In 2016 we once again received fresh impetus and new ideas from our doctoral candidates, of whom there are now nearly 20. Their work reflects Fraunhofer EMFT’s broad portfolio, with dissertation topics including sensor-controlled micro dosing systems, novel circuit design for energy-efficient high-performance chips, printed sensors on foil and color change sensors for food analysis.

In addition to this, I am pleased we have been able to gain the services of Prof. Marc Tornow as the new division director in area of Silicon Technologies and Devices, thereby intensifying our links with TU Munich. Prof. Tornow holds the Professorship for Molecular Electronics there, his work being mainly focused on nanoscale components in molecular electronics and biosensors.

Last but not least, the scientific excellence of our Analysis & Test group once again received international recognition and a grant from the 2016 Educational Research Council of the American ESD Association Inc. promoting outstanding industry-related research in the area of electrostatic discharge.

Dear reader, all that remains is for me to hope that you enjoy reading our fascinating 2016 annual report.

Best regards,

Prof. Christoph Kutter
Director of Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT
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FRAUNHOFER EMFT

HISTORY

PROFILE

THE INSTITUTION IN FIGURES

ADVISORY BOARD
The following infrastructure is available on the premises of Fraunhofer EMFT at Hansastrasse 27d:

- Class 10/100 cleanroom and gray room (866 m²)
- Class 1000 cleanroom and higher (121 m²)
- Laboratories: (1477 m²)
- Office areas and meeting rooms: (1852 m²)

In Regensburg, Fraunhofer EMFT rents offices and labs at Biopark opposite the University of Regensburg. Staff also use the labs at the University of Regensburg itself. This ensures close professional dialog.

Fraunhofer EMFT’s most important asset is its highly-qualified staff. The institution trains young scientists working on bachelor’s, master’s and doctoral assignments and attaches great importance to the ongoing professional development of its permanent employees. Due to the institution’s long history, the Fraunhofer EMFT team has a very broad background and experience as well as excellent familiarity with the world of microelectronics and microsystem technology. The staff’s high level of motivation and the satisfaction they derive from their work results in exceptional commitment and dedication, ultimately producing good results.

The following infrastructure is available on the premises of Fraunhofer EMFT at Hansastrasse 27d:

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- Class 1000 cleanroom and higher (121 m²)
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The Fraunhofer EMFT labs are fitted for a range of different research purposes (biology lab, chemistry lab, electronics lab, etc.).

In order to ensure efficient use of capacity, Fraunhofer EMFT also hires out its labs, cleanrooms and office spaces to industrial companies. This generally happens as part of cooperation contracts or on joint projects. The aim is also to strengthen strategic partnerships and facilitate intense professional dialog.
The Fraunhofer EMFT Advisory Board is a consultative and supervisory body. It consists of a number of distinguished representatives from the areas of science and business. Members of the Advisory Board advise the Fraunhofer EMFT management and board on issues relating to the specialist orientation and structural development of the institution.

Chair:
Dr. Hans-Jürgen Bigus
Hirschmann Laborgeräte
GmbH & Co. KG

Deputy chair:
Prof. Dr. phil. Merith Niehuss,
Universität der Bundeswehr
München

Member:
Dr. Reinhard Fojt
KETEK GmbH

Member:
Prof. Dr. phil. Merith Niehuss,
Universität der Bundeswehr
München

Member:
Dr. Thomas Scheiter
Siemens AG,
Corporate Technology

Member:
Prof. Dr. rer. nat.
Doris Schmitt-Landsiedel
Technische Universität München

Member:
Dr. Peter Wawer
Infineon Technologies AG

Member:
Dr. Stefan Wimbauer
Bayerisches Staatsministerium
für Wirtschaft und Medien, Energie und Technologie, München

Member:
Prof. Dr.-Ing. habil. Dr. h.c. mult.
Ulrich L. Rohde
Synergy Microwave Europe
GmbH & Co. KG
BUSINESS AREAS

SENSOR MATERIALS

SILICON TECHNOLOGIES AND DEVICES

MICRO DOSING SYSTEMS

FLEXIBLE SYSTEMS

CIRCUITS & SYSTEMS

Sensor materials for combined in-line measurements
At Fraunhofer EMFT, sensor materials are developed for the areas of medicine and hygiene, environmental monitoring, food production and occupational safety. The focus is on solutions which deliver results quickly and reliably and make do with simple, mobile analysis devices. Together with other Fraunhofer EMFT technologies this business area works to enable the development of novel sensor systems.

