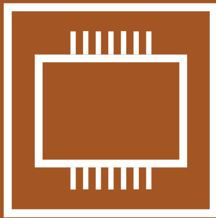
Forschungsfabrik Mikroelektronik Deutschland

RESEARCH FAB MICROELECTRONICS GERMANY

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



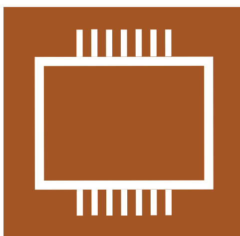
Microwave and Terahertz

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.

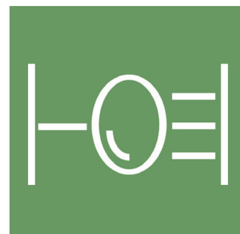
Our Technology Portfolio



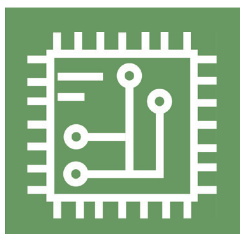
Microwave and Terahertz
Cutting-edge devices and circuits for frequencies up to and including the THz range.

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

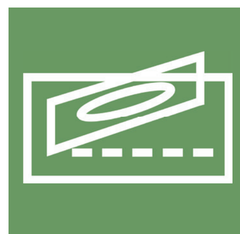
Power Electronics
Design and fabrication of power electronic devices, including integration in modules and systems.



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.



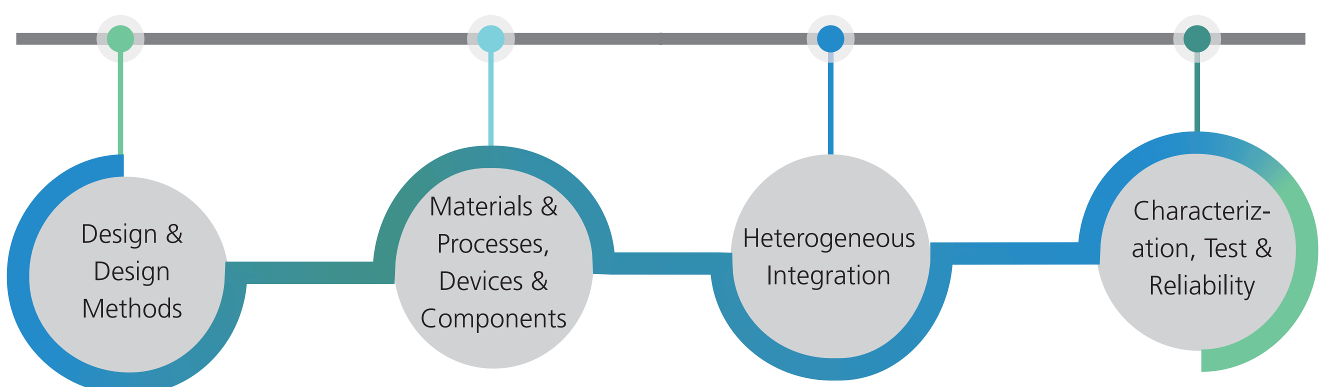
MEMS Actuators
Design and fabrication, as well as characterization, testing and system integration of MEMS actuators.

Technology Platform: Microwave and Terahertz

As part of Research Fab Microelectronics Germany (FMD), the technology platform Microwave & Terahertz makes microelectronic development accessible to industry and research by providing consulting, development, and access to infrastructure. We cover the complete value chain, from design, materials selection, processing, system integration, materials characterization, device testing and reliability assessment. Our technology platform specializes in turnkey and custom solutions for the design, manufacturing, packaging, characterization and testing of cost-effective, high-performance and reliable devices, integrated circuits and systems for applications up to the THz-regime. Your specifications are top priority throughout the development process, from modeling and design, to fabrication using advanced manufacturing techniques. Application-specific requirements and boundary conditions are factored in at the very beginning of the design process. This allows us to focus on future and emerging applications, especially applications related to communication and sensing (e.g., 5G mm-wave or radar sensing for autonomous vehicles).

We are uniquely equipped for rapid prototyping and manufacturing of devices, circuits and systems for applications up to THz range. For this our cleanrooms for silicon (200 mm and 300 mm) and for compound-semiconductors (up to 6") are the basis. We fabricate and process a variety of devices, including HBTs, HEMTs, passive structures and mm-wave integrated circuits (MMICs) using a wide range of ultra-fast technologies, such as Si, SiGe, InP, GaN/SiC, InGaAs/GaAs. In addition to our in-house processes we apply standard CMOS processes of external foundries to prototype and design CMOS MMICs for our customers or partners. Furthermore, we research and develop the integration of III-V materials into Si-based technologies, successfully demonstrated with a transfer-substrate process for integration of an InP-based HBT with SiGe:C BICMOS technology in a single chip.

