Fraunhofer IZM

Fraunhofer Institute for Reliability
and Microintegration IZM

Department

System Integration and Interconnection Technologies

System Integration and Interconnection Technologies

Embedded highly miniaturized sensor and controller module

The Fraunhofer Institute for Reliability and Microintegration IZM is dedicated to the development and introduction of innovative concepts for the construction of highly integrated electronic and photonic systems. With our application-driven research, the Institute represents the link between the producers of microelectronic components and the makers of technical systems in a wide range of industries, including automotive, energy, manufacturing, and medical technology. The System Integration and Interconnection Technology department with its approx. 170 members of staff offers a range of services from process development to complete system solutions. Our team is committed to developing processes and materials for new interconnection approaches on the board, module, and package level and to the integration of electrical, optical, and power electronics components and systems.

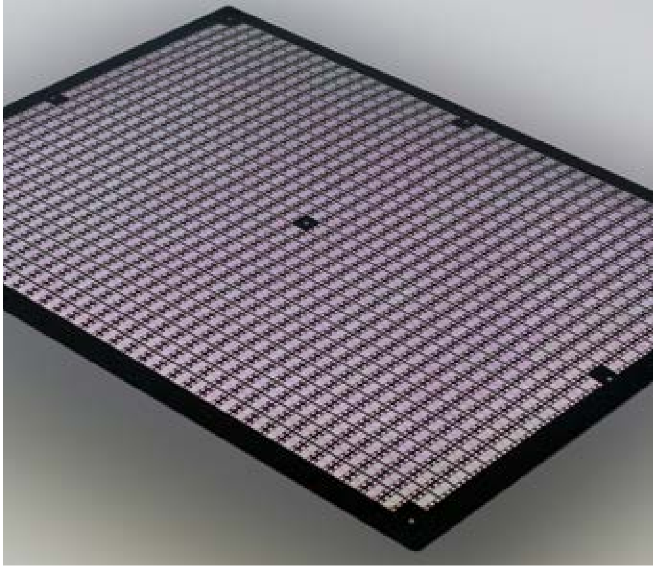
We assist enterprises in applied, pre-commercial research as well as prototype and small series production. Our work includes application consulting, technology transfer, and practice-oriented training for our partners' staff.

We are focusing on interconnection and encapsulation technology for electronic and photonic packaging, including

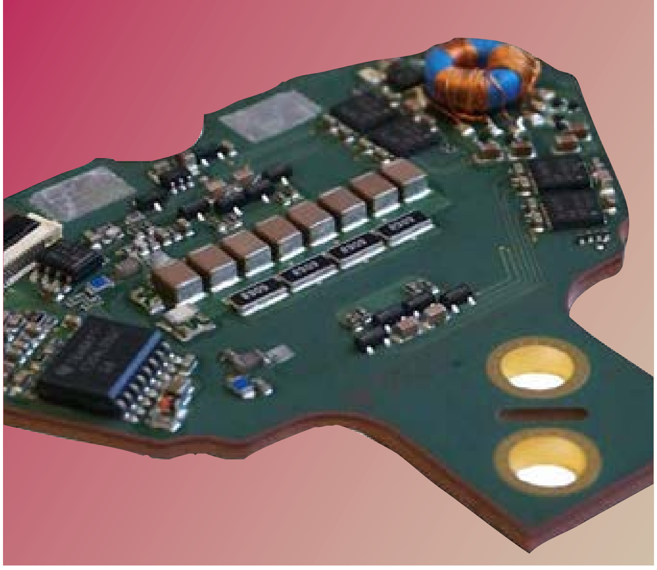
- SMD, CSP, BGA, POP and Bare-Die-precision assembly
- Flip-chip technology (soldering, sintering, gluing, thermocompression and thermosonic bonding)
- Die attachment (soldering, sintering, gluing)
- Wire and ribbon bonding (ball/wedge, wedge/wedge, thick wire and ribbon bonding)
- Flip-chip underfilling and COB glob topping
- Transfer and compression molding
- Chip and component embedding
- Power electronics: Electrical / electromagnetic/thermal/ thermomechanical designs, module selection, prototyping
- Thin glass and silicon photonics packaging
- Fiber coupling and optical connections to planar waveguides, fiber lenses, and laser bonding

Optoelectronics and power electronics and their challenges are part of our focus, as are the specific needs of high-temperature or high-frequency applications and the use of advanced integration technology in e.g. medical technology applications. We work in cutting-edge cleanroom, technology, and reliability laboratories, designed to be ideally suited to process and analytics development for a range of technologies.