Researchers in the Sensor Materials business area develop new materials that indicate the presence of certain substances by changing their optical or electrical properties. Integration of such sensor materials in particles, polymers, foils or textiles combined with the relevant analysis systems opens up a range of applications including early diagnosis of certain illnesses, effective occupational safety measures in lab environments or quality control of food, drinking water and production processes.

For applications in the area of gas sensorics, systems are being created based on materials that show optical changes (absorption or emission spectrum) or electrical changes on contact with the analyte. For example in a project where the quality of foodstuff containing oils or fats is to be monitored, the solution principle is based on the measurement of volatile aldehydes such as hexanal by means of sensor materials that make use of color changes. These materials provide the basis for intelligent packaging in packaging foils or in closure seals for bottles. The end consumer is thus given reliable feedback on quality changes in products containing oil and fat, since these perish due to oxidation. But the insights gained are also used as a basis on which to develop sensor systems for other types of food (e.g. meat, fish, ready-made products) and will be fed into the area of sensor technology, too.

For applications in the area of hygiene, fluorescence-based sensor materials and detection methods are developed for selective bacteria detection. In combination with the relevant analysis systems, it is possible to selectively detect living bacteria very quickly. This type of system can contribute to improving hygiene measures. In a current research project, Fraunhofer EMFT is collaborating with Asklepios Kliniken GmbH and KETEK GmbH to develop a fast on-site method to detect the methicillin-resistant pathogen Staphylococcus aureus (MRSA). The goal is to use the system for access control at hospitals. The specific detection strategy that distinguishes the MRSA from other bacteria was developed in the Sensor Materials business area, but researchers from a number of different Fraunhofer EMFT business areas work on creating the system as a whole, involving different areas of expertise. The Sensor Materials business area will continue to develop other detection strategies for specific bacteria in the future. Other potential areas of use for this type of system are food production or water analytics, for example.

Sensor materials are well-suited for combination with other Fraunhofer EMFT technologies, offering the possibility of selective development of complex sensor systems for integration of the materials in existing production processes and adaptation to user and customer requirements.

The business area is currently focusing on the following areas of application and customer groups:

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Packaging industry</td>
<td>Food safety</td>
</tr>
<tr>
<td>Food industry</td>
<td></td>
</tr>
<tr>
<td>Hospitals</td>
<td>Hygiene</td>
</tr>
<tr>
<td>Appliance manufacturers</td>
<td></td>
</tr>
<tr>
<td>Textile industry</td>
<td></td>
</tr>
<tr>
<td>Chemical industry</td>
<td>Civil security and occupational safety</td>
</tr>
<tr>
<td>Environmental industry</td>
<td>Water quality</td>
</tr>
</tbody>
</table>

Current projects in this business area concentrate on the following R&D focus areas:

- Development of new methods and materials for gas detection
- Development of new methods and materials for ion detection
- Development of new methods and materials for the detection of neutral molecules
- Development of new methods and materials for the detection of bacteria
- Integration of new methods and materials in entire sensor systems

In the Sensor Materials business area, intensive preparatory research is being carried out in R&D projects so as to advance the focus topics and extend partnerships.
SILICON TECHNOLOGIES AND DEVICES

This business area targets the development of new types of sensors for parameters not yet addressed by the market, with the potential of opening up whole new markets. Fraunhofer EMFT also offers its customers a wide range of different services in the field of silicon technologies, such as process development, mini series production of sensors and actuators, and the qualification of process media and individual processes.

