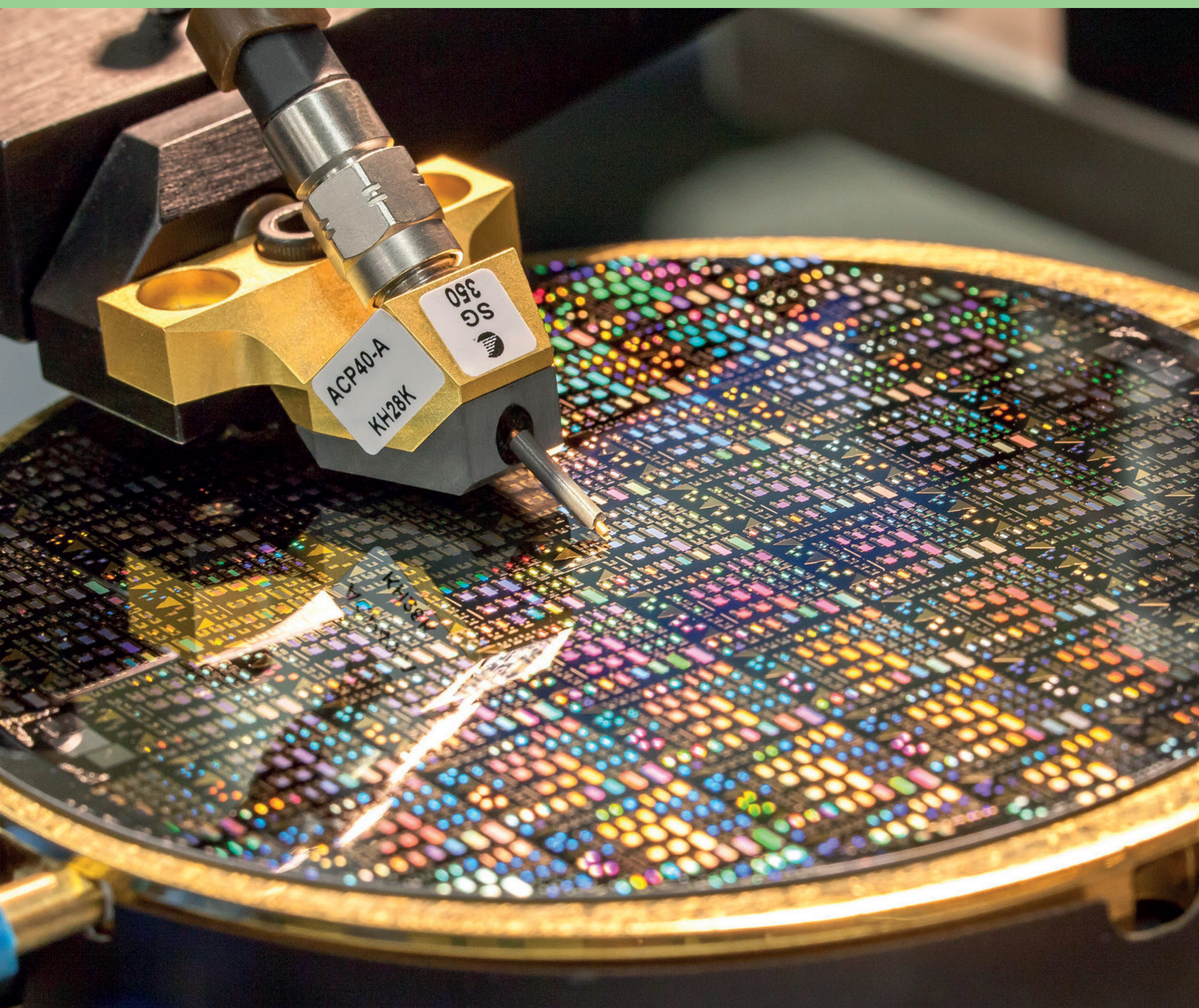
Forschungsfabrik
Mikroelektronik
Deutschland

