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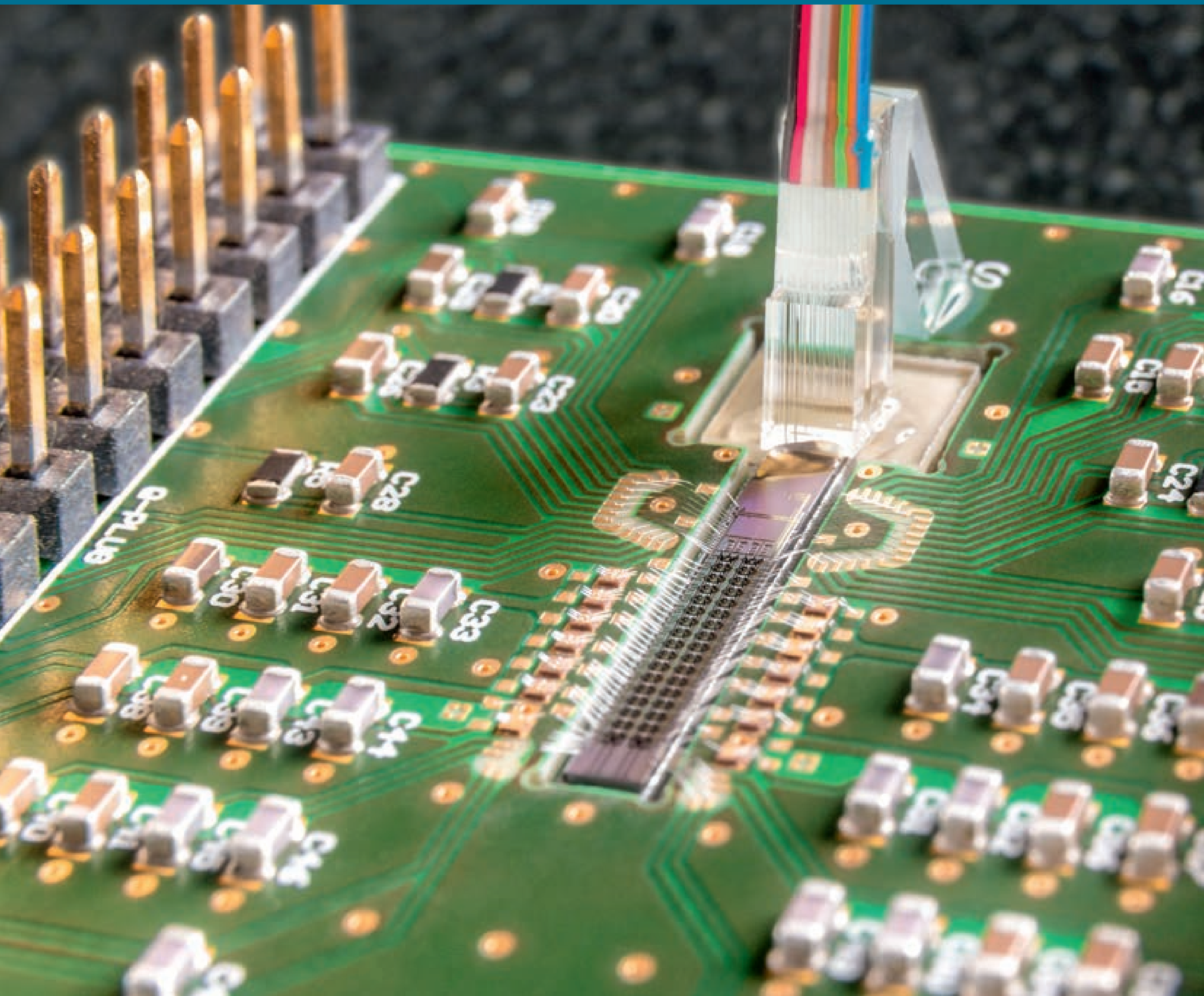
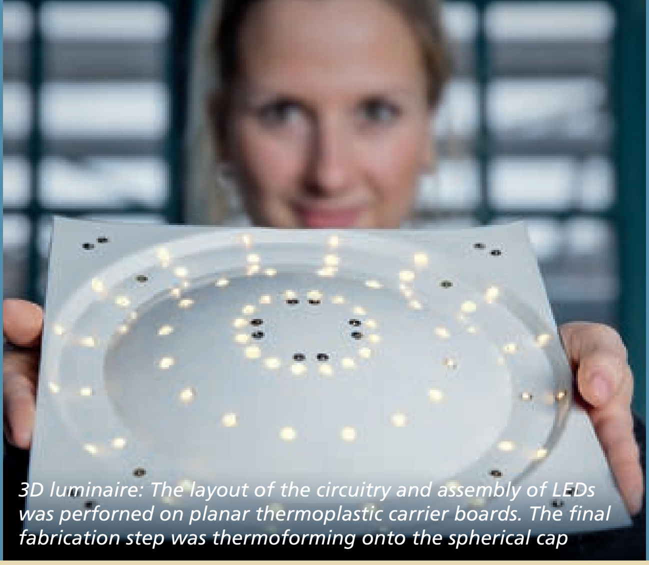
IZM

FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

DEPARTMENT
SYSTEM INTEGRATION AND INTERCONNECTION TECHNOLOGIES



FRAUNHOFER IZM



3D luminaire: The layout of the circuitry and assembly of LEDs was performed on planar thermoplastic carrier boards. The final fabrication step was thermoforming onto the spherical cap

SYSTEM INTEGRATION & INTERCONNECTION TECHNOLOGIES

The Fraunhofer Institute for Reliability and Microintegration IZM develops and implements new concepts for the assembly of highly integrated electronic and photonic systems. Its application-oriented research bridges the gap between the microelectronic component providers and technical system manufacturers for a broad range of industries, such as automotive, energy or medical technologies, as well as industrial engineering.

The range of services provided by the department System Integration and Interconnection Technologies (SIIT) with its roughly 170 employees spans from consultation to process development, right through to technical system solutions. Developing processes and materials for interconnection technologies on board, module and package levels and the integration of electrical, optical and power-electronic components and systems are at the forefront of our activities.

We assist companies with application-oriented pre-competitive research, as well as the development of prototypes and small volume production. Our services include application advice, technology transfer and further qualification of personnel through practical training.

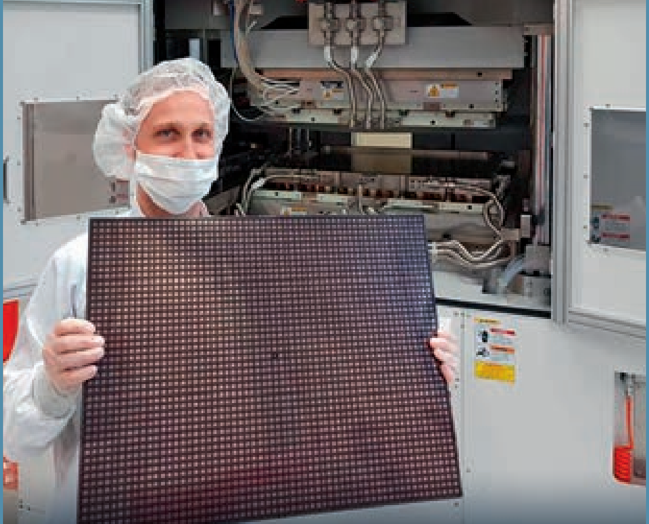
We cooperate closely with the Technical University of Berlin (Center for Microperipheric Technologies), especially within European joint projects and on basic research into materials for packaging technology.

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

- New packaging materials: solder, wires, bumps, adhesives and encapsulants
- SMD, CSP, BGA, POP and bare die precision assembly
- Flip-chip techniques (soldering, sintering, adhesive joining, thermo-compression and thermosonic welding)
- Die attachment (soldering, sintering and adhesive joining)
- Wire and ribbon bonding (ball/wedge, wedge/wedge, heavy wire and ribbon)
- Flip-chip underfilling and COB glob topping
- Transfer molding of sensor packages and power modules on lead frame devices
- Wafer level & panel level molding up to 600 × 450 mm²
- Potting and conformal coating
- Embedding of chips and components
- Fiber coupling and optical interconnection to planar waveguides, fiber lenses and laser joining
- Thin-glass and silicon photonic packaging
- Power electronics: Electrical/electromagnetic/thermal/thermomechanical design, component selection, prototype manufacturing

We focus in particular on the challenges of optical and power electronics, as well as the requirements of high-temperature and high-frequency applications and enabling technologies, e.g. for medical devices.