Sensors and actuators will play an increasingly important role in our society in future. Current themes such as the “Internet of Things” and “Industry 4.0” bear out this trend. There are already sophisticated solutions available to measure most physical parameters; here markets can only be penetrated by means of novel concepts. These are mainly to be expected in the area of MEMS and NEMS components or by combining conventional silicon technology with novel material systems. The situation in the field of chemical sensorics is rather different. Gases and fluids can be analyzed very precisely by determining their physical properties, but the measuring systems used tend to be excessively large and expensive. What is more, measuring is disrupted due to chemical reactions caused by the cross-sensitivities that occur. So there is considerable demand for the development of low-cost transducers that convert chemical reactions into electrical signals.

Due to the complexity of the molecules, the measurement of biological substances and parameters poses an even greater challenge. For this reason, medical technology often uses indirect detection of illness symptoms (e.g. respiratory gas analysis) which can be covered by chemical sensors.

Extremely low-noise electronics is a niche market which is much too small for most companies operating globally. Low-noise field-effect transistors are not supplied by industry at all, for example. Fraunhofer EMFT has gathered extensive expertise in this field and its technology line can handle the volumes required for this niche market.

There is great interest on the part of industry in the topics addressed by this business area, in terms of both individual processes and components. In recent years there has also been a considerable increase in the number of companies seeking to engage in long-term research and development collaboration.

The business area focusses on two market areas with the following offerings:

**Services and components**
- Process development
- Process qualification
- Prototype manufacture of sensors and actuators

**Microsystems and applications**
- Sensor systems for physical parameters
- Sensor systems for chemical/biological parameters
- Low-noise electronics

The microsystems developed at Fraunhofer EMFT are used in numerous applications and sectors, including material analysis (e.g. characterization of semiconductor materials), process analytics (e.g. quality analysis of process gases, novel purification methods), environmental analytics (e.g. room climate control), medical technology (e.g. identification of multi-drug-resistant pathogens in hospitals), telecommunications (e.g. MEMS microphone) and industrial electronics (e.g. coating sensors for cleaning processes). The business area’s most important customers include both large-scale clients and SMEs.

The R&D services offered by the business area in its current projects include the following:
- Process development and optimization for front-end and back-end processes
- Technological support in the production of radiation detectors
- MEMS back-end processing of product batches for IR sensors
- Prototyping of MEMS micropumps (together with the business area Micro Dosing Systems)
- Prototyping of MEMS acceleration sensors and potentiometric sensors
- Development and production prototyping of low-noise components (diodes, JFET, MOSFET)
- Development of 3D sensor structures
- Test structures for 2D materials
- Development of fluorescence sensorics (together with the business areas Sensor Materials and Circuits & Systems)
- Development of chemical sensorics (together with the business areas Sensor Materials and Circuits & Systems)
- Development of radiation sensorics (together with the business area Circuits & Systems)

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- Development of 3D sensor structures
- Test structures for 2D materials
- Development of fluorescence sensorics (together with the business areas Sensor Materials and Circuits & Systems)
- Development of chemical sensorics (together with the business areas Sensor Materials and Circuits & Systems)
- Development of radiation sensorics (together with the business area Circuits & Systems)
In the business area Micro Dosing Systems, individually tailored microdosing solutions are developed for the most diverse applications – from the conception of components and systems through to component development and realization of entire microdosing systems, as well as their transfer to products with industrial capability.

Robust, precise and yet miniaturized microdosing systems offer considerable application potential: in the area of medication dosage, externally portable micro dosing systems could be used in such areas as pain therapy, treatment of tinnitus, hormone therapy, tumor therapy and diabetes therapy. In the field of mechanical engineering and plant construction, micro lubrication systems will make it possible to apply tiny quantities of lubrication oil to bearings, thereby saving 98% of lubricant consumption. All these applications require precise dosage of the minutest quantities. At the same time, the dosage components used have to be very low-cost.

