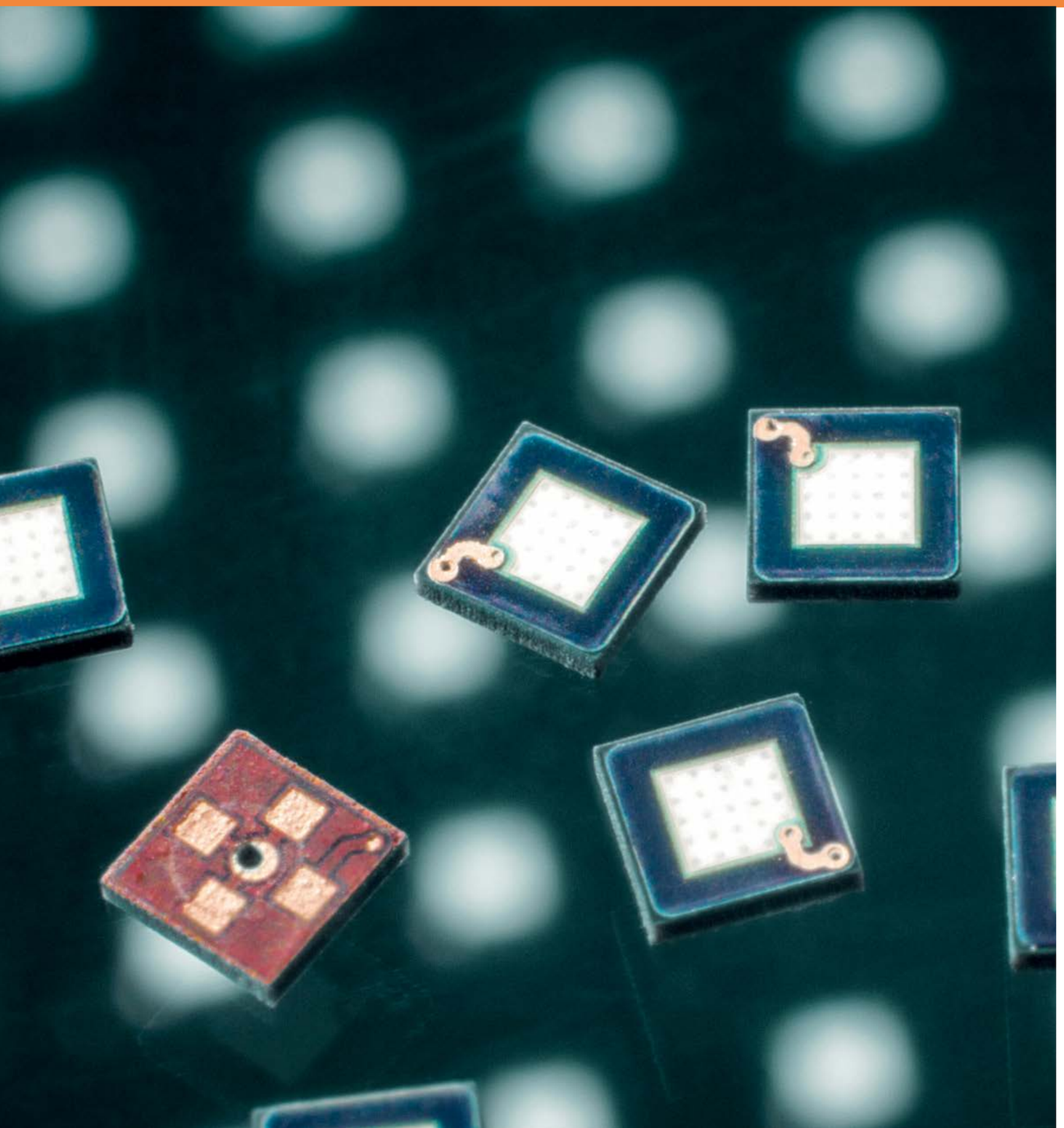
This is not the first time the Fraunhofer IZM has reached out into schools – young researchers are a dear and sought-after resource. The institute has already committed itself to promoting promising technology talent. On top of the mentioned opportunities, ambitious young researchers can get active at the School Technology Days of the Technical University Berlin or find out more about the technology on show at fairs and exhibitions.