Cover: Evaluation board with optical and electrical coupling to a SiGe chip containing integrated IQ modulators for optical telecom with 100 Gbps and faster (SPeeD project, funded by the BMBF, in cooperation with IHP)



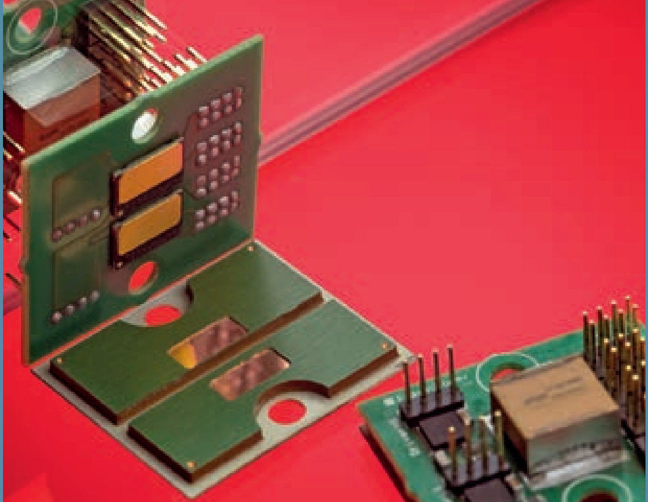
Panel manufactured at Fraunhofer IZM (610×457 mm)

PANEL LEVEL PACKAGING

Two trends are shaping the current development of system integration technologies. The first is an ongoing increase in the number of functions directly included in a system – such as electrical, optical, mechanical, biological and chemical processes – combined with the demand for higher reliability and longer system lifetime. Second is the increasingly seamless merging of products and electronics, which necessitates adapting electronics to predefined materials, forms and application environments.

Large area mold embedding technologies and embedding of active components into printed circuit boards (chip-in-polymer) are two major packaging trends in this area. Both technologies are included in the panel level packaging research at Fraunhofer IZM.

Fan-out wafer level packaging (FOWLP) is one of the latest packaging trends in microelectronics. Besides technology developments towards heterogeneous integration including multiple die packaging, passive component integration in package and redistribution layer or package-on-package approaches also, larger substrates formats are also targeted. FOWLP has a high potential in significant package miniaturization, both with regard to package volume and thickness. In addition, the redistribution layer can also provide embedded passives (R, L, C) as well as antenna structures using a multi-layer structure. It can be used for multi-chip packages for system in package (SiP) and heterogeneous integration. Manufacturing is currently done on wafer level up to 12"/300 mm and 330 mm, respectively. For higher productivity and thus lower costs larger form factors are introduced. Consequently, panel level packaging has higher potential than following the wafer level roadmaps to 450 mm.



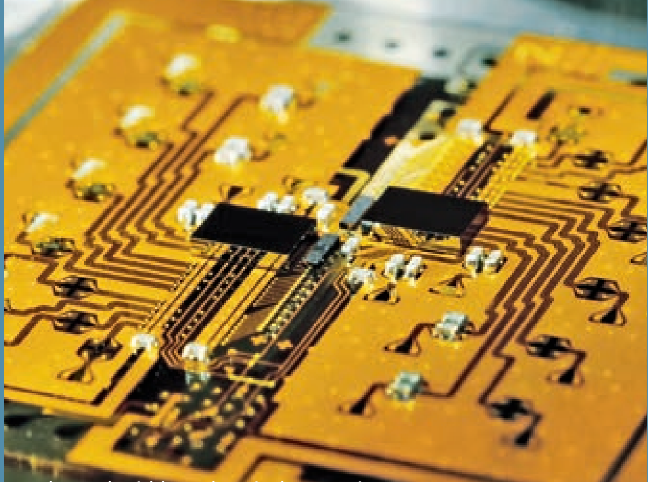
Low inductive Gallium Nitride IPM on insulated metal substrate

