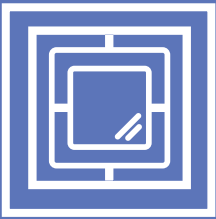




**Forschungsfabrik
Mikroelektronik**
Deutschland

RESEARCH FAB MICROELECTRONICS GERMANY

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



Extended CMOS



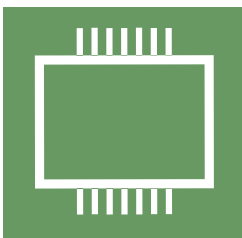
Research Fab Microelectronics Germany: Benefit from Europe's Largest R&D Cooperation for Micro- and Nanoelectronics

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



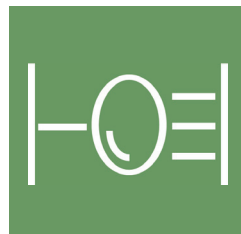
Microwave and Terahertz
Cutting-edge devices and circuits for frequencies up to and including the THz range.



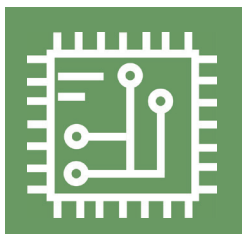
Extended CMOS
Design, fabrication and system integration of CMOS circuits.



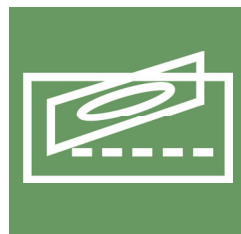
Power Electronics
Design and fabrication of power electronic devices, including integration in modules and systems.



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: Extended CMOS

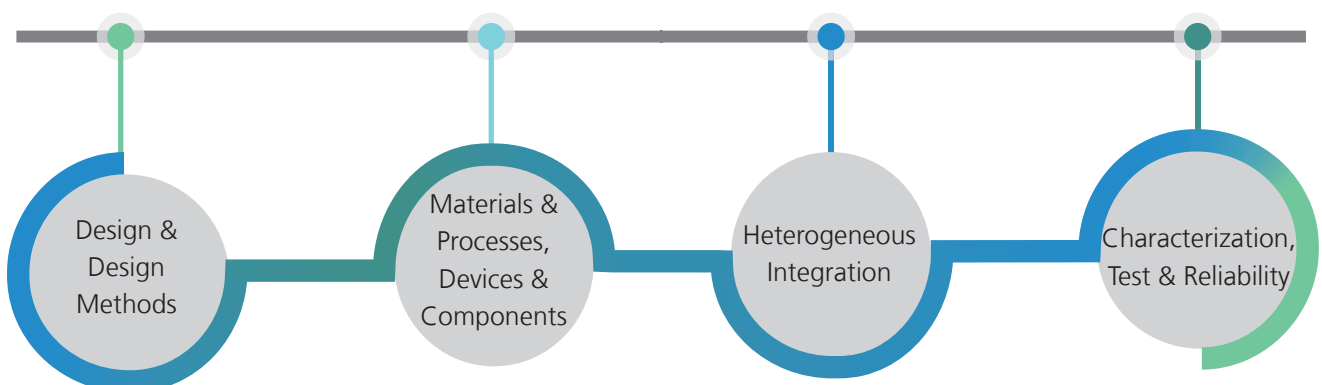
As part of Research Fab Microelectronics Germany (FMD), the technology platform Extended CMOS makes micro-electronic development accessible by providing consulting, development, and access to infrastructure. We cover the complete value chain, from design, materials selection, processing, system integration, materials characterization, device testing and reliability assessment.