From glowing statues to flying eggs – Girls' Day at Fraunhofer IZM
On April 17, 14 schoolgirls visited Fraunhofer IZM to get an insight into the world of microelectronics for Girls´ Day 2017. Not only were they offered an over-the-shoulder perspective on the researchers´ work, they got a hands-on experience. The students were able to either build a circuit board in the shape of a famous film persona in the cleanroom, solder together a glowing statue from electronic components, or find out during a smartphone teardown what components and materials are used to make them. »I didn't think there would be so many parts, it's very interesting,« said 13-year-old Meriliis from Bremen. Toward the end the participants were able to put their creativity to the test by constructing so-called »Flying egg machines« in small groups. This involved finding a way to drop a raw egg from the second floor without it breaking. Girls' Day is an integral part of promoting young talents at Fraunhofer IZM and is taking place in 2018 for the 15th time in a row.

1 *Institute Director Prof. Klaus-Dieter Lang explains the technological highlights of Fraunhofer IZM to the headmistress of the Gabriele von Bülow Highschool, Heike Briesemeister, and her colleagues*

2 *The Fraunhofer Science Campus visits Fraunhofer IZM*

FACTS & FIGURES



FRAUNHOFER IZM IN FACTS AND FIGURES

Financial situation

At Fraunhofer IZM, 2017 was another year of successful partnerships with industry in applied research projects. Earnings from activities with German and international enterprises and industry associations remained stable at the previous year's high level of 14.1 million euros. Industry projects allowed Fraunhofer IZM to cover 46.7 percent of its costs. Public funding for projects increased again to a level of 11.2 million euros. The overall revenue of Fraunhofer IZM grew to a total of 30.2 million euros.

In 2017, Fraunhofer IZM covered 83.8 percent of its operating budget from third party funds. In total, external funding accounted for 25.3 million euros of ongoing project spending.

Investment in facilities

The Institute invested 1.3 million euros of its own funds into equipment upgrades and maintenance work. These investments were made specifically to improve the facilities and equipment of Fraunhofer IZM in a considerable number of detailed initiatives and to increase the efficiency of the existing infrastructure. One highlight included the setting-up of Start-a-Factory, a reimagining of the legendary »founder's garage«, co-funded by the European Regional Development Funds (ERDF), the State of Berlin, and the Federal Ministry of Education and Research (BMBF). A further 1.3 million euros were used to cover various small-scale construction projects. These include targeted improvements and changes designed to reinforce the capabilities of Fraunhofer IZM and to comply with new HSE requirements. Support from Germany's Ministry of Education and Research meant that a first investment of 8 million euros could be made into the establishment of the Research Fab Microelectronics Germany (FMD).

HR development

The staffing levels of Fraunhofer IZM continue to reflect the positive development in the Institute's project work. A total of 233 members of staff were employed at the IZM sites in Berlin and Dresden/Moritzburg. Fraunhofer IZM offers students an opportunity to combine their studies with applied scientific work in the offices and laboratories of the Institute. By the end of 2017, 146 student interns, bachelor and master degree candidates, and student assistants had passed through the Institute. Fraunhofer IZM remains committed to its ethos of training and developing the professionals of tomorrow. In 2017, nine apprentices were in training in roles ranging from microtechnologists to office management assistants.

Fraunhofer IZM 2017	
Turnover	30.2 million euros
External revenue	25.3 million euros (83.8 percent of total turnover)
Sites	Berlin and Dresden/Moritzburg
Number of staff	388 (including 146 student assistants, master students, interns and 9 apprentices)

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AWARDS

Klaus-Dieter Lang receives the William D. Ashman Achievement Award
The International Microelectronics Assembly and Packaging Society (IMAPS) awards the William D. Ashman Achievement Award once every year to an individual who has made significant technical contributions to the electronics packaging industry. The 2016 William D. Ashman Achievement Award was given to Prof. Klaus-Dieter Lang for his exceptional contribution to the development of electronic packaging for advanced system integration. The prestigious prize was handed over to Prof. Lang by IMAPS President, Susan Trulli, on October 10, 2017 during the award presentation ceremony at the 50th International Symposium on Microelectronics in Raleigh, NC, USA.