RESEARCH FAB MICROELECTRONICS GERMANY

FRAUNHOFER GROUP FOR MICROELECTRONICS IN COOPERATION WITH LEIBNIZ INSTITUTES FBH AND IHP

Power Electronics

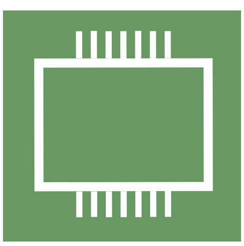


Research Fab Microelectronics Germany: Benefit from Europe's Largest R&D Cooperation for Micro- and Nanoelectronics

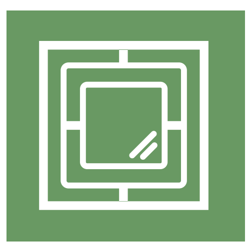
The Research Fab Microelectronics Germany (FMD) is a multisite cooperation advancing micro- and nanoelectronics research and development and comprises eleven institutes of the Fraunhofer Group for Microelectronics, as well as the two Leibniz institutes FBH and IHP. We are a one-stop shop for cutting-edge R&D services, application solutions and new technologies for a wide range of industrial customers.

By joining forces, we are able to provide tailor-made technology and system solutions from a single source. Drawing on FMD's broad technology portfolio, we have established six technology platforms: Microwave and Terahertz, Power Electronics, Extended CMOS, Optoelectronic Systems, Sensor Systems, and MEMS Actuators. Together these bundle the necessary individual expertise – from system design to testing and reliability assessment – to meet customer needs. Apart from leveraging synergies between technological know-how and the development of technological innovation, the platforms prioritize close cooperation with customers throughout the development process and the bundling of technological competencies along the entire value chain.

Our Technology Portfolio



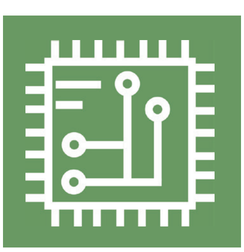
Microwave and Terahertz
Cutting-edge devices and circuits for frequencies up to and including the THz range.



Extended CMOS
Design, fabrication and system integration of CMOS circuits.

Power Electronics
Design and fabrication of power electronic devices, including integration in modules and systems.

Optoelectronic Systems
Fully integrated optoelectronic systems for image acquisition and processing, and communication up to Tbit/s speed.



Sensor Systems
Sensor design, fabrication, integration, characterization, and testing within systems.

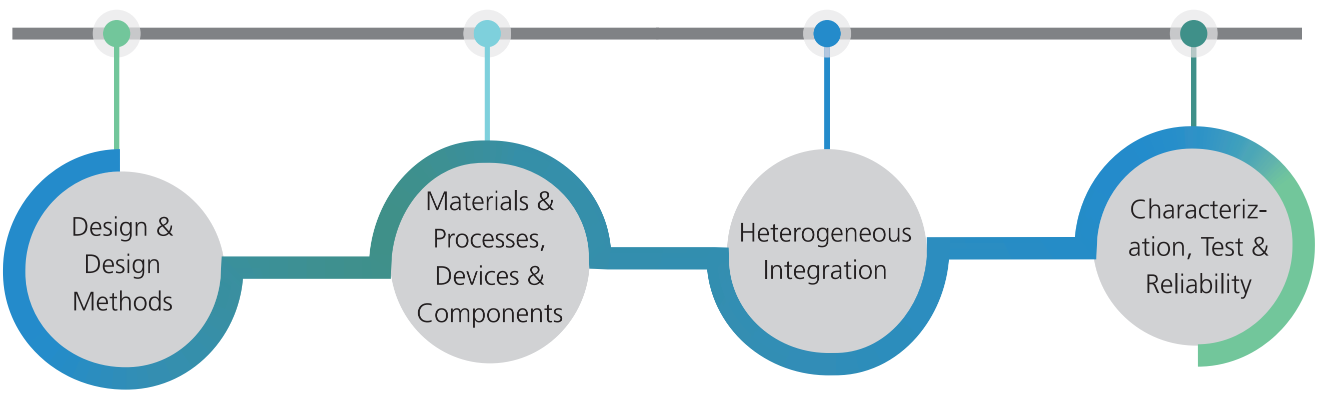
MEMS Actuators
Design and fabrication, as well as characterization, testing and system integration of MEMS actuators.