- Processing line for substrate and panel production up to 24" × 18"
- Laser direct imaging system (up to 4 µm L/S) for large-format lithography processes
- High-precision assembly line for fully automated SMD, COB, FC, and large-format chip assembly in embedding processes
- Equipment for selective, plasma, vapor-phase, and convection soldering
- Wafer and panel-level encapsulation
- Transfer molding for SiPs and high-volume power electronics packages
- Laboratory for the textile integration of electronics
- Development of glass substrates: Laser structuring, etching and smoothing, metallization, integrated optical waveguides, microlenses, lattices, resonators
- Joining technology: Design, optical fiber coupling, fiber lenses, automated optical microassembly
- Fully equipped electrical characterization lab for power electronics commissioning tests
- Power electronics design tools: electrical, electromagnetic, constructional, thermal, mechanical
- SSXPS, X-ray CT, ultrasound microscopy, FIB, and REM
- Detailed surface topography analysis with tactile, confocal scanning and optical large-area technology as well as package warpage
- Material analysis: DSC, TMA, DMA, TGA, rheometrics, dielectric analysis, sorption analysis
- Reliability tests including TCT, HT, HAST, drop, vibration, …



Molded fan-out panel



Fully integrated low inductive SiC power module, embedded in circuit board

Panel Level Packaging

Two trends are shaping the current development of system integration technologies. The first is an ongoing functional integration into systems – 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.

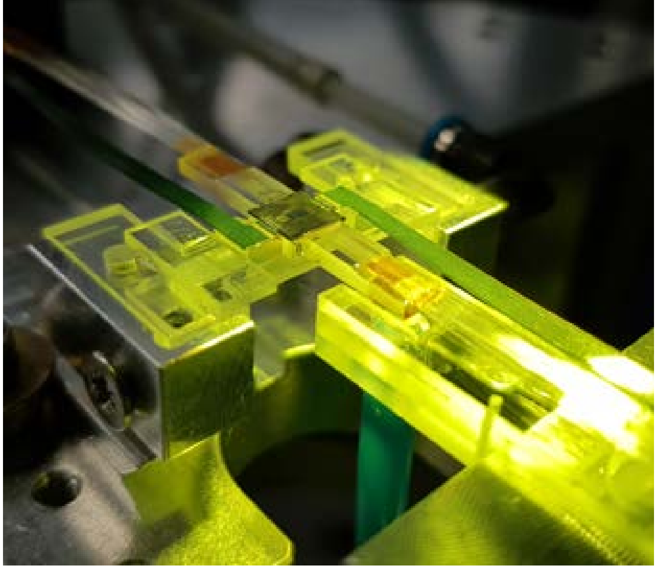
Mold embedding with its two flavors fan-out wafer level packaging (FOWLP) with form factors of 200 and 300 mm circular and fan-out panel level packaging (FOPLP) with sizes around 610 x 457 mm² is one of the hottest packaging trends in microelectronics. It addresses heterogeneous integration including multiple die packaging, passive component integration in package and redistribution layer or package-on-package approaches. Both FO technologies have 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 or even 3D structure. It can be used for multi-chip packages for system in package (SiP) and heterogeneous integration and thus addresses the key challenges of advanced packaging.

Power Electronics

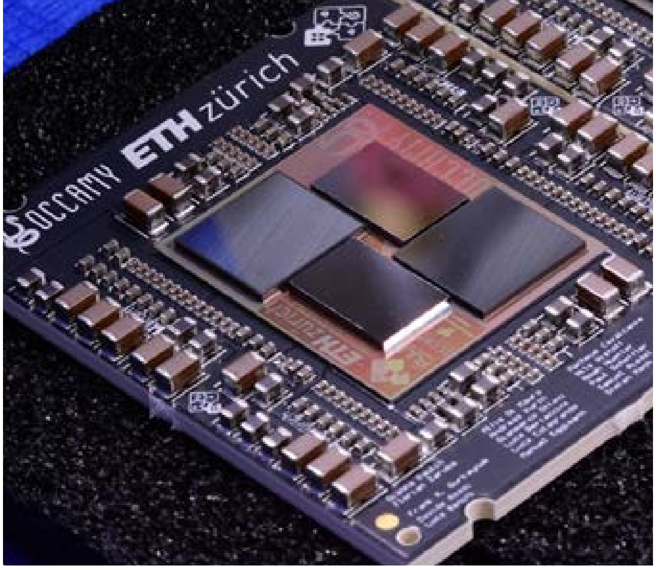
New power semiconductors like silicon carbide (SiC) or gallium nitride (GaN) can significantly increase energy conversion efficiency. However, the gain is limited in conventional semiconductor packaging using wire bonds by parasitic electromagnetic effects. Control and DC link are often positioned a 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.