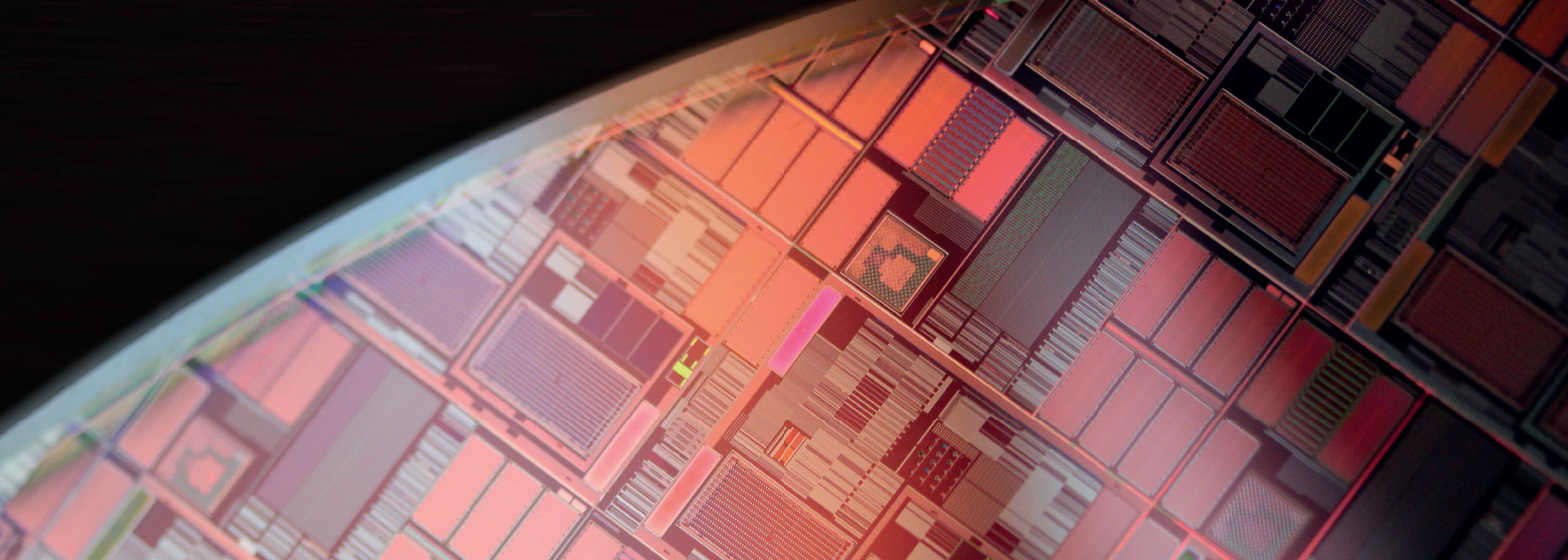
We have bundled the extensive experience and know-how of FMD in the development and manufacture of CMOS based components and systems into our technology platform. Our range of equipment is also impressive. Fully equipped, state-of-the-art 200 mm BiCMOS and CMOS lines are available for a wide range of R&D activities and can even be individually adapted to specific customer needs. Moreover, we also offer frontend and backend processing. Our frontend equipment includes process modules for frontend-of-line (FEOL), mid-of-line (MOL), and backend-of-line (BEOL). We also have the entire range of processing technologies on hand, including deposition, patterning, implanting, planarization and metallization. Last, but not least, we advance new materials, processes and technologies, inclu-

ding new memory concepts and neuromorphic computing technologies, on our 300 mm wafer line.

Our design services include digital design, analog and mixed signal design, as well as design for reliability. We offer expert support for 1D and 2D materials, technologies and processes, as well as 2.5/3D integration technologies. We also provide R&D support for TSV, wafer bumping, redistribution layers and solder balls.

Furthermore, fabrication of high density silicon, glass and polymer interposers, wafer thinning, dicing, wafer-to-wafer bonding, high precision multi-die assembly, die stacking, and molding all feature in our technology portfolio. Testing and characterization of materials and devices, including in harsh environments, electrical tests on digital and analog devices are further services we provide, along with reliability assessment, lifetime prediction and lifetime optimization. As part of the FMD one-stop shop for microelectronic research and development, our aim is to help you realize your development goals. We are also open to tailoring our solutions to your individual application needs.