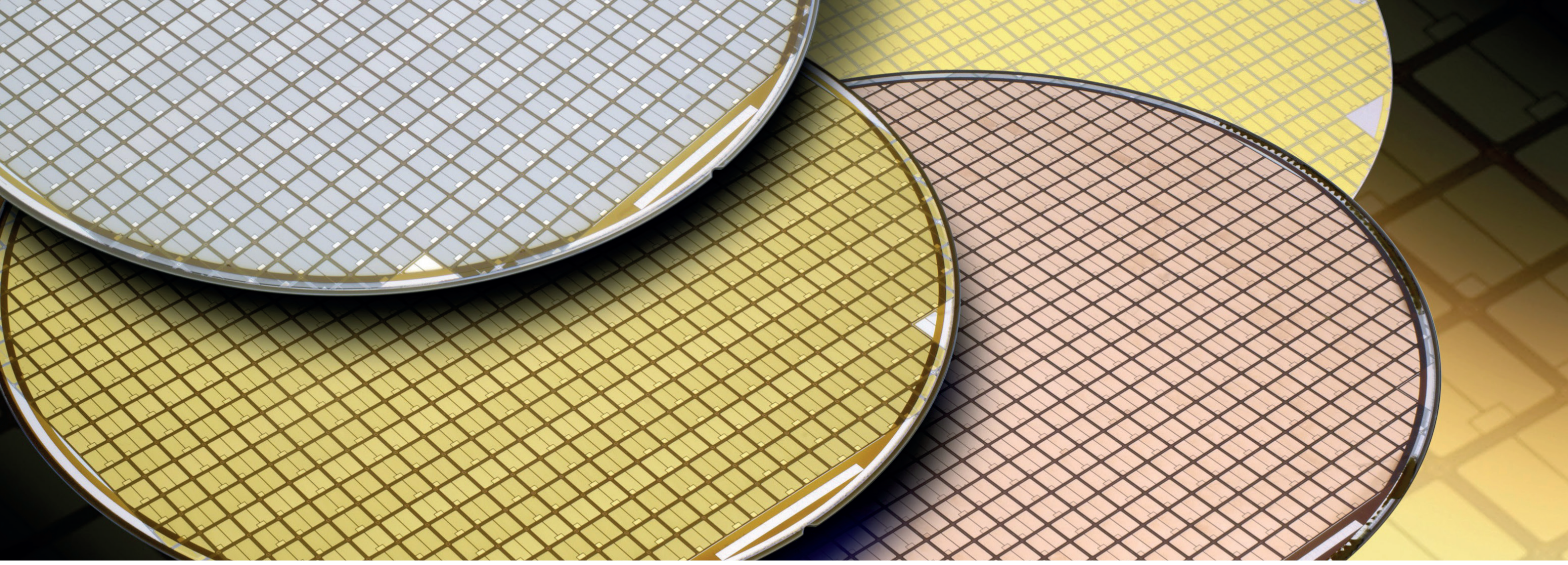
Technology Platform: Power Electronics

The technology platform Power Electronics brings together the know-how of Research Fab Microelectronics Germany (FMD) along the entire value chain for power electronics devices, including the integration of devices into modules and system-level development. FMD has unparalleled expertise in design and prototyping and materials of wide bandgap (WBG) semiconductors such as silicon carbide (SiC) and gallium nitride (GaN). WBG semiconductors are key devices in more power-efficient and leaner modules and systems, even at higher operating temperatures than those of conventional Si-based power electronics. In our cleanroom facilities, we are able to build devices using Si-based, SiC-based or GaN-based technologies.