The technology platform is expert in all aspects of package-integrated antennas and the packaging and heterointegration of high frequency SiP applications. We apply our advanced assembly, packaging and system-integration technologies at wafer and board levels for the development of miniaturized mm-wave and terahertz components, modules and systems. We can characterize and test the functionality of already designed, manufactured and assembled systems, including under harsh environments, and perform reliability assessments. To top it off, several of the FMD team are also members of Europractice consortium, which allows us to offer our partners advance access with minimum fuss to novel Microwave & Terahertz modules and technologies.



Our Competencies in Microwave and Terahertz along the Value Chain

Design & Design Methods

Component Design

- MMIC Design up to 600 GHz
- Switch development and optimization
- Periodic structures, antennas and meta-materials

Package & System Design

- Modeling, simulation, design and test for signal integrity, power integrity and intra-system electromagnetic compatibility
- Development of MIMO and massive MIMO-based transceiver system architecture concepts considering analog, digital and hybrid beamforming techniques
- Planar and 3D package-integrated antenna arrays for 5G MIMO and massive MIMO, as well as for radar sensing applications
- FMCW radar back- and front-ends: chip generation, data acquisition, transceiver solutions
- Waveguide-based packaging up to THz frequencies
- RF modeling and assessment of the impact of fabrication processes

Design Methods

- Automated simulation-based design tools for component, module and system, numerical analysis and optimization
- PDK development for devices and technologies

Materials & Processes, Devices & Components

Materials

- Si, SiGe, SiC, group III-arsenides (e.g. InGaAs), group III-phosphides (e.g. InP), GaN, AlN, Ga_2O_3, parylene
- AlN as piezoelectric converters

Heterogeneous System Integration

- $BiFeO_3$ and TiO_xN_y for memristive devices
- CNT synthesis, specialized dispersions
- Metamaterials

Process Development

- Fully integrated process lines including epitaxy, implantation, backside thinning, and through-substrate vias
- Special technologies such as GaN on SiC, InP on Si, SiGe:C, InGaAs on Si
- CNT integration on wafer-level & heterogeneous integration with ASIC, MEMS, RF-circuits etc.

Devices & Components

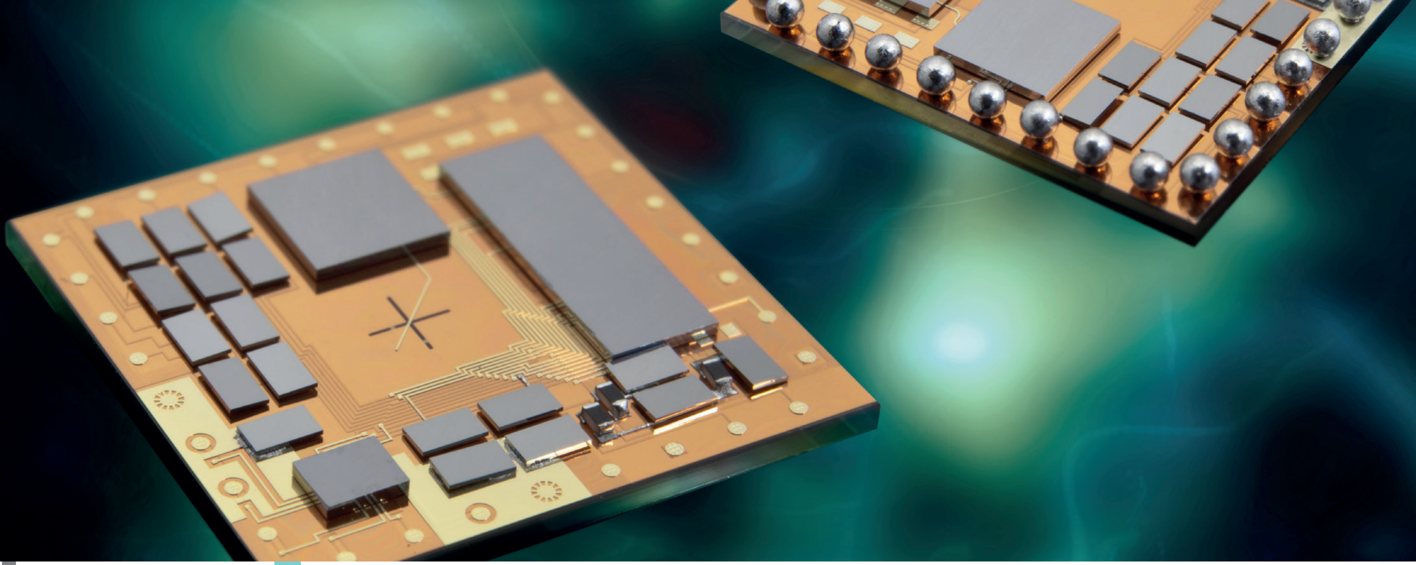
- mHEMT, GaN HEMTs, GaN diodes, InP-DHBTs, SiGe HBTs, etc.
- Inductors, capacitors, filters, antennas, etc.
- RF MEMS active structures for THz modulation, RF MEMS switch (SPST, SPDT), micro-coil, true delay line (TDL) phase shifter
- RF CNT-FETs and circuits, CNT-based THz polarizer and THz detectors
- Printed antennas, conductive paths and batteries
- Low-noise and high power amplifiers, transceivers, broad-band and high efficiency MMICs