Our Competencies in Extended CMOS along the Value Chain

Design &
Design
Methods

Component Design

- Application-specific active and passive component design
- High-quality design kits and toolsets for device development
- Power management concepts for ultra-low power
- Component simulation and modelling, e.g. transistor aging/degradation
- Cell and array design for nonvolatile memories

Package & System Design

- Cross-domain system modelling and simulation
- Analog, digital, and mixed-signal designs
- Design under constraints – functional safety, reliability, harsh environment, yield
- Chip/package co-design including ADK development and verification
- Functional system verification

Prototyping

- HW/SW co-design and hardware-in-the-loop concepts
- MPW runs for module testing of extended CMOS flows in “early access” level within Europractice down to 28/22nm technologies

Design Methods

- Add-ons for automated design tools e.g. for reliability-centered design optimization, design under constraints



Materials & Processes, Components & Circuits

Facilities

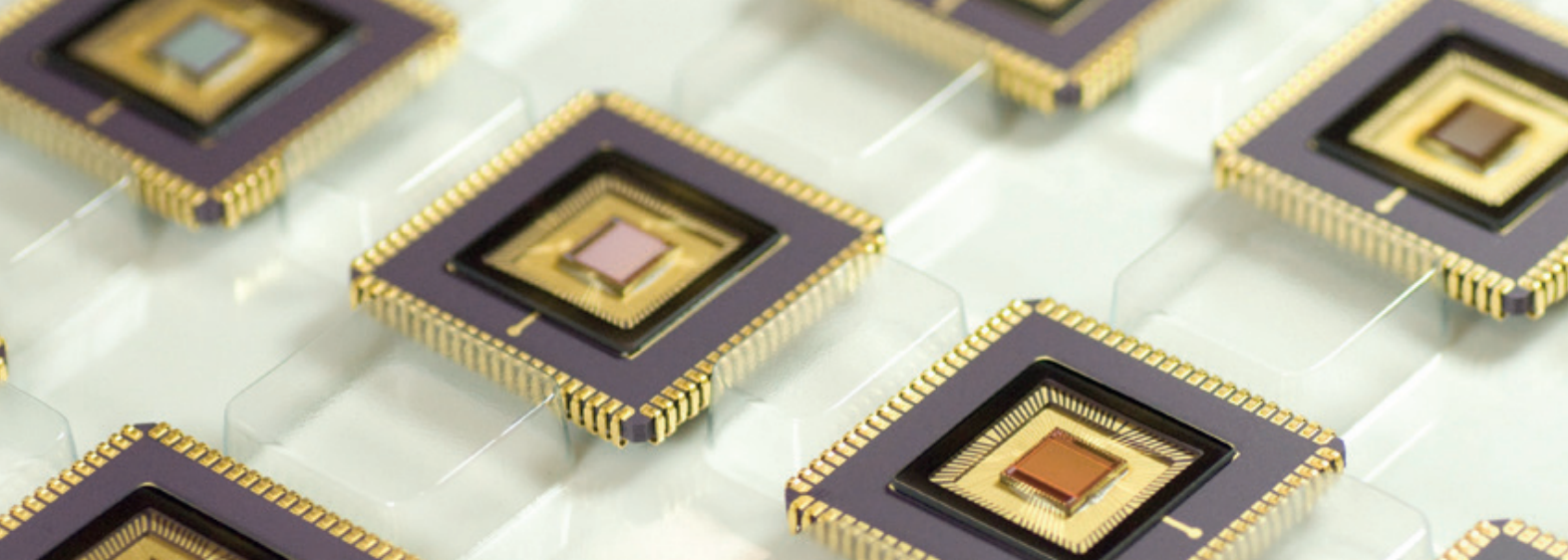
- 7 cleanrooms, ISO9001 and partially automotive certified
- 200 mm complete BiCMOS/CMOS, high temperature CMOS, HV CMOS lines and foundry, incl. FEOL and BEOL modules
- Interface to other foundries, wafer exchange to 200 mm/300 mm foundries and IDMs
- 300 mm material, process and equipment screening line
- 200 mm/300 mm packaging lines
- Automated in-line process monitoring
- Frontend and backend contamination procedure and control

