Fraunhofer
MIKROELEKTRONIK

FRAUNHOFER GROUP FOR MICROELECTRONICS

# ONE-STOP-SHOP FOR TECHNOLOGIES AND SYSTEMS

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Chair of the Fraunhofer Group for Microelectronics

# OUR RANGE OF SERVICES

For more than 20 years we have been working on developing robust, high-performance microelectronics for modern industry. Our expertise allows us to bridge the gap between application-oriented fundamantal research and product developement along the entire added-value chain:

- We offer you a globally unique range of know-how in smart systems
- You have the expertise of all 18 institutes in the Fraunhofer Group for Microelectronics at your disposal
- Our technological and system developments are tailor-made and from a single provider
- We offer access to our joint laboratories and shared production facilities
- We can support you with demonstrator or prototype production, specific technology services, as well as the creation of reports and analysis process
- We offer different possibilities for training and continuing education of personnel
- We observe technological trends and market developments and can carry out feasibility studies for you
- We accompany you through R&D projects as well as technological and process development
- You can take advantage of the results of our preliminary research in the areas of micro- and nanoelectronics as well as microsystem and communication technologies (through license contracts)
- You will benefit from our wide-ranging research network and numerous cooperation arrangements with renowned international research institutes and universities

# ONE-STOP-SHOP FOR MICRO- AND NANO-ELECTRONICS, POWERED BY 18 FRAUNHOFER INSTITUTES ACROSS GERMANY

## STRENGTHENING INNOVATION IN GERMANY AND EUROPE BY BRIDGING THE GAP BETWEEN FUNDAMENTAL RESEARCH AND APPLICATION OF SMART SYSTEMS

# SMART AND HEALTHY LIVING

In the "Smart and Healthy Living" business area, scientists within the Fraunhofer Group for Microelectronics do research into all the ways that technology can support our lives and our work in a modern world. Which new technologies create smart living and working environments for us? Where can microelectronics be used to give us perfect work-life balance? How can electronic applications support people with disabilities as well as the elderly?

The "Smart and Healthy Living" thus combines two previously separate R&D areas within the group – "Ambient Assisted Living, Health and Well-being" and "Smart Living" – and focuses on all electronic assistance as a symbiotic cooperation between humans and technology.

# ENERGY EFFICIENT SYSTEMS

For a sustainable and yet affordable energy supply, it is essential to use available resources more economically, to increase energy efficiency, and to reduce the cost of generating and using renewable energies. The focus of the "Energy Efficient Systems" business area is on the development of electronics for efficient energy conversion and energy management.

Particularly in the case of mobile applications, constantly increased power and energy densities are required while design sizes and weight must be reduced. The energy supply is relevant to all areas of application as a subsystem. It affects issues such as the smart grid and energy harvesting, power electronics, energy storage, and energy management.

# APPLICATION-ORIENTED DEVELOPEMENT

FROM TECHNOLOGY RESEARCH TO THE END PRODUCT

## MOBILITY AND URBANIZATION

In urban areas, quality of life is closely tied up with mobility – widespread introduction of low-emission cars and avoiding unnecessary journeys through suitable means of communication would both be of enormous benefit to residents.
That's why the "Mobility and Urbanization" business area focuses its efforts on car-related developments. For electromobility applications, for example, the institutes in the Group develop systems to add electric vehicles to a network, including such information as consumption figures and the necessary communication systems. Drive systems, storage, and the smart power electronics behind them are closely linked to the "Energy Efficient Systems" business area. An additional focus is the use of microelectronics for communication and distribution infrastructures.

## INDUSTRIAL AUTOMATION

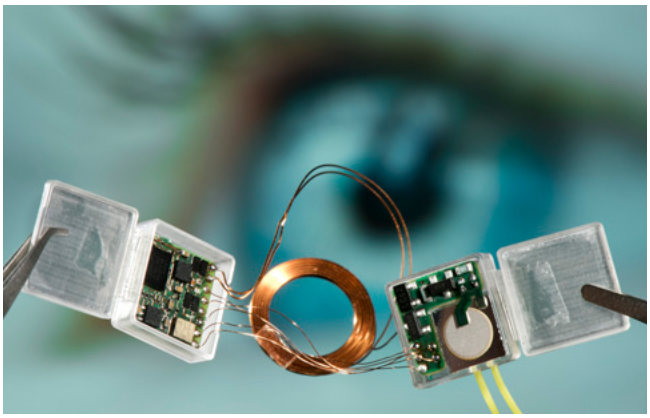
Modern industry is marked by a strong tendency towards digitization of all industrial processes. Whether they are individual machines, industrial robots, or complete assembly lines – all the components of an intelligent factory require robust, efficient, and reliable microelectronics as basic technology. Tiny, multifunctional, independent sensors record all systemically relevant physical, chemical, and biological readings and results, together with their spatial and temporal coordinates. They transmit the data to the control computers operating in the background, smoothing the way for smart industrial production. Smart power electronics, in turn, allow energy-efficient regulation and control of all processes.
In the "Industrial Automation" business area of the Fraunhofer Group for Microelectronics, researchers are developing the required micro-electromechanical systems (MEMS), sensors and actuators as well as power electronics and system integration technologies for the industry of the future.

## HEVC – software and hardware for efficient encoding and decoding

Compared to the H.264/MPEG4-AVC video coding standard, the next-generation video coding standard – H.265/MPEG-HEVC or HEVC for short (High Efficiency Video Coding) – reduces the data rate by 50 percent with the same image quality. The standard was developed in substantial cooperation with Fraunhofer HHI. HEVC encoders and decoders developed by Fraunhofer HHI support the transmission of ultra-high resolution video data in real time and are a world leader when it comes to quality.

*© istockphoto.com / Pawel Gaul*

## Micropump helps to prevent blindness



Elevated or too low intraocular pressure can cause problems with the eyesight and in the worst case even lead to blindness. There are no reliable long-term therapies to these ailments available today. In the "MIKROAUG" project funded by the BMBF, Fraunhofer EMFT, together with its industry partners, is developing a microfluidic system for treating such diseases of the eye. The microsystem, designed to be mounted directly on the ocular bulb, shall permanently stabilize the intraocular pressure.

*"MIKROAUG" Regulation system for intraocular pressure.*

*© Fraunhofer EMFT*

# SMART AND HEALTHY LIVING

FROM TECHNOLOGY RESEARCH TO THE END PRODUCT – APPLICATION EXAMPLES

## Intracranial pressure monitoring whenever you need it

Fraunhofer IMS has developed a micro senor system with wireless readout of pressure and temperature. People suffering from hydrocephalus are enabled to monitor their intracranial pressure at any time without any elaborate examination. The sensor is therefore implanted directly into the patient's brain with the shunt-system. Thus, physicians are able to read out the intracranial pressure with a hand-held read-out device within seconds. Elaborate and costly computer and magnet resonance tomography for the attestation of dangerous overdrainage can be avoided in the future. The system is already approved as medical product and in clinical use.

*© Fraunhofer IMS*

## Personalized hearing assistance in telephones

By using methods from hearing aid technology, the Project Group Hearing, Speech and Audio Technology of the Fraunhofer IDMT develops signal processing algorithms which allow users to adapt the telephone signal to their individual hearing requirements. The software solution can be integrated in telephone networks as well as in telephone systems, terminal devices and conference systems or in internet applications for voice or video telephony.

*Adaptive signal processing makes it possible also for persons with hearing impairment to better understand telephone calls even under conditions with background noise.*

*© MEV Verlag*

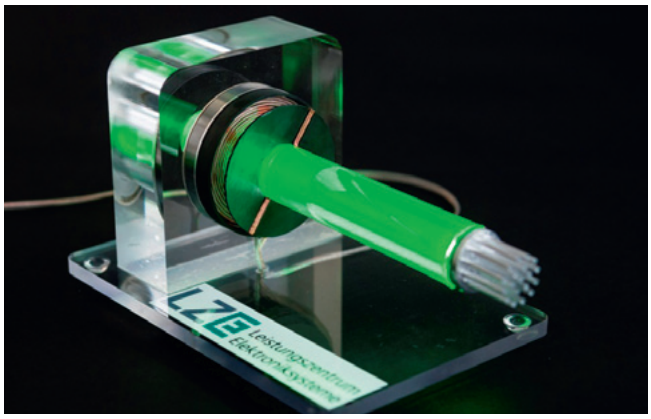
## Fraunhofer IIS technologies supporting effective toothbrushing

Procter & Gamble has been working together with scientists from Fraunhofer IIS on the development of a new smart tooth-brushing system.
Based on the image analysis software SHORE™ developed by Fraunhofer IIS as well as its localization technologies for position recognition, users know whether they are brushing too little or too long in one place, or whether they have missed an area. The system supports them in their daily dental hygiene as recommended by dentists.