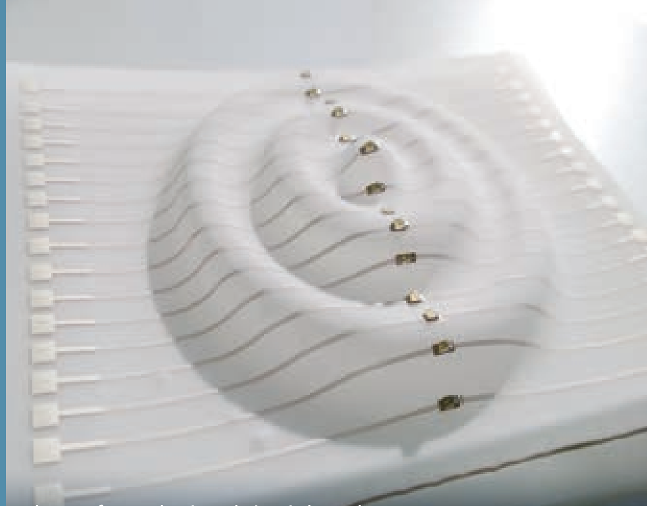
POWER ELECTRONICS

New power semiconductors like silicon carbide (SiC) or gallium nitride (GaN) can significantly increase energy conversion efficiency. However, the gain is limited in conventional semiconductor packaging using wire bonds by parasitic electromagnetic effects. Control and DC link are often positioned a certain distance apart and connected to the power module via press or screw contacts. These parts of a power inverter's packaging also generate a high degree of electromagnetic effects, leading to increased losses in the inverter and, thus, to a reduction in efficacy.

For this reason, we at Fraunhofer IZM have been researching new solutions for power modules and power electronic circuits for many years. In terms of modules, the most successful approach is connecting the DCB/AMB or IM substrate with PCB technology (DCB: Direct Copper Bonded, AMB: Active Metal Brazed, IMS: Insulated Metal Substrate). This technology exploits both the advantages of the substrate, which, apart from the electrical insulation, include the ability to handle higher currents and outstanding thermal behavior, and the advantages of PCB technology. This allows control and DC link to be mounted in the direct vicinity of the semiconductor and switching cell inductions of under 1 nH can be achieved.

Thanks to these innovative modules, significantly smaller and more efficient power electronic circuits are possible. The research group Power Electronics demonstrates this with its development of primarily grid-connected circuits, such as solar inverters and PFC or DC/DC converters. As part of this, we have developed key expertise in ensuring compatibility between magnetic components, on the one hand, and control processes and switching losses, on the other, which is fed into the development and evaluation of prototypes for our customers.


4-channel mid-board optical transceiver, flip-chip assembly of electro-optical components on glass interposer with integrated micro lens array


Thermoformed printed circuit board with LEDs surface mounted prior to forming

PHOTONIC SYSTEMS

Photonic integration technologies are becoming indispensable, from chip level through board and module level to complete systems. In data communication and telecommunication such technologies are pushed forward by rapidly increasing bandwidths and energy efficiency needs, while simultaneously being subject to the demands for miniaturization and increased packaging density. In the area of solid state lighting high functionality and low costs are required, while laser modules for material processing are designed for high performance and long term reliability. Optical sensors, on the other hand, need maximum functionality combined with minimum space requirements. At Fraunhofer IZM we exceed the simple combination of discrete components – up to highly integrated systems using state-of-the-art technologies, such as silicon photonics and plasmonics.

Key technologies in module packaging:

- Optoelectronic chip assembly:
  Flip-chip, self-alignment, CTE adjustment
- Photonic module packaging:
  Optical design, fiber lensing, laser fusing of fibers, fiber-to-chip coupling, automatic active/passive alignment of micro-optics and PIC, silicon photonic packaging
- Optical backplane & EOCB:
  Integrated optical waveguides (polymer and ion exchange in thin glass), optical out-of-plane coupling
- Sensors:
  Biomedical sensors, microfluidics, fiber gyroscopes, integration of micro resonators and PIC
- Photonic and plasmonic systems:
  Design, simulation, characterization
- LED modules: Simulation, process development, assembly, characterization, failure analysis