Material Development

- Si, SOI, SiGe
- Materials for frontend processes – metals, High k, Low k, Oxides, magnetic films
- Functional materials: piezo materials (lead free materials), ferroelectrics, low dimensional – 1D/2D (e.g. metal-dichalcogenides (MoS_2 , WS_2), CNTs, graphene), spintronic stacks
- Packaging: Si, glass, polyimide

Process Development

- Own 130 nm - 350 nm CMOS processes
- Special CMOS technologies for high temperature (up to 300 °C)
- BiCMOS compatible module integration, like IR sensors and NVM
- Developments for memories, neuromorphic computing, quantum computing
- Single process development and optimization such as etch, clean, CMP, epitaxy (Si, SiGe), plating, ALD/ALE, thin film deposition
- Process and equipment simulation (e.g. lithography, PVD, CVD, ALD, ECD, CMP)
- Bonding processes for CMOS-compatible module integration



Heterogeneous System Integration

Components & Circuits Realization

- Passives (inductors, MIM capacitors, resistors)
- High-performance and high-voltage SiGe HBTs, RF-LDMOS devices and monolithically integrated Si-photonic devices
- Emerging memories (Fe-FET, FRAM, MRAM, RRAM)
- CNT-FETs, memristors, spintronic
- Digital, analog, mixed-signal, high frequency circuits

Assembly & Packaging

- Memory, CPU, FPGA – (single- and multi-chip) packaging – advanced packaging, die stacking, D2W bonding and die stacking
- Wafer level packaging, 2.5D/3D integration, TSV/TGV and RDL
- Advanced PCB substrates including chip embedding
- High density Si, glass and polymer interposer for high performance applications
- Fan-out molding (200/300 mm or panel format (18" x 24"))
- MEMS on CMOS
- Full-wafer thinning down to 10 μm
- Permanent / temporary wafer bonding, hybrid bonding / low temperature wafer bonding