*ORAL B GENIUS in corporation with Fraunhofer SHORE TM-technology and localization technology for positioning.*

*© Procter & Gamble*

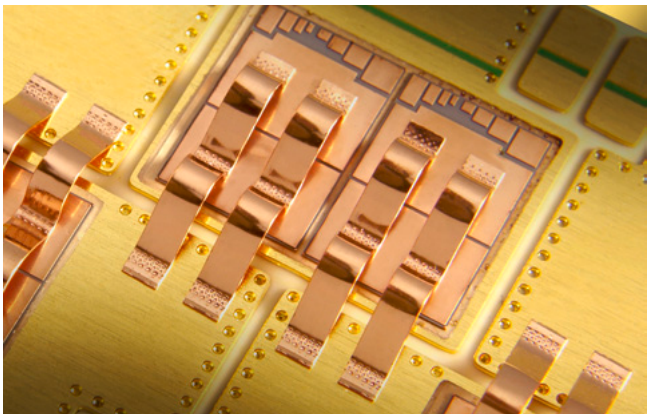
## Wireless power and data transfer in systems with fast-moving parts




The reliable transfer of power in moving systems or harsh environments is required for a wide range of applications, such as in wind energy, Industry 4.0, healthcare, agriculture, or chemical industry. The inductive system, which was realized by the partners of the Leistungszentrum Elektroniksysteme (LZE) at the example of a ball bearing, offers bidirectional power and data transfer and improved safety as a wear-free alternative to failure-prone cable-based solutions.

*Wireless power and data transfer through a ball bearing.*
*© Fraunhofer IISB*

## Reliable power modules with copper ribbon bonding technology



The conversion of chip contacting by aluminum wires, with copper wires or ribbons will significantly improve the potential and the reliability of power modules in the near future. Scientists at Fraunhofer ISIT have developed a copper deposition process on wafer level, and an automatic bonding process for copper ribbons.

*Power electronics module with sintered chips bonded with 2000 µm wide copper ribbons. © Fraunhofer ISIT*

# ENERGY EFFICIENT SYSTEMS

FROM TECHNOLOGY RESEARCH TO THE END PRODUCT – APPLICATION EXAMPLES

## Optical communications for more efficient data centers

Using optical interconnections

- from rack-to-rack
- between boards
- on chip level

will cut energy consumption by at least 50 %, while simultaneously doubling the capacity of data connections to 2 Tb/s.

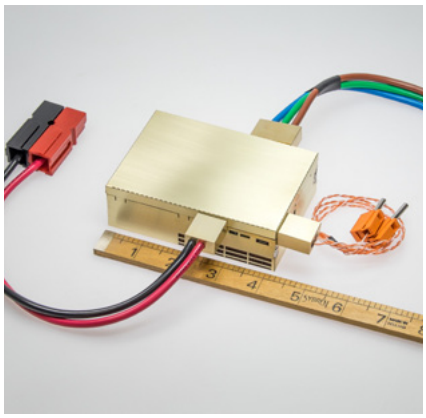
*Optical data transmission involves just a fraction of the processes required by earlier systems. © MEV Verlag*

## Modular & wheel-hub integrated SiC inverter for commercial vehicles


An SiC inverter for a smart, compact, modular, and durable in-wheel drive unit was developed at Fraunhofer IISB. The inverter provides easy servicing of the complete powerstage due to a plug-and-play interface, good manufacturabilty, and flexibility. This helps to increase the availability of hybrid and electric vehicles, which is essential for commercial use. Main component of the modular integration approach is an newly designed Inverter Building Block (IBB).

*Wheel-hub integrated SiC inverter for commercialvehicles (EU project COSIVU).*
*© Fraunhofer IISB*

## One of the world's tiniest inverters



- Very fast switching speeds are possible using gallium nitride semiconductors with a reverse voltage of 650 V.
- With a switching frequency of up to 1.6 MHz, the Fraunhofer IZM transformer is approximately 100 times faster than the current standard of 16 kHz.

*Peak efficiency of 97 percent: The solar inverter converts 2 kW. © Fraunhofer IZM*

## "CleanSky": Environmentally friendly air traffic

CleanSky is the most ambitious aeronautical research program ever launched in Europe. Its mission is to develop breakthrough technologies to significantly increase the environmental performance of airplanes and air transport, resulting in less noisy and more fuel efficient aircraft, hence making a key contribution to achieve the "Single European Sky" environmental objectives. Fraunhofer ENAS is contributing with the development of a new "intelligent" wing, which could save fuel and create less noise.

*In the future, intelligent wings could save fuel and create less noise.*

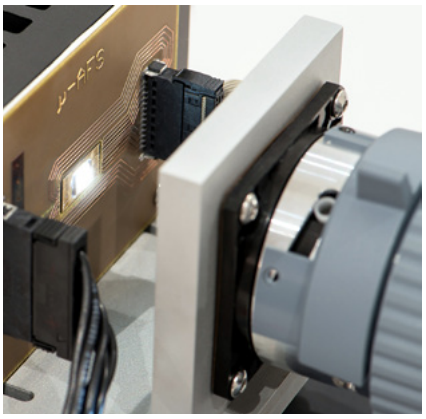
*© Fraunhofer ENAS*

## Fraunhofer Symphoria®: Spectacular sound for automotive entertainment

- Symphoria by Fraunhofer is a high-end 2D/3D surround sound post processing technology for up-mixing and playing back any type of audio content in a car.
- The high-quality universal rendering solution significantly improves the perceived audio quality on all seats for any pre-defined hardware configurations.
- Now available in the latest Audi A4, Audi TT, Audi Q7, and Audi R8.

*© Audi Media Service*

## Intelligent headlight: Improved sight for night travelling



- Instead of single LEDs each equipped with respective driver chips, adaptive front-end lighting now comprises 256 pixels.
- The headlight includes the option of permanent high-beam, variable light distribution and reduces blinding of on-coming traffic.

Partners: Infineon, Osram, Hella, Daimler, Fraunhofer IAF, Fraunhofer IZM.

*First step to more intelligent LED-based front-lighting systems. © Osram*

# MOBILITY AND URBANIZATION

FROM TECHNOLOGY RESEARCH TO THE END PRODUCT – APPLICATION EXAMPLES

## Wireless mobile phone charging in automobiles

- Technology for wireless charging device to be integrated into Audi A8 and Audi TT consoles.
- Thermal characterization, EMC and embedding were carried out at Fraunhofer IZM.
- Five months from idea to prototype.

Partners: Audi, Novero Dabendorf, Freescale, Elektrisola.

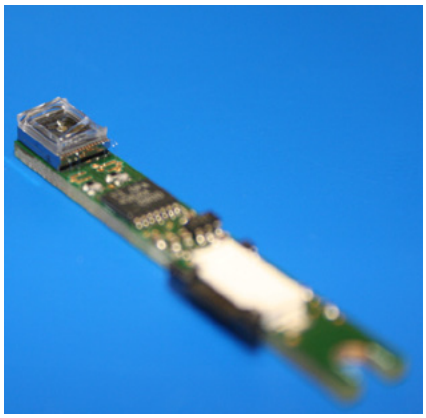
*Integrated charging device for car consoles.*
*© Audi AG*

## Full SiC-DC/DC converter


Entering new territory for power density and efficiency thanks to the use of silicon carbide power semiconductors: the bidirectional DC/DC converter from Fraunhofer IISB for the drive train of electric vehicles. The DC/DC converters are designed with silicon carbide switches and are intended for battery voltages of up to 850 V and battery charge and discharge currents of up to 700 A. With advanced integration concepts the power densities were pushed up to 143 kW/dm³ – the first time this level of power density has been achieved when producing these kinds of converters.

*© Fraunhofer IISB*

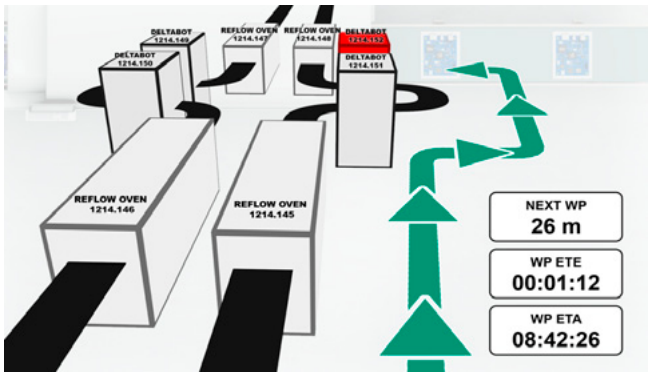
## LIDAR system for gesture recognition



Fraunhofer ISIT has developed a 3D camera based on a 2D MEMS scanner, which uses the principle of phase difference of a laser beam to the detected "echo" as distance measurement. The phase detection algorithm allows 60 million 3D measurements per second. The camera has a resolution of 450 × 450 pixels and provides six images per second. The depth resolution is a few millimeters and the maximum detectable distance to the object is 2 m.