Highly reliable integration of fiber pigtailed QuantumPIC on 3D glass platform



AI-Chip/HBM-assembly on Si-interposer mounted on carrier PCB

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 quantum high coupling efficiency and low temperatures 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 develop advanced photonic system-in-packages – up to hybrid integrated systems combining PICs, such as silicon photonics, SiN and glass with microelectronics.

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, photonic wire bonding
- Optical backplane and 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
- Quantum photonic packaging for ion traps, neutral atoms, NV centers, QPICS

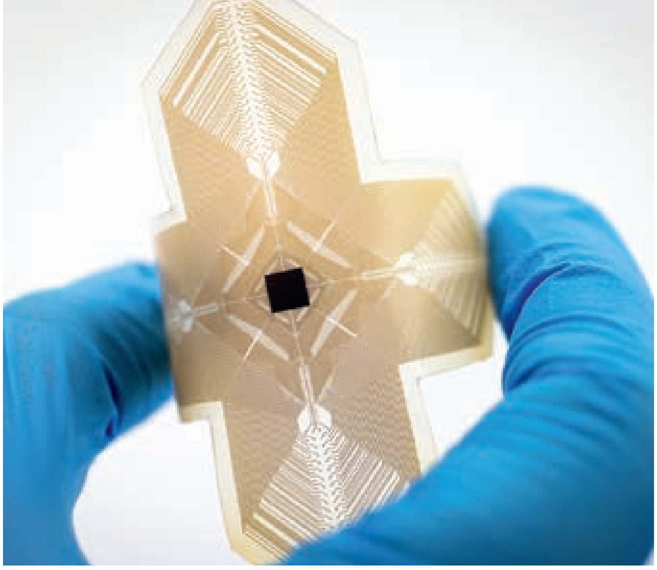
Packaging for Chiplets

Flip-chip and fan-out designs or ICs embedded in their substrate: Technologies like these have made advanced packaging a cornerstone of modern microelectronics. The industry and its research partners have responded to these trends by introducing novel techniques and architectures like chiplets or heterogeneous integration that promise to pave the way for cost-efficient high-performance systems. Chiplets in particular are garnering increasing attention as one of the key solutions for the high-performance computers of the future. The advantages of chiplets lie in their far greater yield when compared to system-on-chip designs, in the increased security that can be achieved in distributed manufacturing, and in the cost efficiencies to be had from designing systems with chiplets from the foundries that offer the best value for the purpose.

Current research efforts are aimed at producing tiny conductors on organic carriers (with a l/s of 2 µm), e. g. as chiplet interposers, assembling fine-pitch components (~ 100 µm), using large-format glass substrates with polymer wiring layers in highly integrated circuit carriers, improving reliability by encapsulation (underfilling / molding) or generally developing new design rules or entire assembly design kits for chiplet packaging processes.

The long-standing packaging know-how of Fraunhofer IZM is being put to use in a range of projects in the field, including the BMBF-funded CeCaS project that has brought Infineon and other tier-1 partners on board for research into the eponymous Central Car Server (CeCaS) chiplet modules with organic interposers. Fraunhofer IZM is contributing as a specialist for flip-chip assembly and for producing digital twins of the chiplet modules.