Component Packaging

- Fan-in and fan-out wafer-/panel-level packaging
- Silicon and glass interposers
- Advanced bonding techniques (reactive bonding) and packaging methods (parylene encapsulation, Ag sintering)
- RF MEMS packaging

Module & System Packaging

- 3D multilayer integration and chip embedding in polymer, ceramics and silcon substrates



Characterization, Test & Reliability

- Encapsulation (molding, potting, parylene) and housing
- Multi-projects runs using fan-out WLP

Materials & Devices Test

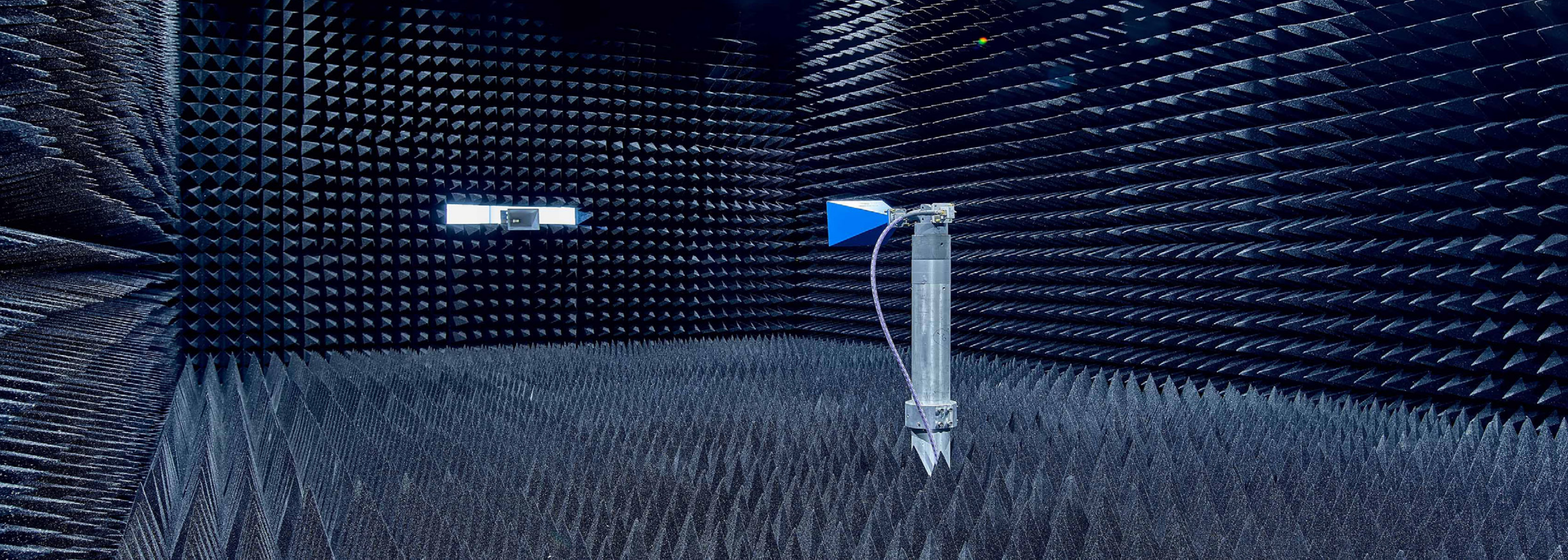
- RF measurement, characterization and test of dielectric materials, interconnects and packaging technologies, RF spectroscopy