*3D MEMS camera with scanning mirror.*
*© Fraunhofer ISIT*

## Indoor navigation and localization




With its systems for wireless tracking of materials, objects, people and tools, Fraunhofer IPMS offers its customers real-time location services (RTLS) for gapless tracking of mobile assests and navigation throughout buildings. RTLS solutions created at Fraunhofer IPMS are designed to be used in restricted areas as well as in various environments such as factories, hospitals and public buildings. Tracking methods are based on an existing WiFi infrastructure and require no additional hardware.

*Scenario for real time location services in production environments. © Fraunhofer IPMS*

## 360-degree radar for a safe human-machine collaboration

The new high frequency radar scanner can monitor its environment in a 360-degree radius with a precision of less than a micrometer and a transmission range of up to several hundred meters. It also shines through optically intransparent materials such as smoke, fog, paper, boxes, or plastic boards.

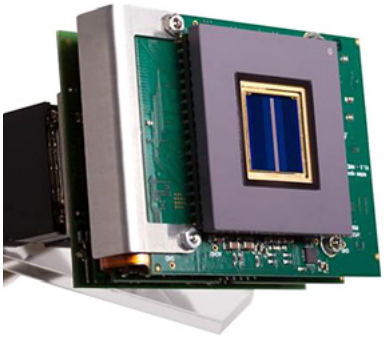
- Safety in Industry 4.0: The radar scanner detects humans even when they are behind obstacles and prevents collisions with industry robots
- Level sensor: Determination of filling levels
- Logistics: Monitoring of container ports
- Flight safety: The radar provides exact height & ground clearance data as a landing assistance

*The 360-degree radar scanner is signiftcantly more compact than previous radar systems. The module is no larger than a pack of cigarettes. © Fraunhofer IAF*

# INDUSTRIAL AUTOMATION

FROM TECHNOLOGY RESEARCH TO THE END PRODUCT – APPLICATION EXAMPLES

## "xposure": 600/200 kHz high speed RGB line-scan sensor



Together with the AIT Austrian Institute of Technology, Fraunhofer IMS has developed the fastest line-scan sensor for highly sensitive inspection tasks. The multiple-line-sensor enables colored imaging with a resolution of 0.05 mm at a transport-speed of 36 km/h. Thus, the fast sensor can detect even smallest defects on surfaces and can be ideally used for the surface-control of valuable printed material.

*xposure camera system.*

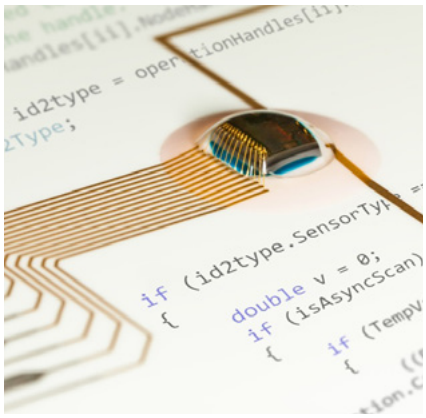
*© AIT Austrian Institute of Technology*

## RFID-based fire protection for electrical cabinets


One of the most important measures for fire protection is early detection. That is exactly what "Electrical Cabinet Monitoring" from Fraunhofer IMS ensures. The RFID-based solution guarantees early recognition of hotspots in electrical cabinets by using temperature transponders which do not need any wiring to the point of measurement. With a certain antennae arrangement, 60 or more transponders can operate in one single electrical cabinet. Malfunctions and fires in electrical cabinets can thereby generally be avoided.

*Assembled transponder. © Fraunhofer IMS*

## ROAD-Server



Fraunhofer IPMS offers a **R**FID **O**PC-UA **A**uto**ID** (ROAD) server for Industry 4.0 environments. This middleware enables the easy integration of RFID readers, tags and sensors into complex production environments regardless of manufacturer. Once implemented on the basis of the OPC-UA interface, applications can continue to be used unaffected even by changes in reader or transponder population.

*RFID tag with ROAD support.*

*© Fraunhofer IPMS*

# TECHNOLOGY: FROM CMOS TO SMART SYSTEMS

Our business area "Technology: From CMOS to Smart Systems" focuses on the development of reliable, robust, energy-efficient, and yet cost-effective miniaturization technologies for microelectronics and microsystem technologies. Our range of expertise spans from classic CMOS and MEMS technologies to integration technologies for smart systems. As a service provider for technologies, we can support you in realizing ground-breaking product ideas, can develop new technologies, and can manufacture your prototype. We also have the necessary expertise to provide small-series production if there are special requirements.

# SAFETY AND SECURITY

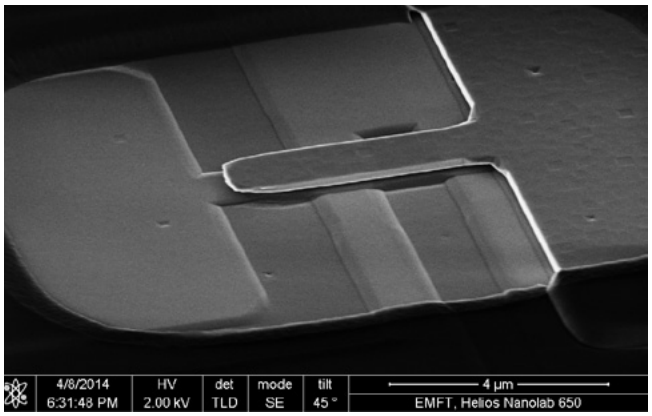
Trustworthy and reliable transmission and processing of information is the key to modern, smart societies. This requires reliable, safe, and secure microelectronics. Microelectronics is also an essential part of most safety and security systems including tools for the protection against terrorism. Both aspects are covered in our technology-oriented business area "Safety and Security". Based on the member institutes' expertise in system design, reliability, sensor systems, and systems integration, we are developing application-specific system solutions for surveillance and reconnaissance, structural and functional monitoring of machine parts and buildings, secure communication, and fail-safe hardware and software.

# EXPERT SUPPORT IN TECHNOLOGICAL AREAS

## INFORMATION AND COMMUNICATION

Information and communication technologies (ICT) are required to make hardware "smart." The combination of hardware and ICT in an application forms what is today called a "Cyber Physical System." Like "Technology: From CMOS to Smart Systems", "ICT" for us is both a core competence as well as a cross-cutting business area. The ICT oriented R&D activities mainly address transmission and processing of information, with a specific focus on transmission systems for broadband data communication and services. The institutes' activities are covering the whole value chain from chip to system level including networks and systems for wide area communication, wireless broadband communication systems, wireless sensor networks, components and subsystems, and algorithms and software. Our success is based on comprehensive competences for development and characterization of complete system solutions for communication systems and sensor networks. The institutes involved design, develop, and realize the necessary application specific electronic and photonic circuits and devices.

## NEMS technology for highly sensitive sensors




In the NanoFET project Fraunhofer EMFT is developing a miniaturized Nanogap Field Effect Transistor for highly sensitive sensors, together with industry partners. Due to the deployed nanostructures, even the slightest mechanical deflection causes a significant change in the electrical characteristics of the field effect transistor.
This technology opens up potential for the development of novel, highly sensitive and yet cost-efficient sensors for measuring physical parameters such as pressure or acceleration.

*SEM picture of a NanoFET-Device. © Fraunhofer EMFT*

## The MST Lab&Fab – a development and assembly line for smart sensors

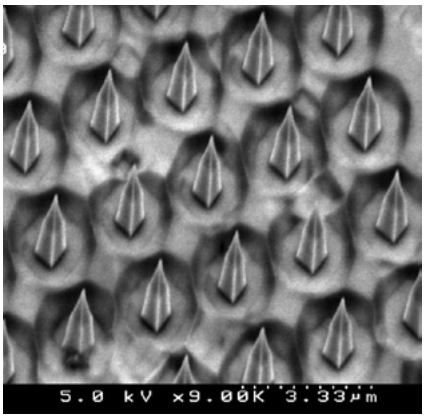
The MST Lab&Fab at Fraunhofer IMS is focused on post-processing, whereby smart sensors are produced by integrating the sensor element directly onto a CMOS read-out circuit. The goal of this facility is to develop new, smart sensors. Currently, optical sensors and sensor arrays ranging from UV up to long-waved IR are being developed as highly sensitive camera chips for LIDAR or thermal micro bolometer imagers. Small pressure sensors with a transponder interface transmit the data and receive their needed energy via radio transmission or an integrated solar cell. Also discrete sensors, for example for pressure measurements at high temperatures, are being developed.