Bonded light modules – EU-project Re-Fream – Second Skins designed by Malou Beemer



A flexible active microsystem for recording and stimulation of neural tissue

E-Textiles

Electronic textiles or E-textiles merge electronic components with textiles. This smart combination results in intelligent products with increased functionality for e. g. wearable products like clothing or medical devices but also smart surfaces in buildings or vehicles. Specific applications for e-textiles include health and fitness: monitoring vital signs or active stimulation of the body with electric impulses or light. E-textiles can track physical activity, monitor posture, and even detect falls, helping to prevent injuries. In protective clothing for workers or soldiers, e-textiles enable body-worn power and data networks to connect different sensors, processing units, EUDs, and power supplies ergonomically and comfortably. Besides, E-Textiles can be used in smart buildings to monitor temperature, humidity, and other environmental conditions.

To achieve their full and huge potential, we are working on solving technological challenges for E-Textiles. One of the most significant is reliably integrating electronic components or modules into the textile base. This entails contacting textile circuits that connect the distributed parts of the e-textiles system and allow for power and data transfer with functional components or textile sensors.

Depending on the requirements of the e-textile, we use different technologies like embroidery, knitting, printing, lamination or ribbons to create such textile circuits. Textile bonding and other interconnection methods allow for assembly of electronic modules onto the circuits. To validate our or your technology we use intensive testing and analytics in house. Our participation in industrial standardization and scientific committees complements our R&D activities.

Flexible Active Neural Implants

Active neural interfaces are intelligent, customizable micro-implants that can target certain regions of the nervous system for the stimulation of and recording from neural tissue. The micro-implants need to fit the anatomy of the targeted sites and withstand the aggressive conditions in the human body.

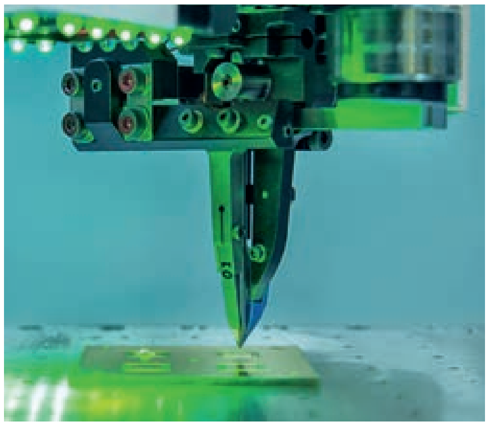
We design and fabricate active neural interfaces by integrating small custom-designed electronics into flexible microsystems. Our microsystems are often based on soft biocompatible materials and are tailored for the central or peripheral nervous system. To power these when they are implanted in the body, new approaches for wireless power transfer are needed. We are particularly interested in the use of ultrasound for wireless power transfer and communication for deep implants. Active implants need reliable protection from the body at small form factors. To address this challenge, we develop innovative solutions based on conformal coating with polymers and thin film ceramics.

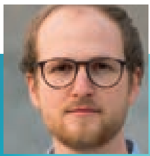
At Fraunhofer IZM, we are dedicated to advancing the field of neural interfaces through cutting-edge research, innovative design, and meticulous testing. We are committed to creating devices that are safe, effective, and reliable, and we are always looking for new opportunities to push the boundaries of what is possible in this exciting field.

Key focus areas:

- Electrode fabrication for neural stimulation and recording
- Protection of active implantable devices based on soft materials
- Testing and characterization of neural implants (incl. accelerated lifetime tests)
- Ultrasound wireless power transfer and communication for deep implants

Working Groups



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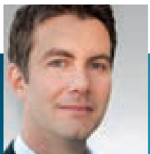
Optical Interconnection Technology

We realize customized photonic packages integrating PIC, 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, bio-photonics and quantum. Our competences are optical design, ion exchange and fs-laser writing for optical waveguides and lenses in thin glass, automatic assembly, photonic wire bonding and fiber coupling, 3D polymer optics, splicing, laser welding of fibers to PIC 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



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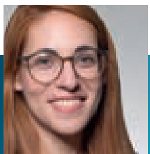
Power Electronic Systems

The Power Electronics group covers the development of power electronic equipment from packaging bare dies to prototype manufacturing. Developing power modules according to customer requirements beyond state of the art, manufacturing and testing is one of the activities. Developing equipment like motor drives for EV, on-board chargers or DC/DC converters the other one, this includes topology selection, pareto front optimization for size and efficiency as well as design and control programming. The unique background in manufacturing technologies allows us to offer completely new solutions easy to be transfered to industry production.