Devices & Components Characterization & Test

- Wafer level characterization (current-, capacitance-voltage, biased temperature stress, TSV measurement, mercury probe)
- On-wafer small- and large-signal characterization (from DC to THz)
- In-circuit measurements of mm-wave components and modules up to 1.1 THz
- Antenna measurement and characterization, EM near-field characterization, beamforming and functional tests
- Functional and layout verification, electromagnetic modeling, simulation and testing, real-time time-domain dynamic analysis
- Pulsed isothermal S-parameter measurements
- Load-pull, noise, power and DC measurements
- Digital PA-based MIMO characterization

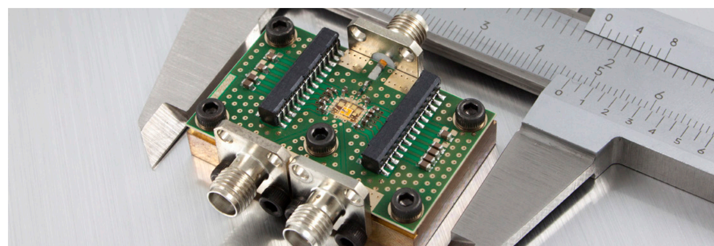
System Test & Reliability

- Power capability, third-order intercept point (IIP3), 1 dB compression point
- Wideband power amplifier measurements with DPD
- Supply and load modulation systems (MISO) with DPD
- THz imaging and spectrometer setup
- System analysis, environmental assessment and eco-design for RF systems



Technology Example: 5G Infrastructure for Future Wireless Communication

The increased data rates of 5G mobile communication will meet user demands in urban areas and make efficient use of today's limited bandwidth. However, the technologies required for 5G communication will differ vastly in terms of energy efficiency, agility, bandwidth, RF output power, frequency usage, and latency. The extremely efficient, flexible solutions developed at Leibniz FBH are a crucial step toward meeting the requirements of future 5G systems up to the mm-wave range. The semiconductor technologies applied in their development are based on in-house GaN and InP processes for highest output power in the mm-wave range. Two main strategies are pursued: (1) improving back-off efficiency with GaN-based envelope tracking systems and a fully digital transmitter; (2) developing InP-based components for a mm-wave 5G infrastructure with unprecedented performance. The first approach requires very efficient GaN switching stages, the design and fabrication of which Leibniz FBH now specializes in. Game-changing results have been achieved, including back-off efficiencies superior to established solutions. The second main strategy has also yielded results, including the realization of front-end components for future 140 GHz 5G wireless networks.



Fully digital transmitter chain for base station application.

Technology Example: MIRANDA-94 – High Resolution Real Time SAR Imaging

FMD member institutes Fraunhofer FHR and IAF joined forces to develop an advanced, real-time synthetic aperture radar (SAR) – known as MIRANDA-94. The mm-wave system is a miniaturized radar sensor optimized for use in ultralight aircrafts. The radar is backed on the aircraft by a mechanical beam stabilization - using a programmable gimbal that allows linear and nonlinear trajectories to perform SAR imaging for various applications. The real-time evaluation for the MIRANDA-94 SAR images was developed in a multinational EU project. The SAR image depicts the compound of Fraunhofer FHR. MIRANDA-94 operates at a center frequency of 94 GHz at a resolution of less than 15 cm. To achieve such high resolution, the system has to work with a bandwidth larger than 1 GHz. The high operational frequency and large bandwidth place great demands on the components of the RF transceiver, signal generation, and signal processing. Fraunhofer IAF drew on their sophisticated III-V semiconductor technologies to construct the mm-wave components for the transceiver module, while Fraunhofer FHR took responsibility for the system integration and applied its long-standing experience in measurement campaigns of airborne radar systems to the project.

SAR image of the compound of Fraunhofer FHR measured with MIRANDA-94 with 94 GHz operational frequency and 2 GHz bandwidth. The resulting image resolution is 7.5 cm.

Contact

Dr. Stephan Guttowski
Phone +49 172 81 66 781
stephan.guttowski@mikroelektronik.fraunhofer.de

Dr. Andreas Grimm
Phone + 49 152 54 64 23 11
andreas.grimm@mikroelektronik.fraunhofer.de

Research Fab Microelectronics Germany
Anna-Louisa-Karsch-Str. 2
10178 Berlin, Germany

www.forschungsfabrik-mikroelektronik.de/en

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