*© Fraunhofer IMS*

# TECHNOLOGY: FROM CMOS TO SMART SYSTEMS

OUR RESEARCH AND DEVELOPMENT EXPERTISE – EXAMPLES OF TECHNOLOGIES

## Diamond as a bridge to quantum physics

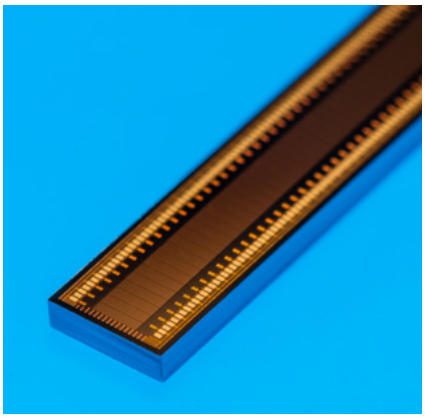



Based on nuclear magnetic resonance spectroscopy (NMR), Fraunhofer IAF and Max Planck society are developing diamond sensors which can identify magentic fields at the nanoscale. In the future, these sensors will be used for the quality control of storage discs to reduce reject rates and productions costs.

- Hard drives: measuring sensors for the quality control of storage media and reading heads
- Bio medicine: characterization of proteins for the detection of diseases and poisonous substances
- Material sciences: reliability testing and safety inspections

*With NMR diamond tips, defective sectors on hard disks can be located and excluded from the reading and writing process in the future. © Fraunhofer IAF*

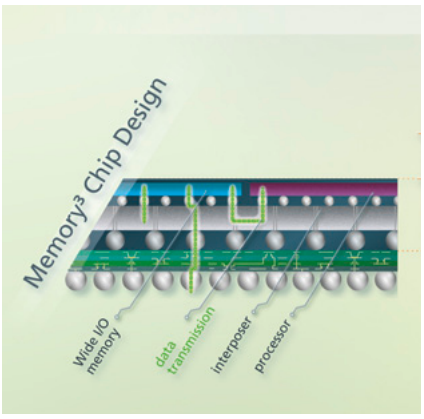
## Micromachined ultrasonic transducers



Fraunhofer IPMS develops micromachined ultrasonic components for various areas of application. These elements are uniquely capable of being integrated into CMOS processes as post-CMOS modules, paving the way for highly-miniaturized components with integrated evaluation electronics.Therefore, Fraunhofer IPMS is focused on the development of capacitive micromachined ultrasonic transducers (CMUTs).

*128 channel chip of a capacitive micromachined ultrasonic transducer.*
*© Fraunhofer IPMS*

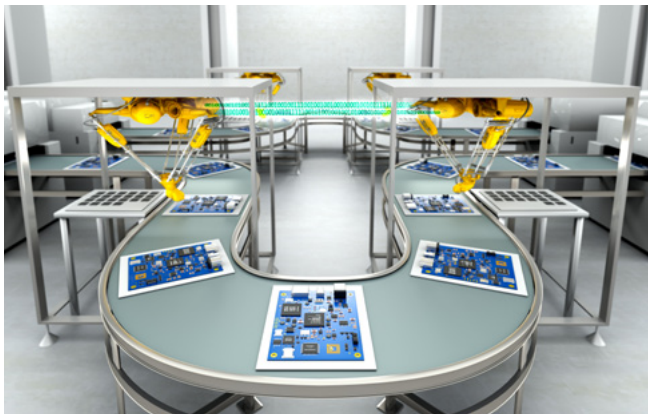
## Innovative IPs with „More than Moore"-technologies




Classic chip designs are increasingly reaching their limits. For many applications components have to be even higher performing with an even more compact arrangement. This future belongs to three-dimensional integrated microchips. Fraunhofer IIS / EAS researchers are working in the project MEMORY³ to develop a 3D chip design for 4K video cameras for professional applications. To reach their goals, they place a processor and a Wide I/O memory on one interposer (substrate) in the same package. The 3D technology allows a high miniaturization, shorter connections and an effective heat removal. The goal is to achieve data rates between the memory and the processor of up to 400 Gbit/s.

*Heat removal of a Memory³ chip in comparison with an conventional chip.*
*© Fraunhofer IIS / EAS*

## Wireless gigabit-class communication



Today's devices almost always use RF-based solutions such as WLAN or Bluetooth to communicate wirelessly. Those solutions support up to some hundred Mbit/s data rate. Currently, that is no longer sufficient for many applications and large file transfers.

With this in mind, Fraunhofer IPMS has developed an optical wireless communication link with up to 10 Gbit/s data rate. This can be used for docking solutions or to replace cable connections such as USB or Gigabit Ethernet.

*Optical wireless communication in the context of Industrie 4.0.*

*© Fraunhofer IPMS*

## Acoustic event detection using sensor network


The Project Group Hearing, Speech and Audio Technology of Fraunhofer IDMT develops signal processing and hardware for computer-based acoustic monitoring in areas such as Industry 4.0, Security and Smart Cities/Smart Buildings. The hardware units for acoustic signal acquisition and processing can easily be integrated in existing cable-based or wireless sensor networks.

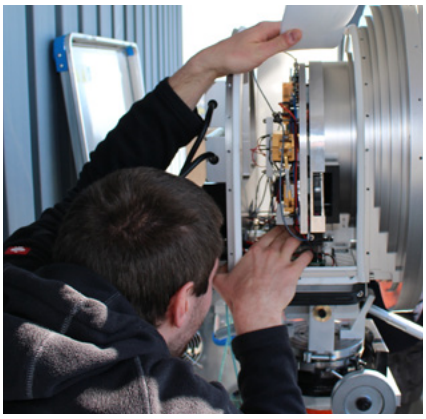
*The core of the "Acoustic Processing Unit" (APU) is an embedded board that allows complex signal processing algorithms to also be applied to wide-band, high-resolution audio signals.*

*© Fraunhofer IDMT*

# INFORMATION AND COMMUNICATION

OUR RESEARCH AND DEVELOPMENT EXPERTISE – EXAMPLES OF TECHNOLOGIES

## New world record in wireless data transmission



With a data rate of 6 Gbit per second over 37 kilometers, a research network including the Fraunhofer IAF has exceeded the state of the art by a factor of 10. The new world record corresponds to the transmission of a DVD in under 10 seconds.

Application fields:

- Cost-efficient replacement for the deployment of optical fibre
- Supplying of rural areas and remote regions with fast internet
- Ad-hoc networks in case of crises and catastrophes
- Connecting of base stations in mobile communication

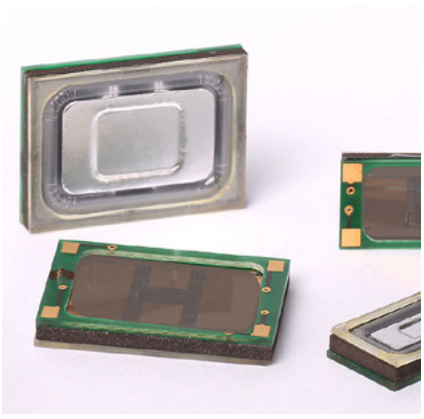
*E band transmitter with a parabolic antenna. The installed integrated circuits of the Fraunhofer IAF achieve particularly high performance. © Jörg Eisenbeis / KIT*

## High-speed Internet from the ceiling lamp

Visible Light Communication (VLC), also known as LiFi, is an attractive solution, especially in environment settings where radio communication encounters difficulties. The Fraunhofer HHI has developed modern transmission techniques that enable data-rates up to 1.25 Gbit/s. LED-lamps, normally used for lighting purposes, simultaneously transmit data, even when mobile terminals are not aligned with the access point.

*© Fraunhofer HHI*

## MEMS loudspeakers for mobile communication devices



In collaboration with partners from industry and science Fraunhofer ISIT is developing a new generation of miniaturized loudspeakers, which are fabricated using silicon technology. In contrast to conventional electrodynamic micro speakers the new chip speakers are based on powerful piezoelectric MEMS drives and feature high energy efficiency and extremely low fabrication tolerances. Fields of application are mobile communication devices like tablets, smartphones and headphones.

*MEMS loudspeakers with piezoelectric drive. © Fraunhofer ISIT / USound*

## Retinal scanner that fits in a purse

The blood vessel pattern of the retina is a biometric feature that is different in each human being. Using special eye scanners, a person could give proof of identity safely, securely and unambiguously while on the go. For example, in order to conduct bank transactions, or to unlock the car.
However these devices are much too large for mobile use. Together with other partners within the BMBF-funded project "MARS," scientists at Fraunhofer IPMS develop a prototype of a small retinal scanner. Researchers housed the needed optical components within a volume of about 12 × 9 × 6 cm³.