We have a fully integrated 150 mm line to manufacture state-of-the-art SiC devices. For GaN-based devices, we can also provide integration on cost-efficient 200 mm Si substrates. Moreover, we have the equipment to explore R&D approaches to new technology concepts, such as vertical GaN-transistors, Al-GaN-/GaN-based devices for fast switching, and emerging WBG semiconductors like aluminum nitride (AlN) and Gallium oxide (Ga_2O_3). The integration of single devices, the first step in building modules, plays a crucial role in the design of power electronic systems. We have the necessary expertise, not only in heterogeneous system integration, but also in the characterization of single devices, integrated modules or complete systems. For module manufacturing, single-device packaging, as well as integration on large areas up to 610 x 457 mm² is possible. Additionally, we conduct test and reliability assessment of power modules and power electronic systems.

A holistic approach to designing power electronic systems, which applies both semiconductor and packaging technologies at the same time, is a prerequisite for reducing size and cost. The FMD portfolio features the development of extremely highly integrated devices like DC/DC-converters, solar inverters, drive inverters, and chargers. As part of this, our technology platform offers tailor-made solutions for power electronics, including along the complete microelectronic value chain, for your specific application.





Our Competencies in Power Electronics along the Value Chain

Design & Design Methods

Component Design

- Application-specific active and passive component design, especially magnetics development, EMC design, thermal management
- Design for electrical, thermal, mechanical and lifetime constraints

Package & System Design

- Power module development
- Power system-in-package and switching-cell-in-package design
- System topology, component selection and optimization (EMC, thermal management, reliability, weight, cost, miniaturization, efficiency, …)