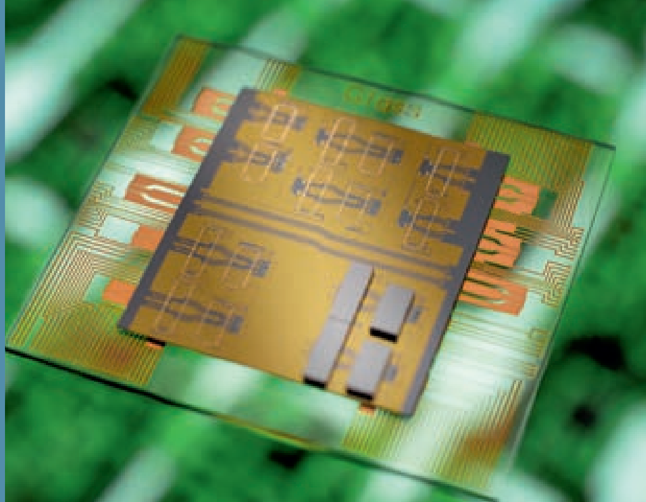
CONFORMABLE ELECTRONICS

Rigid and flexible PCBs have been the standard for circuit carriers in the electronics industry for decades. In recent years, development has extended to new types of electronic systems and circuit carriers that can be applied on or integrated into three-dimensional rigid or flexible freeform surfaces. The new technologies not only reduce weight and volume in already familiar applications, but also make entirely new functionalities and systemic changes possible. Structures and surfaces with integrated sensors, actuators and electronics here give rise to novel interaction between the environment and the individual.

A key aspect of conformable electronics is the process flow. The term "conformable" indicates the primary focus on moldability, as opposed to pre-designed three-dimensional electronics (an approach advanced, for example, in MID technology). The design of conformable electronics draws heavily on established two-dimensional processing technologies, used in the assembly of circuit carriers (PCBs), and component assembly techniques established over recent decades. As such, conformable electronics are manufactured in the same way as conventional electronic systems. The advantages over rigid and flexible PCBs are only introduced in the final manufacturing step (thermoforming) or in the application (e.g. as an electronic band-aid).

We at Fraunhofer IZM research materials for carrier substrates and circuit tracks, as well as design rules and processes for conformable electronics. The manufacturing and product concepts include electronic systems on polymer or textile circuit carriers that can distended once or manifold by more than five percent, thus allowing coverage of three-dimensional freeform surfaces without creasing. Apart from specially structured Cu tracks, printed tracks are also employed. Currently, optimized forming processes are being researched to increase the degree of forming while improving control of local strain.

WORKING GROUPS

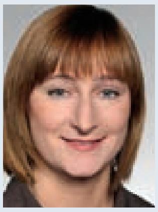


Photonic 3D interposer with electronic and optical add-ons assembled on a glass substrate

System-on-Flex

We develop and qualify packaging technologies on flexible substrates. Our research focuses on adhesive bonding and soldering of bare dies. We have many years of experience in material selection, process development and reliability assessment for ACA, NCA and ICA flip-chip bonding on various substrate materials. New approaches in nanostructure technology are also being investigated, including their potential for new low-temperature interconnection technology. Over recent years, we have also begun developing and evaluating emerging technologies for the integration of electronics in textiles.

- Adhesive bonding
- Ultra-thin flip-chip interconnections
- Thermoplastic substrates
- Electronics in textiles
- Medical microsystems with heterogeneous components



Christine Kallmayer
+49 30 46403-228
christine.kallmayer@izm.fraunhofer.de

Optical Interconnection Technology

We realize customized photonic packages integrating micro- and fiber-optical components with a high degree of automation. The electro-optical boards and modules that we design and assemble enable miniaturized and highly complex photonic subsystems for telecom and datacom, sensors, biophotonics and integrated lighting.
Our competences are: optical design, ion exchange for optical waveguides and lenses in thin glass in panel format, automatic alignment, fiber coupling, 3D polymer optics, adhesive bonding and optical casting, splicing, laser welding of fibers and fiber lensing, characterization and reliability testing.

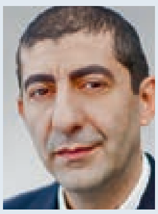
- EOCB and optical backplane
- Integration of micro resonators and lenses
- Automation of micro-optical assembly
- Fiber packaging for UV, VIS, IR, MIR-sensors