Fraunhofer IZM named »Research Institute of the Year«
Fraunhofer IZM is very excited about coming in first place among the »Research Institutes of the Year« honored at the 3DInCites Awards 2018. Every year, the 3DInCites Awards are given to individual and institutional recipients for their exceptional contributions to the hetero system integration of semiconductors in a range of categories, e.g. for work in the fields of 3D or fan-out wafer-level packaging. The institute's researchers are particularly proud of winning the award in the important category »Research Institute of the Year«, as its winners are chosen by the packaging community as an expression of genuine appreciation among the packaging professionals of the world.

IZM-researchers receive »Techtextil Innovation Award«
Following knee surgery, patients need care and careful supervision. The MOTEX project has developed an intelligent knee brace that supports their recovery from full knee replacement surgery. An innovative fabric sensor monitors how the patients bend and use their knees in real time, and the integrated system feeds the data back to an IT platform and mobile devices. Specially tailored exercise schemes can be selected by physiotherapists and sent to the patients' smart phones. The knee brace records their exercises and gives them direct feedback about what they can do to aid the recovery process. The Motex Consortium includes Fraunhofer IZM alongside the Belgian companies Mobilab and Centexbel and an industry advisory council including representatives from Amohr Technische Textilien, Pegus Apps, Cubigo, and Nea International.

Klaus-Dieter Lang named IEEE Fellow
To mark the new year 2018, Prof. Klaus-Dieter Lang has been offered the fellow grade of the Institute of Electrical and Electronics Engineers (IEEE). With this honor, the world's leading engineers' association recognizes Professor Lang's long track record of excellent scholarship in the field of packaging and the heterogeneous integration of microelectronics. Lang already headed the German chapter of one of the IEEE's societies – today's Electronics Packaging Society (EPS) – between 2008 and 2014 and continues to play a substantial role in the successful development of the IEEE with his scholarly contributions and international networking efforts. Fellowships at the IEEE have been proffered by the Board of Directors for over a century; only 0.1 percent of its many members around the world are chosen for this prestigious honor every year.

Best Journal Paper Award for researchers from Fraunhofer IZM, TU Berlin and TU Hamburg-Harburg
Together with their co-authors from TU Berlin and TU Hamburg-Harburg, IZM-researchers Ivan Ndip, Klaus-Dieter Lang and Xiaomin Duan have been honored with the 2016 IEEE CPMT Best Journal Paper Award in the category, »Electrical Performance of Integrated Systems«, for their paper entitled »Efficient Total Crosstalk Analysis of Large Via Arrays in Silicon Interposers«. The award was presented to David Dahl, Ivan Ndip and Klaus-Dieter Lang on June 1, 2017 by the IEEE CPMT President, Jean Trewhella, during the CPMT award ceremony at the 67th ECTC in Lake Buena Vista, Florida, USA.

The paper is based on a fundamental research project on TSVs (Through Silicon Vias) between TU Berlin, TU Hamburg-Harburg and Fraunhofer IZM Berlin, funded by DFG – Deutsche Forschungsgemeinschaft (German Research Foundation).

Martin Schneider-Ramelow appointed Deputy Director of the Institute
The executive board of the Fraunhofer Society has appointed Prof. Martin Schneider-Ramelow as the new Deputy Director of Fraunhofer IZM, as of September 1, 2017. A materials scientist of global renown, he has been researching microelectronic assembly and interconnection technologies for almost two decades and currently heads the »System Integration & Interconnection Technologies« department. In his new role, Prof. Schneider-Ramelow will contribute in particular to managing Fraunhofer IZM's activities at its Dresden facilities and support the cooperation between the institute and the Technische Universität Berlin. Having been named full professor of »Materials in Hetero System Integration« at the university, Martin Schneider-Ramelow is perfectly placed to intensify the current cooperative ventures.