Materials & Processes, Devices & Components

Material Development

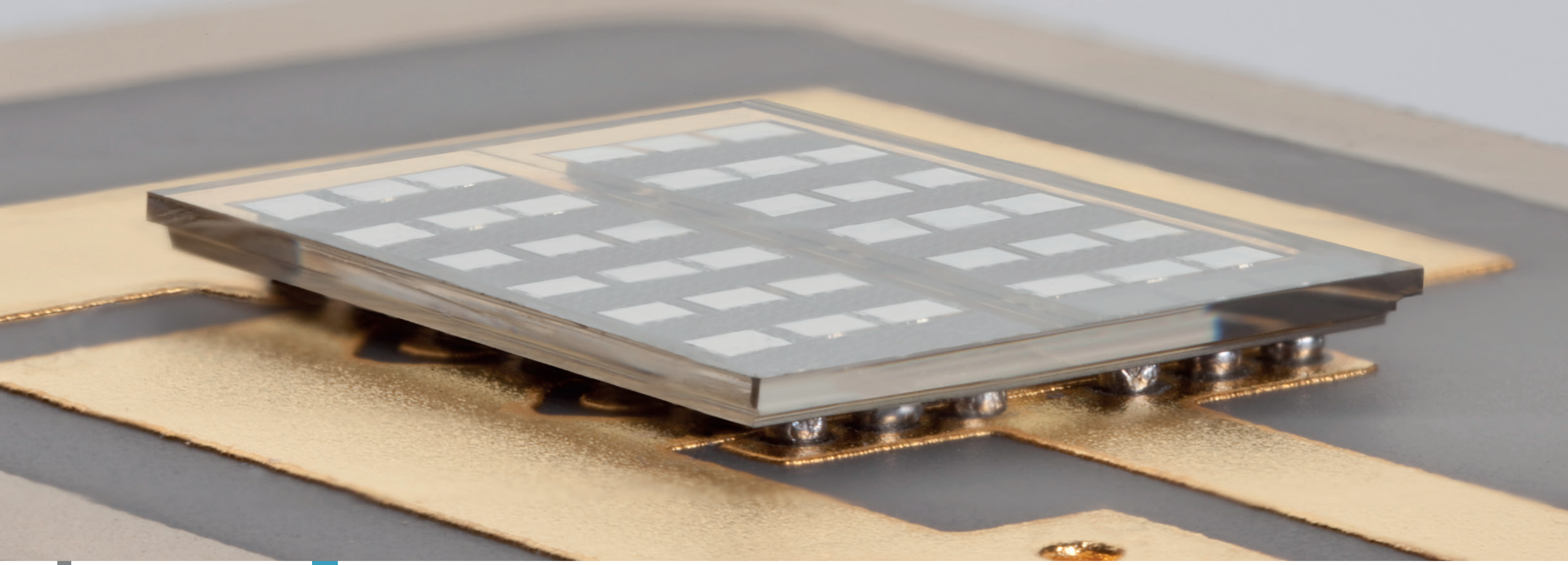
- Si, SiC, GaN, AlN, Ga_2O_3

Process Development

- Fully integrated process lines up to 200 mm including epitaxy, frontside processing, backside processing, characterization, dicing

Devices & Components Realization

- Actives: MOSFET, HEMT, IGBT, diodes, and more
- Passives: Inductors, capacitors, resistors
- Substrates and cooling solutions



Heterogeneous System Integration

Component Packaging

- Die attach and large area interconnection technologies: Ag sintering, TLPB, TLPS, soldering