Dr. Henning Schröder
+49 30 46403-277
henning.schroeder@izm.fraunhofer.de

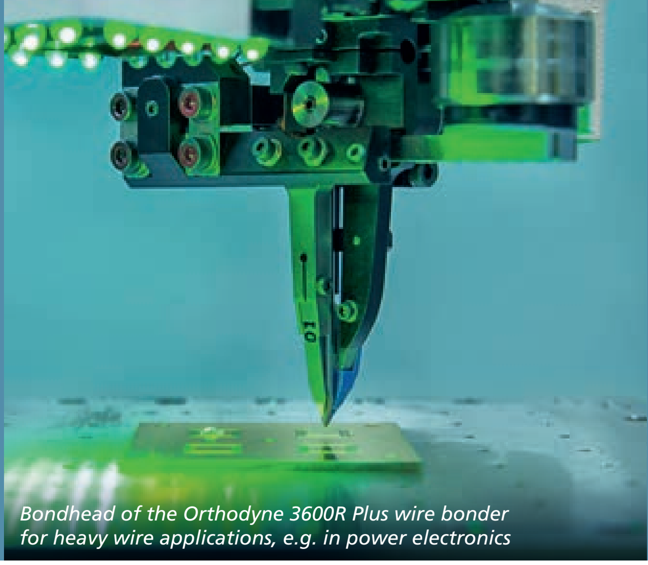
Photonic & Plasmonic Systems

We research information and communication technologies (ICT) and sensor technology. In recent years, these technology areas have begun to converge at a rapidly increasing rate. We specialize in photonic interconnection layers based on 3D system-in-package technologies, using them to develop new, high-performance microsystems that require low latencies, high bandwidth and high integration densities. Photonic, digital, analog, high-frequency (HF), microwave (MW) and optoelectronic mechanical components and systems on both nano and micro-scales have to be factored into this design approach concurrently.

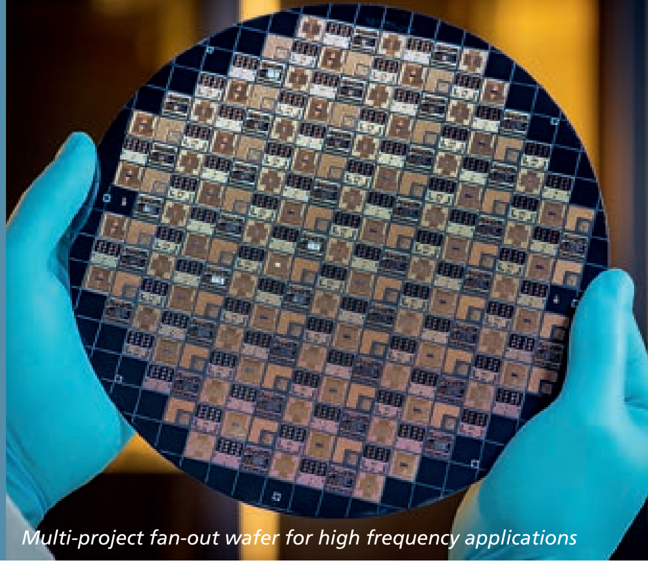
- Photonic and plasmonic components and systems
- Silicon photonics
- Microwave and millimeter-wave photonics



Dr. Tolga Tekin
+49 30 46403-639
tolga.tekin@izm.fraunhofer.de



Bondhead of the Orthodyne 3600R Plus wire bonder for heavy wire applications, e.g. in power electronics



Multi-project fan-out wafer for high frequency applications

Power Electronic Systems

The working group Power Electronic Systems deals with two core fields in power electronics. The first is the development of custom-made prototypes including packaging and housing. Starting with preliminary simulation, we cover design and component selection and finally put prototypes into operation. EMC in power electronics is the second big issue, here a special focus is on trouble shooting for customers from industry. Especially the close interconnection between package development and EMC led to a leading role of the group regarding packaging for fast semiconductors.

- Device development (thermal, electrical, eletromagnetic, mechanical (housing)) and prototype manufacturing
- Simulation (electrical, electromagnetic)
- Putting into operation/trouble shooting

Prof. Eckart Hoene
+49 30 46403-146
eckart.hoene@izm.fraunhofer.de

Chip & Wire Bonding

Our core expertise is the quality and process stability as well as the material and machine selection of fully automatic industrial wire bonding processes. An additional focus of our work are failure analyses and reliability assessments.

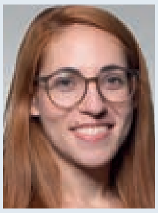
- Ball/wedge & wedge/wedge (Ø 17–75 µm)
- Heavy wire (Ø 125–500 µm), ribbon (up to 2 mm × 300 µm)
- HF-ribbon (20 × 10 µm² to 250 × 50 µm²)
- Au, Cu/(Pd)/(Au), AlSi1 and further materials
- Ultrasonic welding of preforms (Cu/Cu, Cu/Al, Al/Al)
- Reliability testing of bond wire connections (APC / passive)
- Leadframes, PCBs, LTCCs, ceramic hybrids and DCBs in applications like industrial sensors, automotive, interconnection of energy cells, power electronics …