Three Best Paper Awards for IZM-scientists at the IPWLC 2017
The 2017 International Wafer Level Packaging Conference in San Jose, CA, has recognized the work of Dr. Wolfram Steller with not one, but two Best Paper Awards: The »Best of Conference Paper« and »Best of 3D Track Paper« awards were won with his talk on »Dual Side Chip Cooling Realized by Microfluidic Interposer Processing on 300 mm Wafer Diameter«. Dr. Steller's presentation of the technical implementation of a 3D chip stack with the two-sided cooling of high-performance processors convinced the audience of the great promise of the proposed process technologies. The technologies presented by the authors were developed as part of the EU »CarrICool« project in partnership with other European contributors.

Another award went to IZM researcher Dr. Tanja Braun, who received the prize for the »Best of 3D Track Paper« for her contribution »Fan-Out Wafer and Panel Level Technology for Advanced LED Packaging«.

1 *Prof. Klaus-Dieter Lang is presented with the William D. Ashman Achievement Award by IMAPS-President Susan Trulli*

2 *The happy recipients of this year's 3D InCites Awards, among them Lars Böttcher of Fraunhofer IZM (back row in the middle)*

3 *IEEE CPMT President Jean Trewhella and the recipients of the 2016 IEEE CPMT Best Journal Paper Award: Klaus-Dieter Lang, David Dahl from TU Hamburg-Harburg and Ivan Ndip (from left to right)*

BEST PAPER, EDITORIALS, ACADEMIA

Best Paper

IEEE CPMT Best Journal Paper Award for Ivan Ndip
»Efficient Total Crosstalk Analysis of Large Via Arrays in Silicon Interposers«
David Dahl, Torsten Reuschel, Jan Birger Preibisch, Xiaomin Duan, Ivan Ndip, Klaus-Dieter Lang and Christian Schuster

IPWLC 2017: »Best of Conference Paper« and »Best of 3D Track Paper« for Wolfram Steller
»Dual Side Chip Cooling Realized by Microfluidic Interposer Processing on 300mm Wafer Diameter«
Wolfram Steller, Frank Windrich, Philipp Heilfort, Jessica Kleff, Raúl Mroßko, Jürgen Keller, Thomas Brunschwiler, Gerd Schlottig, Hermann Oppermann, M. Jürgen Wolf and Klaus-Dieter Lang

IPWLC 2017: Tanja Braun is awarded the »Best WLP Track Paper«
»Fan-Out Wafer and Panel Level Technology for Advanced LED Packaging«
Tanja Braun, Ruben Kahle, Stefan Raatz, Pascal Graap, Ole Hölck, Jörg Bauer, Karl-Friedrich Becker, Rolf Aschenbrenner, Steve Voges, Marc Dreissigacker, Klaus-Dieter Lang, Jürgen Moosburger, Frank Singer and Lutz Höppel

SENSORCOM 2017: Best Paper for Tanja Braun, Christian Dils and Klaus-Dieter Lang
»SAFESENS – Smart Sensors for Fire Safety (First Responders Occupancy, Activity and Vital Signs Monitoring)«
Brendan O'Flynn, Michael Walsh, Eduardo M. Pereira, Piyush Agrawal, Tino Fuchs, Jos Oudenhoven, Axel Nackaerts, Tanja Braun, Klaus-Dieter Lang, Christian Dils

Editorials

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

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

Smart Systems Integration 2017 Conference Proceedings
Lang, K.-D. (Co-Editor)

Habilitation

Ndip, Ivan (BTU Cottbus)
»Characterization and Optimization of Integrated Antennas and System-Integration Structures for Millimeter-wave/ Terahertz Wireless System Design on the Basis of the M3-Approach«