- Bonding techniques for substrates and heat sink
- Heavy wire and ribbon bonding
- Large area protection/encapsulation

Module & System Packaging

- Integration of semiconductors, passive energy storage components and peripherals
- Power embedding in substrate and molding compound
- Metallization of encapsulated packages (shielding)
- Power systems-in-package

Characterization, Test & Reliability

Material Characterization

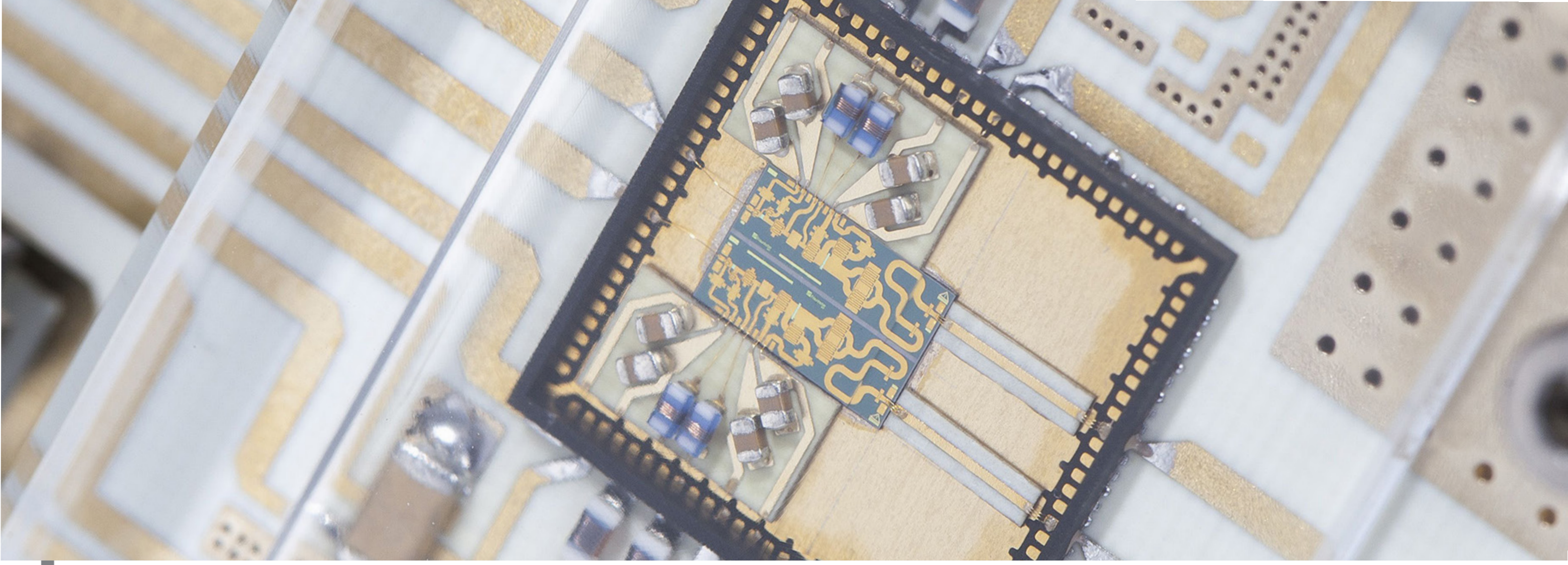
- Characterization and modelling with regard to thermo-mechanical, thermal and dielectric properties in initial state and after ageing (temperature/moisture)