Dr. Martin Hempel
+49 30 46403-159
martin.hempel@izm.fraunhofer.de

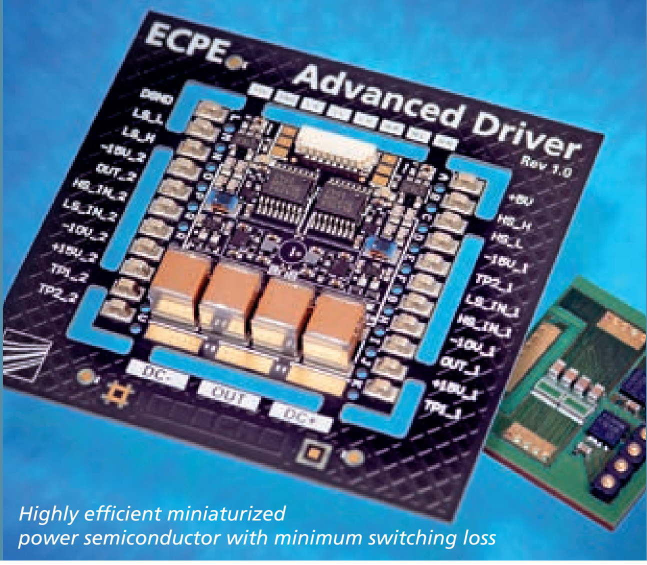
Technologies for Bioelectronics

For the design and fabrication of active neural interfaces, small custom-designed electronics are integrated into microsystems for stimulation of and recording from the neural tissue. Such microsystems are implemented e.g. as flexible implants based on biocompatible materials tailored for the central or peripheral nervous system. The design, fabrication, package and testing of the implants targets long-term use, e.g. for chronic diseases. As part of this, new approaches for neural stimulation and wireless power transfer are investigated as well.

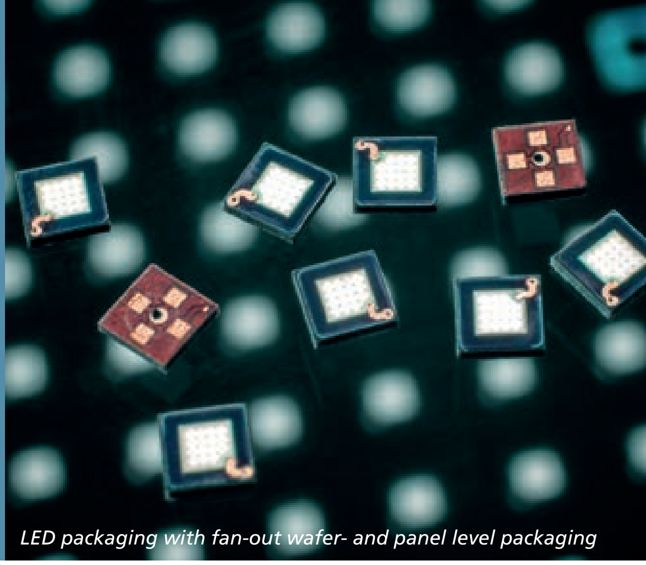
- Flexible electrode fabrication for neural stimulation and recording
- Protecting active implantable devices based on soft materials
- Wireless power transfer for deep implants



Dr. Vasiliki (Vasso) Giagka
+49 30 46403-700
vasiliki.giagka@izm.fraunhofer.de



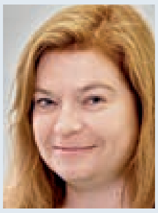
Highly efficient miniaturized power semiconductor with minimum switching loss


LED packaging with fan-out wafer- and panel level packaging

Assembly & Encapsulation

We research integration technologies for system-in-package products, focusing in particular on device assembly for highly integrated packages and encapsulation and coating processes based on polymeric materials. Our technology portfolio includes pick-and-place processes – also for large-area substrates and stacked assemblies – and a wide variety of encapsulation processes, from dispensing, jetting to film coating, through to transfer and compression molding. Material, process and device analyses complete our range of expertise.