- Power module development and manufacturing (thermal, electrical, electromagnetic, mechanical)
- Development of equipment (Drive inverters, OBCs, DC/DC)
- Putting into operation/trouble shooting



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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

System-on-Flex

SoF is a team specializing in flexible hybrid and stretchable electronics. Our experts integrate electronic components into flexible substrates like foils, textiles, or paper using microfabrication, printing, or textile techniques. Collaborating closely with the industry, we create applications like sensors, medical devices, and smart clothing. With expertise in system design, materials science, process development, and reliability testing, we're dedicated to delivering innovative, sustainable solutions that cater to our clients' needs.

- Advanced flip-chip interconnections
- Stretchable/elastic substrates
- Electronics in textiles (substrate and interconnection)
- Medical microsystems with heterogeneous components
- Structural electronics


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Assembly & Encapsulation

We research integration technologies for system-in-package products, focusing in particular on device assembly for highly integrated packages and joining/encapsulation processes based on polymeric materials. Our technology portfolio includes pick-and-place processes – also for large-area substrates and 3D assemblies – and a wide variety of encapsulation processes, from dispensing and jetting to transfer and compression molding. Material, process and device analyses complete our range of expertise.

- Package and process development for highly integrated systems
- Encapsulation processes – liquid encapsulation, transfer and compression molding
- High precision material dosing by jetting/printing
- Polymer and package analysis


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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. Major technology developments and laboratory extensions are under way for multilayer fine line structures as used e. g. in interposers or glass core substrates.

- 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 targeting at 2 µm L/S for panel level packaging and advanced substrates


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Metallic and Interconnection Technologies

Our portfolio includes development of interconnection technologies for LEDs, optical and RF components as well as power electronics comprising:

- Soldering (i.a. SAC, AuSn, SnBiX)
- Ag and Cu sintering
- Transient liquid phase bonding
- Ball/wedge and wedge/wedge bonding; heavy wire and ribbon bonding using e. g. Au, Cu or AlSi1
- Ultrasonic and laser welding
- Metallurgical analysis and assessment of interconnects (i.a. wetting, spreading, solidification, phase transformations, diffusion, electro migration or growth of intermetallic compounds)
- Quality and reliability testing of electronic assemblies (i.a. XPS, FIB, C-SAM, X-ray)

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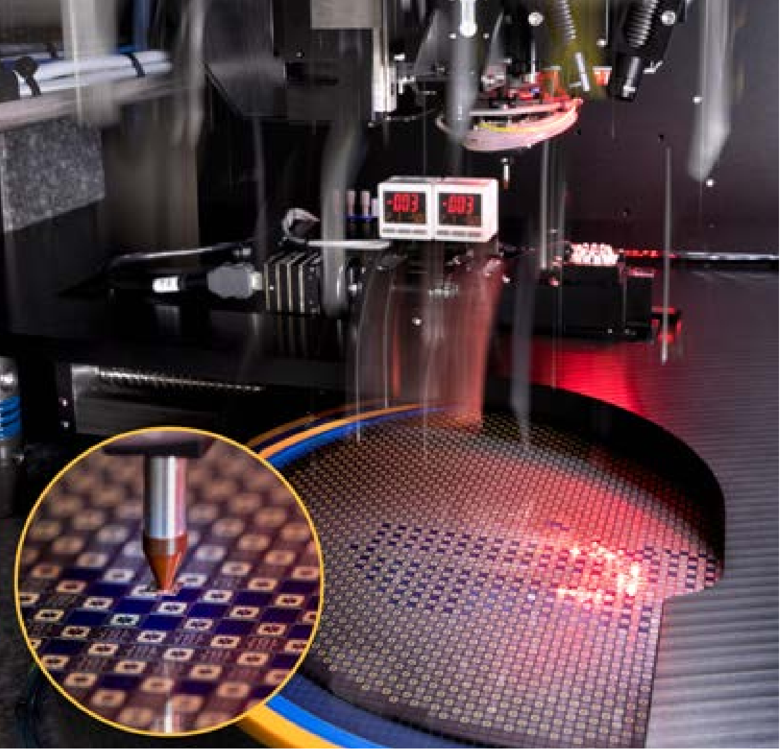

Thin Chip Handling –
Prototyping and small-series production

Cover: World's smallest impedance spectroscopy system in the form of a pill

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