*The approximately 650 cm³ Fraunhofer IPMS retinal scanner.*
*© Fraunhofer IPMS*

## Application lab IR laser spectroscopy: Identifying solids & liquids – in real time

The Fraunhofer IAF application laboratory for IR spectroscopy detects and quantifies chemical reactions and substances with fast tunable quantum cascade lasers – in real time. As a result, various measurement tasks and appplication fields in the 4 – 11 µm wavelength range can be covered:

- Process analysis: monitoring chemical reactions
- Food: identifying sensory defective / spoiled food
- Pharma: analyzing active agent concentration
- Medical therapy: breath & blood glycose analyses
- Clean technology: monitoring drinking water
- Safety engineering: detecting hazardous substances

*Measurement setup for the standoff detection of chemical materials.*
*© Fraunhofer IAF*

# SAFETY AND SECURITY

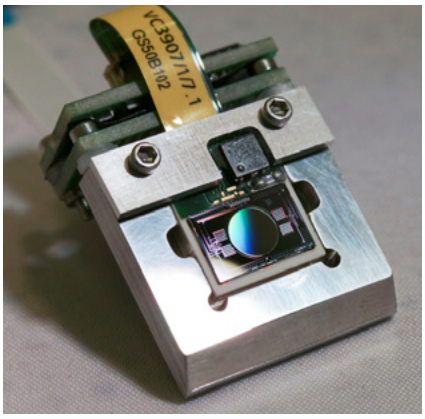
OUR RESEARCH AND DEVELOPMENT EXPERTISE – EXAMPLES OF TECHNOLOGIES

## Reliable vehicle architecture


Highly-automated or autonomous driving, plus the elimination of mechanical connections such as with steering, will place additional demands on the E/E systems of future vehicles.
In the EU-funded project SafeAdapt, Fraunhofer ESK and several European partners developed a fail-operational concept for safety-critical driving functions using an AUTOSAR-compliant process. The system is supported by a generic error resolution mechanism and an automated tool chain.

*If an ECU fails, the generic mechanism deactivates unnecessary functions and activates the critical functions on the remaining ECUs.*
*© Fraunhofer ESK*

## Optical spectroscopy in the MIR



Using spectroscopy the type and concentration of hazardous substances can be determined. Fraunhofer IPMS developed a highly reflective diffraction grating with a diameter of 5 mm that is used to set the light of a miniaturized quantum cascade laser (QCL), which is being developed by researchers of the Fraunhofer IAF to the defined wavelengths. In this way, the sample can be irradiated with different wavelengths in the time multiplex, and conclusions can be drawn with regard to the type and concentration of the hazardous materials using the "fingerprint."

*Moving diffraction grating as an external resonatorof the quantum cascade laser.*
*© Fraunhofer IPMS*

## KATWARN: Free disaster alert system

KATWARN is a free warning system for the population, developed by Fraunhofer FOKUS.
The responsible authorities and agencies send via KATWARN official warning information on disasters, such as large fires, bomb alerts or hurricanes, directly to the mobile phones of affected citizens. Therefore, KATWARN supplements the general warnings issued by the police, fire brigade and radio by providing information that may be vitally important.

*Many cities, counties and federal states are already connected to the system.*
*© Fraunhofer FOKUS / Matthias Heyde*

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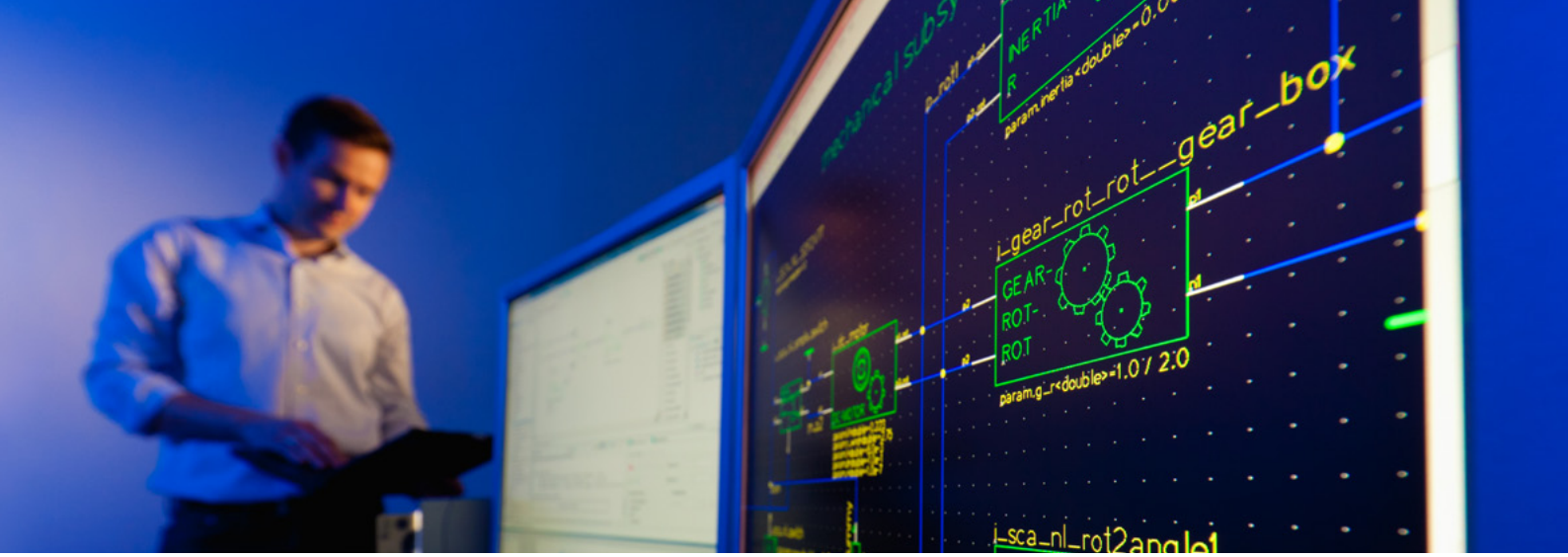



# DESIGN FOR SMART SYSTEMS

New types of components from micromechanics, microphotonics, power electronics, and high-frequency technology, as well as modern mixed-signal circuit concepts, are important building blocks when it comes to realizing innovative microelectronic products. The increasing performance of digital circuits also plays an important role. The combination of functional sensor and actuator units with high-performance modules for signal processing and communication allows smart systems to be implemented in a wide spectrum of applications. However, this also leads to particular challenges that must be overcome in the design process. The causes are the functional variety and complexity of the systems and the influence of manufacturing and integration processes on a system's function.

The strategic core competence "Design for smart systems" therefore comprises research, services, and developments in the area of digital, analog, and mixed-signal systems, including sensors and embedded software.

The design competence of the Fraunhofer Group for Microelectronics thus forms the link between technology and the system level. Thanks to the varying focuses of the member institutes, the Group is able to cover a very wide spectrum. The close cooperation and interconnectedness of design activities in the Group for Microelectronics allows us to combine know-how from different areas and to input it into tailor-made system solutions for customers.

The expertise of the Group for Microelectronics includes:

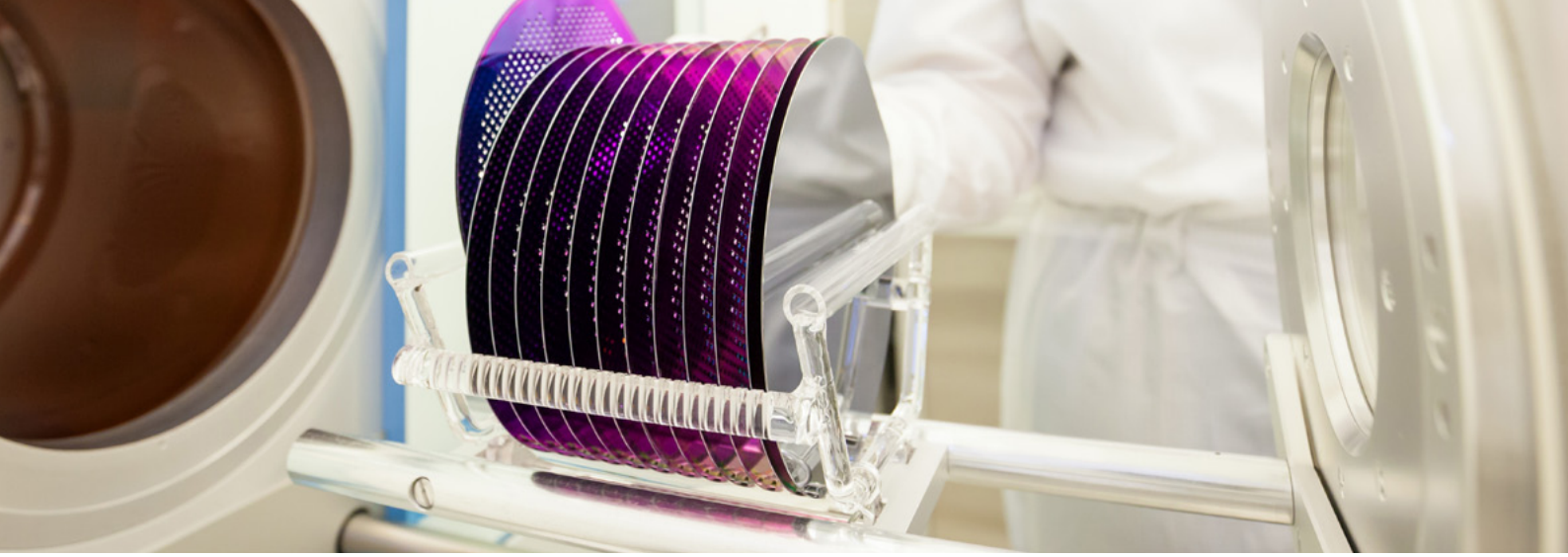
- System design of smart systems
- Component design, particularly in the areas of RF, sensors and sensor interfaces, analog front ends, digital SoCs, power electronics, and optics and opto-electronics
- Consideration of special design constraints: Low power, design for reliability, design for functional safety, design for radiation hard devices, and design approaches for harsh environmental conditions
- Development of design tools: Algorithms and design environments as well as models and model libraries