- Mechanical design for highly integrated systems
- High precision dispensing through printing and jetting
- Encapsulation processes – large-volume & wafer/panel level
- Polymer/package analysis, including ultrasound and X-ray CT

Karl-Friedrich Becker
+49 30 46403-242
karl-friedrich.becker@izm.fraunhofer.de
Dr. Tanja Braun
+49 30 46403-244
tanja.braun@izm.fraunhofer.de

Embedding & Substrates

We specialize in the development of technologies for the embedding of active chips and passive components into organic substrates. This embedding technology is used to manufacture 3D system-in-packages (SiPs), RF modules and power chip packages. Additional research focuses on surface finishes and the development of galvanic nanostructures for low-temperature interconnection processes.

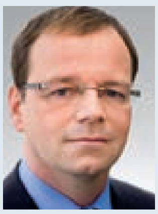
- Embedding of active and passive components into organic substrates
- Stretchable electronic systems
- Modular systems with embedded components
- Power packages and modules with embedded chips
- Fine line wiring down to 5 μm for panel level packaging and advanced substrates


Dr. Andreas Ostmann
+49 30 46403-187
andreas.ostmann@izm.fraunhofer.de
Lars Böttcher
+49 30 46403-643
lars.boettcher@izm.fraunhofer.de

Interconnect Metallurgy and Processes

Our technology portfolio includes flip-chip and die bonding on board and package level for LEDs, optical & RF components as well as power electronics.

- Lead-free reflow solders
- Nano-alloying of solders and fluxes
- Wetting, spreading, solidification
- Fluxless bonding methods
- Ag sintering and transient liquid phase bonding
- Reactions with barrier and wetting layers
- Phase transformation, diffusion and electromigration
- Growth of intermetallic compounds
- Quality assessment of electronic assemblies
- Interconnects for high operating temperatures
- Reliability testing of PWA



Dr. Matthias Hutter
+49 30 46403-167
matthias.hutter@izm.fraunhofer.de

SERVICE & CONTACT

Equipment

We use modern clean-room, technology and reliability laboratories, suited to the development of new processes and analysis techniques for many different technologies.

- Process line for substrate manufacturing up to 610 × 456 mm²
- Laser direct imaging system (10 µm L/S)
- High-precision assembly line for fully automatic chip-on-board processing – from component placement to wire bonding and encapsulation
- Equipment for selective, plasma, vapor phase and convection soldering
- Wafer- and panel-level encapsulation up to 600 × 450 mm²
- Transfer molding for SiPs and large-volume power electronic packages
- TexLab – Laboratory for textile-integrated electronic systems
- Automated micro-optical assembly systems
- Laser processing of glass substrates
- Optical fiber joining techniques, fiber lensing, and bottle resonators made of optical fibers
- Measurement techniques to characterize the optical properties of materials, optical waveguides, micro-optics, and photonic systems
- Automated optical characterization of micro lens arrays
- LED reliability and testing laboratory
- SSXPS, X-ray and acoustic CT, focused ion beam (FIB) and field emission SEM
- Fine-topography analysis of surfaces using tactile, confocal scanning and optical large-area processes as well as package warpage at high temperatures
- Combined vibration/thermal chamber
- Equipment for power electronics
  - Power supply and electrical and mechanical loads
  - Test equipment for EMC (shielding cabin), isolation (partial discharge)
  - Component characterization: impedances (up to 500 MHz), losses (calorimeter), active cycling
  - Design tools: Altium Designer, Simplorer, Portunus, CST, Solid Works, Matlab

Fraunhofer IZM
Head: Prof. Klaus-Dieter Lang
Gustav-Meyer-Allee 25
13355 Berlin
Phone: +49 30 46403-100
Fax: +49 30 46403-111
E-Mail: info@izm.fraunhofer.de
URL: www.izm.fraunhofer.de/en

Your contact for
System Integration and Interconnection Technologies

Rolf Aschenbrenner
Phone: +49 30 46403-164
Fax: +49 30 46403-161
rolf.aschenbrenner@izm.fraunhofer.de

Dr. Andreas Ostmann
Phone: +49 30 46403-187
andreas.ostmann@izm.fraunhofer.de

Our customers can choose from various models for cooperation, from directly assigning a joint project to a cooperation as part of a scientific-technical research project funded on EC, federal or state level. Regardless of which model you choose, our goal remains the same: Providing our customers with the best performance at the fastest turnover times.

- Product-oriented research and development
- Technical service and technology transfer
- Rapid prototype development
- Qualification and reliability tests, failure analysis
- Technical consulting and advanced training
- Research studies and expert assessment
- Certification and training

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