LECTURES

Technische Universität Berlin

Dr. B. Curran
- Design, Simulation and Reliability of Microsystems
- High-Frequency Measurement Techniques for Electronic Packaging

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

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

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

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

Dr. I. Ndip
- Electromagnetic Compatibility in Electrical Systems

Prof. M. Schneider-Ramelow
- Basic Materials of System Integration
- Failure Mechanisms and Failure Analysis in Hetero-Microsystems

Universität Aalborg

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

HTW, Hochschule für Technik und Wirtschaft Berlin

Dr. H. Walter
- Basic Materials for Microsystem Technologies

Dr. R. Hahn
- Miniaturized Energy Supply Systems

Dr. T. Tekin
- Nano Technologies

COOPERATIONS WITH UNIVERSITIES (SELECTION)

Some of Fraunhofer IZM's university partners
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Technical University of Darmstadt
Berlin University of the Arts
Heidelberg University
Paderborn University
Potsdam University
Rostock University

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

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

Since 2011, the traditional double appointment of Fraunhofer IZM Director and Head of the Research Center for Microperipheric Technologies has been held by Professor Klaus-Dieter Lang. Both institutions research and develop smart system integration with a joint goal, namely to integrate components that may have been manufactured using very different technologies on or in a single carrier substrate.

Fraunhofer IZM-ASSID cooperates with the Electronic Packaging Laboratory (IAVT) at TU Dresden
Within the framework of the joint Assistant Professorship between Fraunhofer IZM-ASSID in Dresden Moritzburg and TU Dresden (Electronic Packaging Laboratory, IAVT), junior professor Iuliana Panchenko and her research group work on new materials and technologies for fine-pitch interconnects in 3D/2.5D Si assemblies.

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Airbus Defense & Space	Ulm
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AMS Sensor Germany GmbH	Jena
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Asahi Glass Co., Ltd.	Tokyo (J)
AT&S AG	Leoben (A)
Atotech Deutschland GmbH	Berlin
AUDI AG	Ingolstadt
Baker Hughes INTEQ GmbH	Celle
BMW AG	Munich
BrewerScience	Rolla (USA)
Broadcom Ltd.	Regensburg
Bundesdruckerei GmbH	Berlin
Cascade Microtech GmbH	Thiendorf
Cerebras Systems Inc.	Los Altos (USA)
Coinbau GmbH	Dresden
Continental AG	Frankfurt, Regensburg,
Daimler AG	Stuttgart
First Sensor AG	Berlin, Dresden
EV Group (EVG)	St. Florian a.I. (A)
Evatec Advanced Technologies AG	Trübbach (CH)
Finisar	D, USA
Fujifilm Electronic Materials	EU, USA
Fujitsu Technology GmbH	Augsburg
GLOBALFOUNDRIES INC.	Dresden
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Heterogeneous Integration Roadmap (HIR)	M. J. Wolf	Member Technical Working Group
IEEE Component, Packaging and Manufacturing Technology Society	R. Aschenbrenner	Fellow
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IEEE CPMT German Chapter	R. Aschenbrenner	Chair
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Silicon Saxony e. V.	M. J. Wolf	Member
Smart Lighting	Dr. R. Jordan	Steering Committee
SMT/HYBRID/PACKAGING Congress	Prof. K.-D. Lang	Head of Scientific Committee
Wissenschaftlich-technischer Rat der Fraunhofer-Gesellschaft	Dr. N. F. Nissen	Representative of Fraunhofer IZM

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Zamora, V.; Hofmann, J. ; Marx, S.; Herter, J.; Nguyen, D.; Arndt-Staufenbiel, N.; Schröder, H.
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Ndip, Ivan; Curran, Brian
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Oppermann, Hermann; Hutter, Matthias; Ehrhardt, Christian
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DE 10 2015 113 809 B4

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DE 10 2016 200 063 B4

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Process for the Manufacturing of an Electronic Component and Electronic Component
DE 10 2016 202 548 B3

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Cover:
200 mm wafer-level LED package with four flip-chip LEDs per package,
developed in the HeraKLED project