Processes Characterization

- Automated in-line process monitoring

Devices & Components Characterization & Test

- Accelerated active and passive lifetime testing and modeling based on active power cycling on industrial test benches and thermal shock tests



- Comprehensive physics of failure analysis (microscopy, SAM, SEM, computed tomography, thermal impedance spectroscopy)
- Device and system qualification test using extended test parameters towards high temperatures, high voltages and high currents

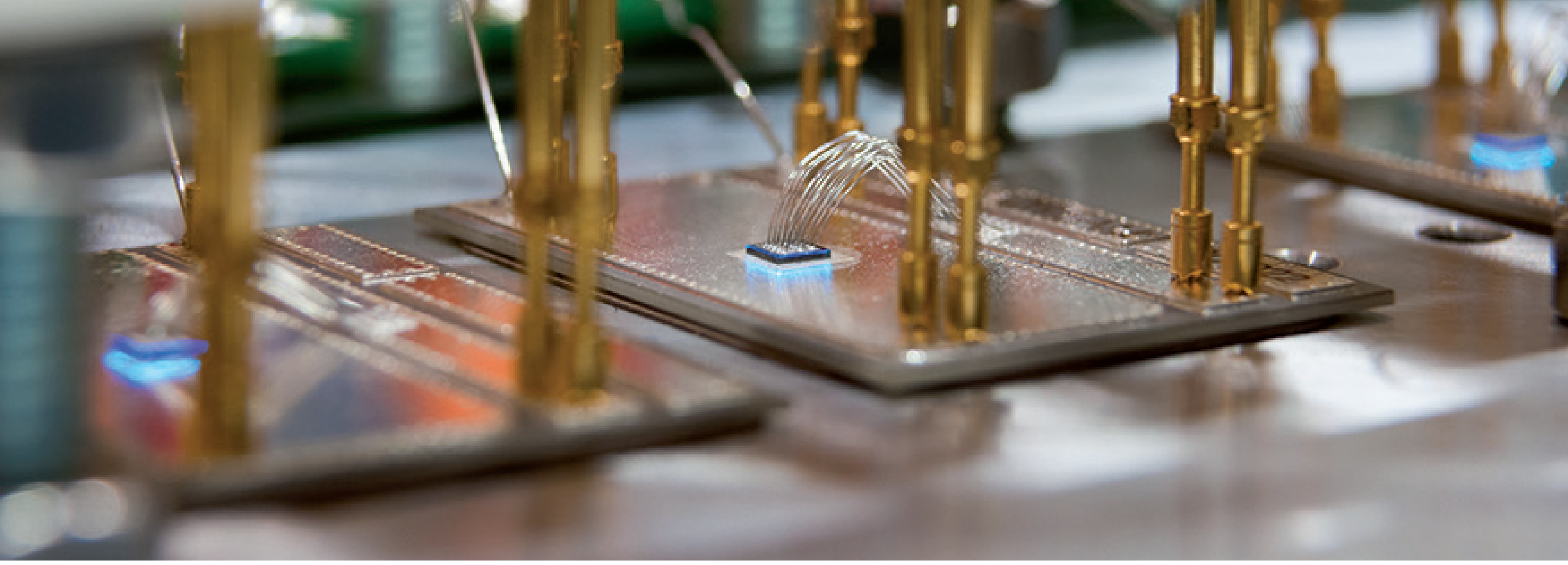
System Test & Reliability

- Efficient system level test under multiple stress scenarios
- Systems modeling and lifetime prediction using FE simulation methods
- EMC application tests
- Thermal simulation and thermographic package & system analysis
- FMEA support

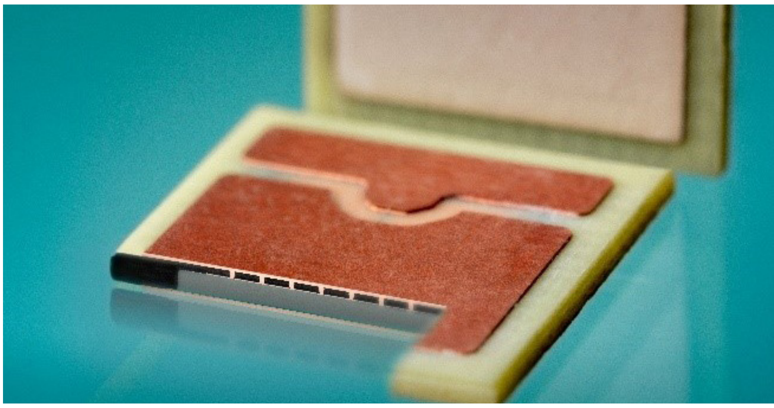
Technology Example: GaN Chip Prepackage

Much of our work places the system center-stage as basic building block of functionality in microelectronics. System integration is necessary to translate technology advances on component level into enhanced functionality – but increasingly, integration involves system-level analysis and even further development or adaptation of existing system infrastructure.

An example is the WBG semiconductor, whose superior switching performance, higher power density, and improved efficiency has caught the attention of early adopters and forward-thinking product designers looking for an edge on the market. However, not only has the new technology required integration on system level, the existing on-board packaging has had to be redesigned to meet the specifications of the semiconductor. We eliminated longstanding limitations in packaging design using the Bernstein module: a two-layer ceramic substrate with a cooler structure on the bottom, that yields extremely low DC link inductance, EMI shielding, a short thermal path, good heat spreading and mechanical stiffness against cooling water pressure. We also combine an innovative metalized transfer mold encapsulation with assembly of local DC link components as SMDs on top of the module. This close



proximity of the SMD to the driver ensures fast switching and avoids parasitic switch-on. The result is a module with perfect switching at even the highest switching speed, high reliability, and lowest possible thermal resistance thanks to a low cost (plastic) cooler.



GaN chip prepackage to be integrated in metallized mold module.

Technology Example: Multi-level Converters – A Key Technology for Efficient and Cost-Effective Power Electronic Systems

The disadvantages of high-blocking voltage semiconductors can be overcome using multi-level converters. The latter are key in efficient and cost-effective power electronic systems in high- and medium-voltage applications. They also provide better EMC performance for smaller size and less cost. Specially adapted joining technologies are used to increase the lifetime of these multilevel systems.

New application-specific power module concepts allow the integration of protection mechanisms to improve the converter behavior and availability in case of system or device failure. One drawback of such multi-level topology concepts is the increased number of semiconductor switches that have to be controlled. Especially in small- and medium-power systems, the effort required to control the simultaneous switching is a significant factor in total system cost. These technology developments are just individual examples of the Fraunhofer IISB development of optimized control and communication systems as key elements in cost-efficient multi-level systems.

Modular multi-level converter.

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