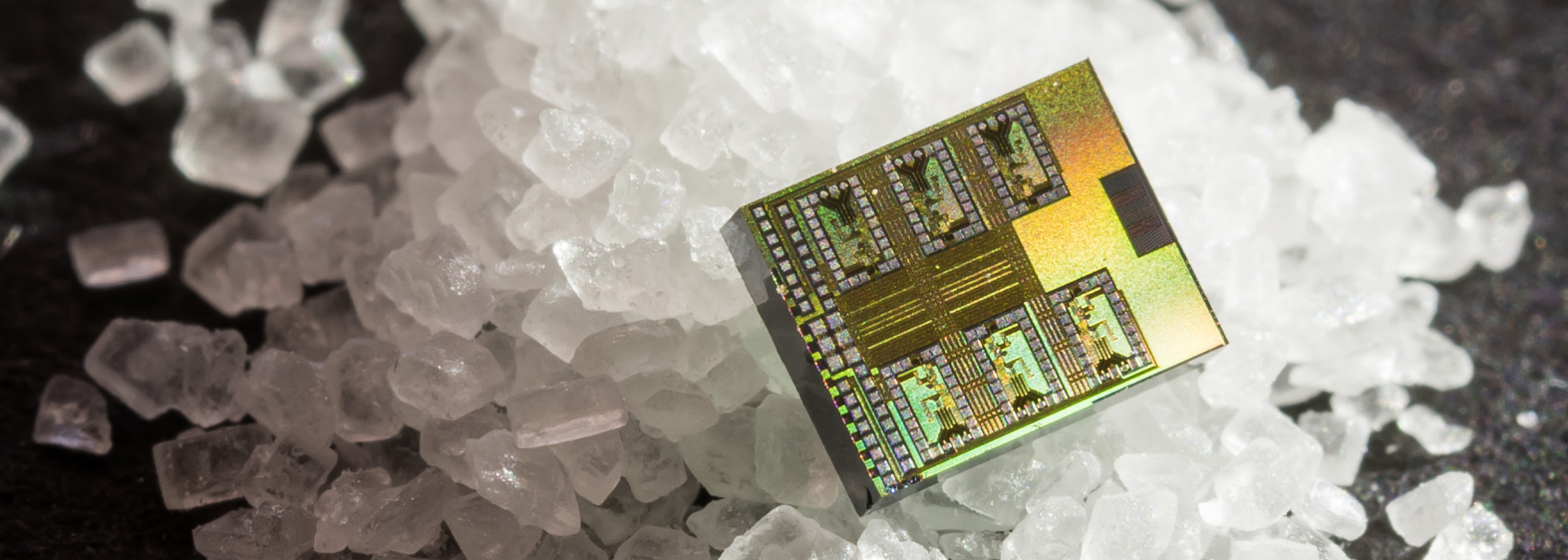
Characterization, Test & Reliability

Materials & Devices Test

- Nondestructive and in-depth analysis of materials, devices and components on micro and nano scale
- Electrical device test for wide range in DC/AC performance

Wafer level Analysis & Test

- Automated in-line monitoring for process and devices
- Test of analog-mixed signal circuits and digital circuits



Materials & Devices Test

- Electromagnetic compatibility (EMC), signal integrity (SI)
- 200/300 mm wafer level in-line metrology
- Degradation, lifetime, failure analysis and system/package test under multiple stress scenarios
- Finite element modeling (FEM) of packaging, life-time estimation and optimization
- Thermoelectrical, mechanical and electromagnetic reliability and combined load testing

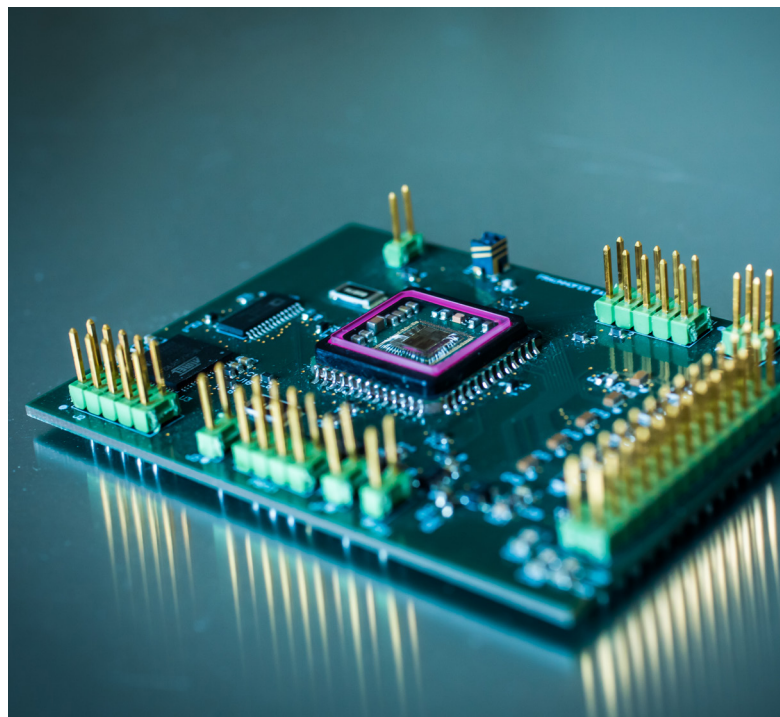
Technology Example: Universal Sensor Platform – USeP

The Fraunhofer institutes ENAS, IIS/EAS, IPMS, IZM-ASSID, in cooperation with GLOBALFOUNDRIES Dresden Module One LLC & Co. KG. are together developing a Universal Sensor Platform (USeP).

GLOBALFOUNDRIES supplies a 22 nm CMOS circuit. A variety of sensors and actuators from the Fraunhofer institutes are integrated into the packaging. The project is advancing innovative packaging, system design, sensor development, data transfer, simulation and testing.

The platform also features novel hardware and IT security solutions.

Example of a chip package.



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