One important aspect of the cross-institute design platform is the efficient connectedness of the various design groups within the Group. This design platform is coordinated by the Division Engineering of Adaptive Systems EAS of the Fraunhofer Institute for Integrated Circuits IIS. Its shared goals for the immediate benefit of customers and ordering parties are:

- The creation of new offers and unique selling points by combining complementary competences;
- A higher degree of efficiency through synergies, leading to a reduction in development costs and development risks;
- Comprehensive integration into the added-value chains and accumulation of application-specific know-how, particularly for small and medium enterprises with innovative products;
- Reduction of development times, allowing faster market entry for customers' products.

In the long term, these activities are rounded off with:

- the establishment of a shared IP offer,
- Platform solutions for comprehensive hardware/software co-design and
- the development of scalable HW/SW modules for maximum re-use.



# SEMICONDUCTOR-BASED TECHNOLOGIES

There is scarcely a technology sector where global competition is as challenging as in electronic systems. Invisible to the naked eye as they usually are, hidden under the surface of the product, electronic systems with a high degree of complexity must be designed, manufactured, and brought to market in an extremely short period of time and they must work absolutely reliably and energy efficiently. Basic technological research, customer-specific process development, and reliable production are the key to the development of innovative system solutions.

In order to be able to offer a stable process platform as the basis for innovative continued development, the employees of the Fraunhofer Group for Microelectronics work on a shared technology platform. This cooperation takes place under the auspices of the Fraunhofer Institute for Photonic Microsystems IPMS.

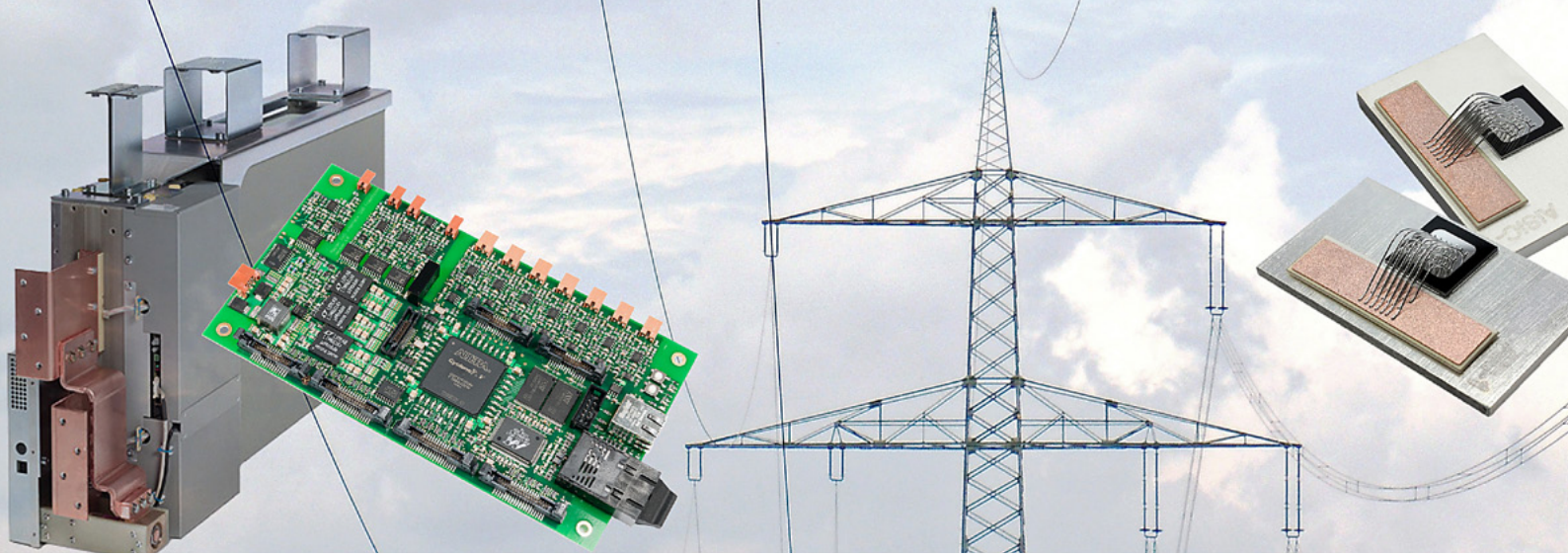
The strategic core competence "Semiconductor-based technologies" bundles the specialist knowledge of the member institutes in this technology platform – particularly within the area of More-than-Moore technologies, as they are known. The basics are the technologies available at the institutes, such as:

- Si process technology for wafer diameters of 150 mm and 200 mm
- Individual processes on 300 mm wafer
- MEMS specific add-on technologies
- Development of SiC materials and technology for power electronics
- GaN process technology for power and ultra-high frequency applications

Topic focuses based on these technologies and with the aim of establishing cross-institute cooperation for functional diversification include:

- Enhancement of the 200 mm Si technology basis for MEMS and MOEMS applications
- Complementary non-Si technology platforms such as central SiC process steps and devices for the highest cutoff voltages
- GaN applications in opto- and power electronics
- Optimized packaging
- Integration of new materials for enhanced functionality and optimized performance 200 mm foundry operation

The Fraunhofer Group for Microelectronics thus positions itself beside its competitors IMEC (Belgium) and CEA-Leti (France) as part of a pan-European smart specialization and offers foundry operations for small and medium batch sizes on a 100 mm and 200 mm wafer basis with the option of later addition of 300 mm.



# POWER ELECTRONICS AND SYSTEM TECHNOLOGIES FOR ENERGY SUPPLY

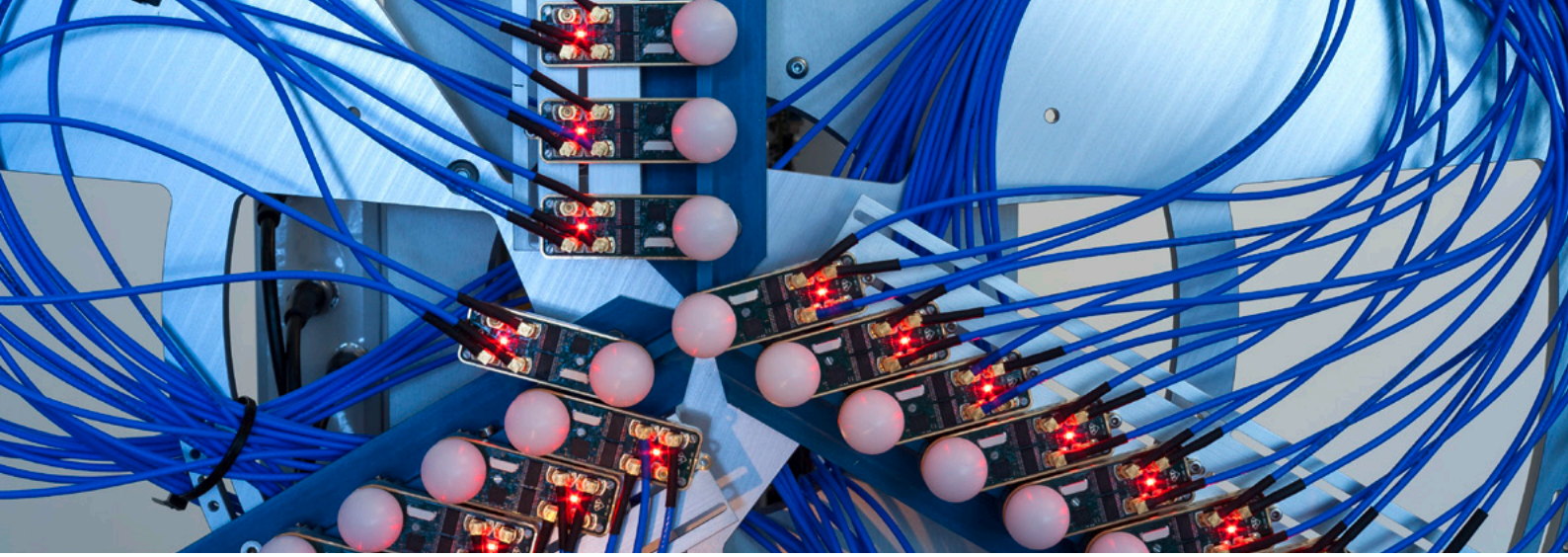
Demand-led supply of electrical energy is a globally important issue. In the smart power grid of the future, a number of energy sources, storage options, and grid levels will be linked together in complex infrastructures. The energy will be used in a very wide range of areas of application and power classes: Largely regenerative, decentralized energy production; high-efficiency sub-grids; and the coupling of electrical energy with other types of energy (chemical, mechanical, thermal) are becoming more and more important. At the same time, electrical and secondary storage options are being more heavily integrated into the grid and load shifting effects are exploited. Large overall systems with a high degree of independence (industry, large building complexes, towns, etc.) need new types of energy concepts.

The Fraunhofer Group for Microelectronics develops high-efficiency systems and components to provide the technology needed for sustainably efficient yet cost-effective energy supply. The strategic core competence "Power Electronics and System Technologies for Energy Supply" bundles the specialist knowledge of the member institutes in the areas of power electronics and information technology for the smart grid as well as energy harvesting, energy storage, and energy management.

The main thematic focuses of the cross-institute platform are:

- System development for power electronics (power grids, energy conversion, and energy storages)
- Information and communication technology for smart grids, including sensors
- Energy management
- Energy storage technologies and battery management
- Technologies for ubiquitous energy harvesting
- Electric drive technology
- Electromagnetic compatibility (EMC)
- Material development, device technology (active/passive), circuit development, and packaging

In addition to minimizing energy losses and lowering costs for the use of renewable energy in the long term, the focus is placed particularly on issues of reliability and robustness as well as increased grid quality and stability. Application-specific optimization of installation space, weight, and material consumption is another aim of the research and development.



# SENSORS AND SENSOR SYSTEMS

It is impossible to imagine life today without sensors to determine measured data. Sensors are often directly linked to increasingly sophisticated data processing systems as well as wireless data transmission. These types of sensor systems form the backbone of modern concepts such as home automation, medical engineering, and industrial process monitoring. The demands being placed on them, however, are becoming ever more varied. The normal development path - prototype construction, troubleshooting, and optimization – is often not sufficient to deal with this level of complexity.

The member institutes of the Fraunhofer Group for Microelectronics bundle all the technologies needed for the development of reliable, robust, energy-efficient, yet cost-effective sensor systems in the "Sensors and Sensor Systems" core competence:

- Micro- and nano-sensors, CMOS-compatible sensor processes
- MEMS and NEMS technologies, add-on technologies, system integration (including 3D)
- Transmission systems, RF technologies
- System and application design
- Systems, signal processing, sensor data fusion

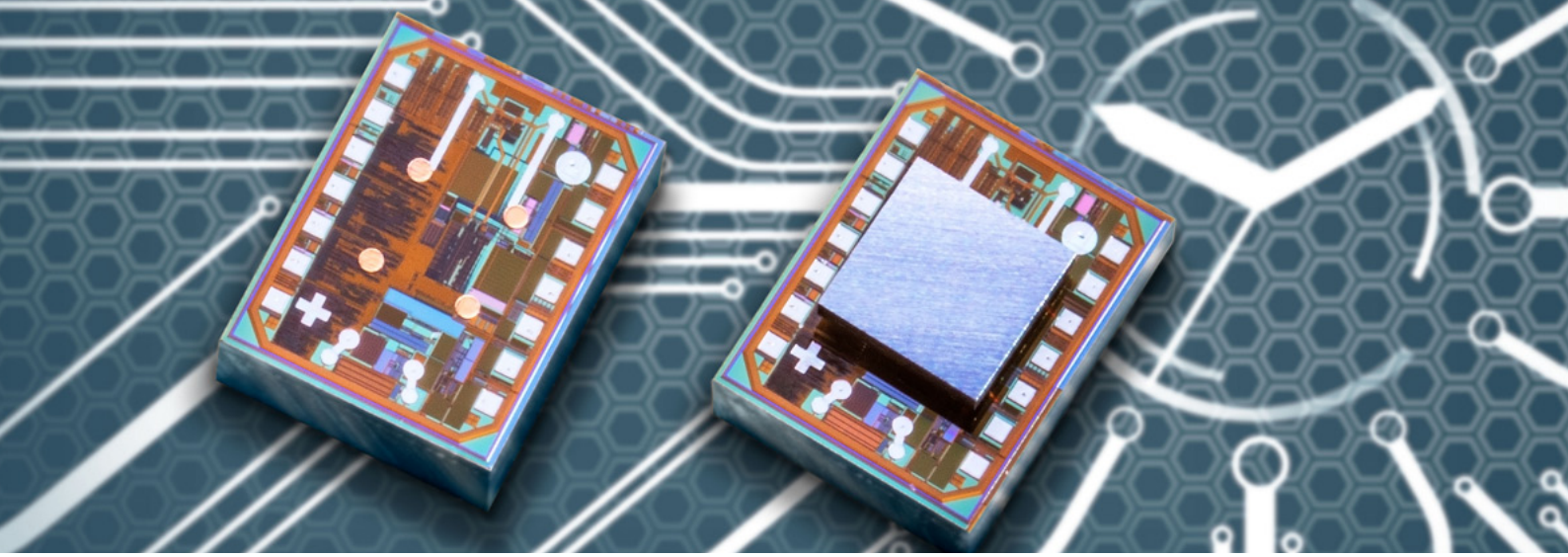
This basis allows us to offer our customers tailor-made sensor solutions from a single provider – from design to the finished system, reliability monitoring, and accompanying services.

**Applications**

Automotive and transport // mechanical and plant engineering // materials testing // medicine and health // environment and process monitoring // safety and security

**Sensor principles**

Electrochemical sensors // inductive sensors // capacitive sensors // optoelectronic sensors // resistive sensors // radar and terahertz sensors



# SYSTEM INTEGRATION TECHNOLOGIES

Invisible, but indispensable: Packaging of electronic systems has the central task of consolidating different components to form a system. The wide-ranging demands placed on this technology can be summarized in four main trends:

- Customer-specific solutions in small and medium batch sizes at low manufacturing costs
- Greater functionality for the incorporating system
- Improved system reliability
- Energy efficiency and reduction of energy requirements

In order to maintain existing strengths and to take advantage of new opportunities, such as excellent value creation as a result of integration into a package of functional devices, close internal cooperation and a merging of technological possibilities are required.

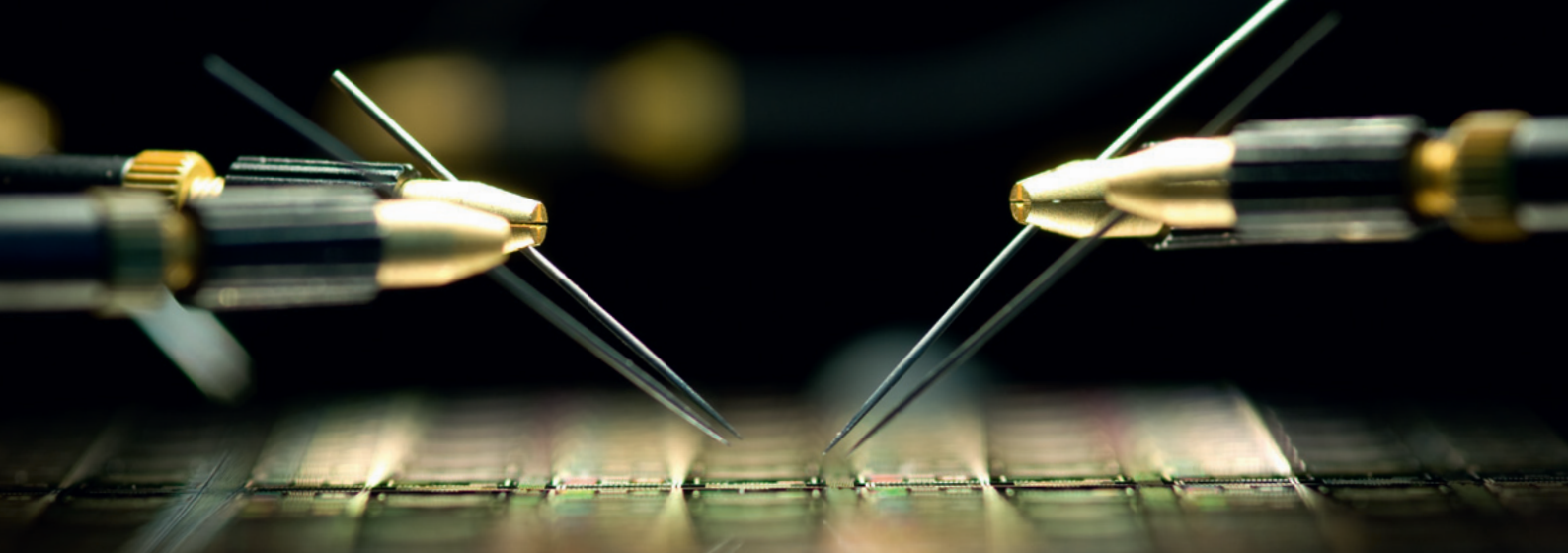
- 3D system integration of digital and analog components on the wafer (use of Si interposers), and panel (SiP, SoF, embedding) levels
- Comprehensive range of technology for system-in-package (SiP) on the following levels: wafer, panel (incl. flex)
- Integration of MEMS components, sensor-actuator components and electronics
- Integration of photonic components and devices
- Assembly of RF systems
- Assembly of compact power electronics
- System integration in atypical materials for electronics (textiles, stretchable substrates)
- Draft analysis of software-based embedded systems
- Networking of embedded systems
- Tool prototypes for integration of embedded systems with multicore processors

Our strategic aim is therefore to establish a cross-institute technology platform that will create a critical mass and will focus on Germany's industrial strengths to ensure that a significant part of the value creation can be returned to Germany. The platform concentrates on the following aims:

- Comprehensive range of technology for system-in-package (SiP) on the following levels: wafer and panel with system solutions from a single provider
- 3D system integration of digital and analog components with TSV in active wafers
- Integration of MEMS components and photonic devices Compact power electronics with integrated driver electronics
- Online networking of embedded systems with cyber physical systems
- Tool chains for comprehensive integration of embedded multicore systems

System integration rounds off the services offered by the semiconductor technology platform, meaning that the Group for Microelectronics is able to offer a comprehensive range of technology from devices to system-in-package, and indeed to capitalize on this range as a system provider would.

We are currently establishing a comprehensive range of technology for system-in-package (SiP). The combination of two levels – wafer and panel – allows us to offer system solutions from a single provider for applications in the areas of ultra-high-frequency technology, power, photonics, and sensors and sensor systems.



# QUALITY AND RELIABILITY

As part of increasing production closeness and the addressing of higher technology readiness levels (TRLs), the investigation of reliability aspects is becoming more important within the Fraunhofer Group for Microelectronics. Reliability is evaluated at different levels of integration, starting from the system and passing over the electronics assembly, the interconnect device, the device itself, and the semiconductor, right up to rewiring and the transistor structures. To assure the quality of electronic systems, the Fraunhofer scientists in the Microelectronics Group are working on coming up with solutions for inspection along the entire added-value chain.

The cross-institute expertise in quality assurance and reliability of materials, devices, assemblies, and systems are multifaceted and are merged together within the strategic core competence "Quality and Reliability" in three central working areas:

- Monitoring and characterization of semiconductor process technology
- Characterization of active and passive devices, MOEMS, and smart systems (SoC)
- Reliability evaluation, test, and service life analysis from the wafer level and the packaging to the overall systems

The semiconductor process technology working area comprises:

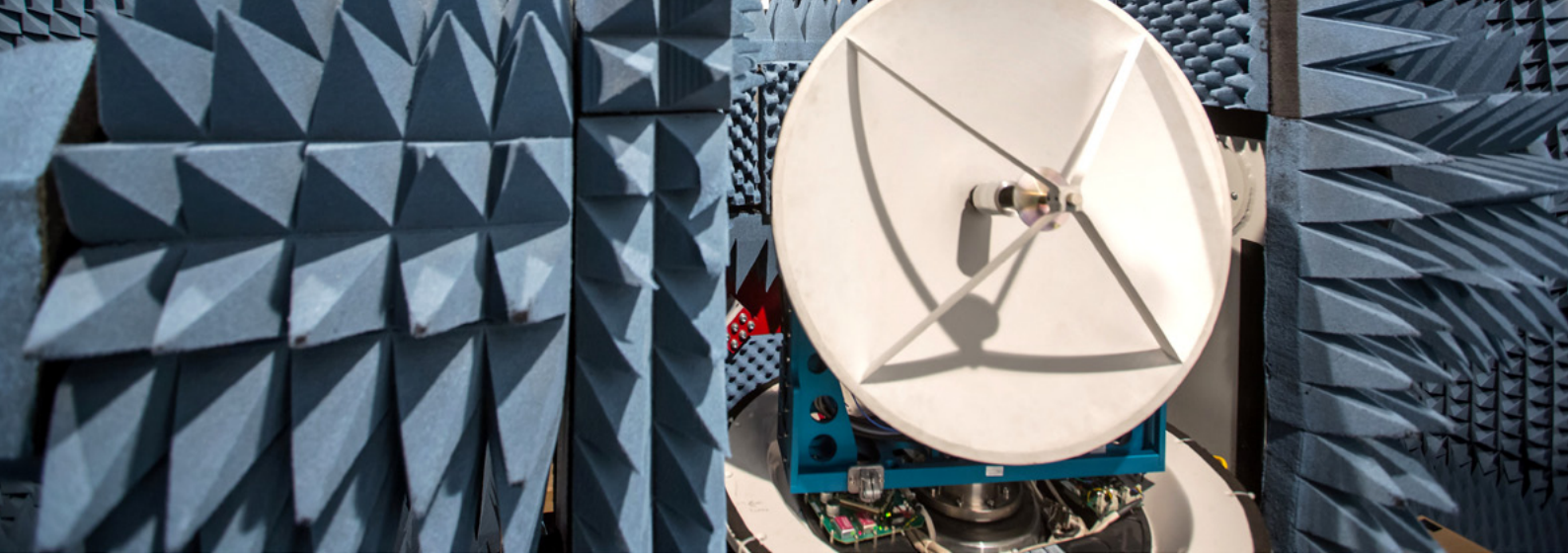
- Structural, chemical, physical, electrical analysis of functional layers and materials
- Nanoscale material characterization
- Characterization of BEoL structures (interconnects) and of TSVs, microbumps etc.
- Simulation and reliability models at the wafer level
- Service life prediction models

The following investigations take place at the device, MOEMS, and smart systems level:

- Modeling of the function and the deployment behavior
- Electrical characterization of devices
- Destructive and non-destructive testing of the functions and superstructures of devices and systems
- Characterization of heterogeneous smart systems
- Evaluation of SoC packages

With regard to system-related reliability testing, other testing, and service life analysis, the focus is on:

- Non-destructive testing methods for quality control (inline-capable, high-resolution, fast)
- Material characterizations for time-dependent processes, provision of simulation-compatible material models
- Self-diagnostic capability of electronics
- In-situ monitoring during testing (electrical, mechanical, visual)
- Simulation-supported design for manufacturing, design for testability and design for reliability, DfX
- New evaluation approaches for embedded electronics, structure-integrated sensoring
- Characterization of materials for bio- and chemical sensoring
- Service life prediction models for design engineering
- Combined stress tests Monitoring of test equipment for assured process stability



# RF AND COMMUNICATION TECHNOLOGIES

Information and communication technologies are changing our society significantly in many areas of life and work. As the largest innovation engine in Germany, key technologies of this kind form the basis for new products, processes, and services. Embedded systems comprising hardware and software components are, for example, decisive when it comes to the successes of the strong European sectors of automobile construction and mechanical engineering, energy technology, medical engineering, and safety and security technology.

The networking of the member institutes of the Fraunhofer Group for Microelectronics covers both hardware and software aspects. With the cross-institute technology platform "RF and Communication Technologies" for wireless network solutions, the Group for Microelectronics is pursuing the aim of countering today's heavy, sometimes even extreme, dependency on external suppliers. The shared thematic focuses cover:

- Algorithms for broadband communication (physical layer)
- Broadband communication (upper protocol layers)
- Localization and navigation
- Digital broadcasting
- Adaptive and cognitive transmission technologies
- Radar systems
- Microelectronically realized components (e.g. AD/DA, RF, power amps)
- Broadband signal processing
- Media technologies
- Networking of embedded systems (fields of application: automotive, industry)
- Satellite Communication

At the same time, a range of development aims for highly specialized niche markets are being pursued:

- Cross-layer real-time-capable test beds for LTE applications
- Application-specific extension to the LTE standard (machine type comms)
- Special telemetry (point-to-point/network, long-range, low-power, high data rate)
- Special telemetry (long-range, low-power system solutions for communication in special application fields (Smart Grid, Car2X))
- Platforms for high-rate signal processing
- Broadband networking of embedded systems (including automotive Ethernet/IP)
- SDR-based cognitive radio demonstrators

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