Microdosing technology is an interface technology: expertise is required in the area of fluid mechanics, elastomechanics, electrical engineering, surface physics, chemistry and phase transformation. These areas are not isolated, however: they interact with each other. So it is important to understand the causal relations between them and the system response.

Meanwhile, there is a range of other interesting challenges in the field of microdosing: these include the management of bubbles, particles and back pressure, monitoring the dosage of minute quantities and also chemical resilience. Fraunhofer EMFT works on all these issues so as to be able to develop robust products on behalf of and in collaboration with its customers.

This interface technology offers industrial customers and end users a wide range of benefits, including the following:

- Precise dosage
- The capacity to monitor dosage
- Low level of material consumption
- Low level of energy consumption
- Miniaturization
- Lower cost, making the technology suitable for mobile devices and disposable applications in medicine
- Lower weight
- Improved mobility
- Simpler integration

R&D activities in this business area are currently focusing on the following customer groups and applications:

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mobile phone manufacturers System manufacturers MEMS fabs</td>
<td>Micropumps in mobile devices</td>
</tr>
<tr>
<td>Mechanical engineering</td>
<td>Lubrication dosage</td>
</tr>
<tr>
<td>Medical technology</td>
<td>Medication dosage, Glaucoma therapy, Sphincters, Wound healing</td>
</tr>
<tr>
<td>Lab technology</td>
<td>Air displacement pipette, Microtiter plate dosage</td>
</tr>
<tr>
<td>Other</td>
<td>Scent dosage, Micro fuel cells, Tissue engineering</td>
</tr>
</tbody>
</table>

The R&D services in this business area are as follows:

- Solving industrial problems in the area of microdosing and consultation of industry clients
- Design of microdosing systems taking into account disturbance variables
- Design of microdosing components such as micropumps, microvalves, free flow stop, bubble separators, dosage monitoring
- Validated library of design tools for microdosing systems and components
- Provision of a 6-inch silicon development platform in the cleanroom
- Provision of a metal development platform (in cooperation with partners)
- Development of production-capable back-end processes (e.g. piezo assembly, fluidic wafer testing device for micro pumps)
- Realization of components on the development platforms (silicon, metal or plastic)
- System development of microdosing systems incl. control and regulation
- Realization of customer-specific prototypes (components and systems)
- Consultation and support in realizing an industrial manufacturing chain for microdosing systems
- Licensing, expertise and technology transfer
The business area Flexible Systems produces ultrathin components, sensors and integrated circuits and incorporates these in entire systems on foil. The development portfolio ranges from large-area, flexible wiring systems, three-dimensional assembly and connection technologies through to printed circuits and systems.

There is an obvious development in electronics towards increasingly flat and flexible systems. As compared to the overall market for electronic systems, the market for foil-based electronic solutions is a niche for special applications where the specific properties of foil electronics offer crucial benefits. The main factors here are the extremely low installation height, the flexibility of the system with very small curvature radii and the feasibility of large-area systems with unconventional form factors. In principle, the foil substrate also allows transition to very low-cost roll-to-roll production, even though the cost argument for current R&D projects is not a high priority.

In the mid-term, another crucial driving force behind developments in the business area Flexible Systems will be the Internet of Things (IoT) with its demand for largely energy-autonomous, wirelessly networked and increasingly low-cost sensor systems.

The particular strengths of Fraunhofer EMFT in this business area are as follows:

- Assembly and interconnection technology for foil systems
- Combination of foil/thin silicon
- Production-oriented hybrid integration on foils
- Ultra fine conductor technology on foil (density, HF)
- Electrostatic carrier techniques: E-carrier (temporary attachment without glue)
- Production development using the roll-to-roll method

Flexible systems are applied wherever flat, flexible, bendable and/or large-area electric systems are required; they are aimed at a wide range of different industries, very often far removed from the electronics field. The business area is currently working on projects for the following groups of customers:

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Security modules</td>
<td>Manipulation detection, Encryption, Chip cards</td>
</tr>
<tr>
<td>Medical technology</td>
<td>Point-of-care diagnostics (lab-on-foil, DNA analysis)</td>
</tr>
<tr>
<td>Industry</td>
<td>Plant and process monitoring (condition monitoring)</td>
</tr>
<tr>
<td>Consumer goods</td>
<td>Printed sensors, Low-cost electronics for consumer products</td>
</tr>
<tr>
<td>Mobile and wearable</td>
<td>Extremely flat electronics, Sensitive surfaces, Robotics</td>
</tr>
<tr>
<td>Measuring technology</td>
<td>Special flat casings (foil casings)</td>
</tr>
<tr>
<td>Electronic components</td>
<td></td>
</tr>
<tr>
<td>Semiconductor industry</td>
<td>Thin wafer handling</td>
</tr>
<tr>
<td>Printed circuit board industry</td>
<td>Processing of foil sheets (ultra thin circuit carriers)</td>
</tr>
<tr>
<td>Flexible printed</td>
<td></td>
</tr>
<tr>
<td>Special ceramics</td>
<td>Handling of fragile substrates</td>
</tr>
</tbody>
</table>

The business area’s main customers currently include large corporations and SMEs.

R&D services provided by Fraunhofer EMFT on current projects are as follows:

- Foil technology, ultra fine conductive technology/ HF lines, assembly and interconnection technology for foil systems
- Material analysis, FEM simulation of the bending and breakage response of thin components
- Development of individual components, demonstrator, small-series production
- Components with differing form factor, integration in utility objects
- Integration of thin ICs, wireless communication interface
- Handling techniques and systems for thin substrates
- Technology consultation and studies
The business area offers individually tailored solutions and services, ranging from the development of integrated and discretely assembled circuitry through to complete modules and systems as well as firmware and software. In addition to this, sophisticated multiparametric characterizations and reliability assessments are carried out as relevant to the application in question as well as special error mechanisms (robustness).

The business area comprises the three subareas “IC Design”, “System Integration” and “Test and Analysis”, which build on one another and complement each other. The primary aim of activities is to integrate Fraunhofer EMFT sensors and actuators with commercial and customer-specific integrated circuits so as to create prototypes and mini series of systems for verification. This facilitates the interface with commercial value creation chains in microsystems engineering and facilitating market entry. The combination of established commercial technologies with innovative Fraunhofer EMFT solutions enables the development of USPs within market-oriented time-frames without taking on undue risks.

Market research institutes agree that the market for electronics – in particular integrated circuits – will continue to grow, and this is something the business area will benefit from. Based on the high growth rates projected for semiconductor elements and electronics, the market for system development and integration is also set to expand. Fraunhofer institutes such as Fraunhofer EMFT are able to draw on the benefits of their excellent technical and technological facilities as well as their interdisciplinary environment.

Safety-related applications, building and industry automation (Industry 4.0) and the medical field require a high degree of reliability as well as interference and manipulation resilience, even in difficult conditions. Manipulation security of electronic systems is becoming increasingly important in the digitized world since chips and electronic components are easy prey for product counterfeiters and industrial spies nowadays. In addition to other error sources, electrostatic discharge (ESD) interferes with integrated circuits and sensors during production, integration in the module and in the application itself, or can cause temporary disturbance. Electronic assistance systems and the trend towards autonomous or partially autonomous driving requires increased fail safety vis-à-vis intrinsic and extrinsic influences. By focusing on the ESD robustness of integrated circuits and systems, Fraunhofer EMFT has successfully occupied a niche for metrological evaluation in technology threshold areas.

The business area’s R&D services are used by customers from a range of different sectors:

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>System manufacturers and suppliers</td>
<td>Medical technology</td>
</tr>
<tr>
<td>Design companies</td>
<td>Diagnostics</td>
</tr>
<tr>
<td>Component manufacturers</td>
<td>Aerospace</td>
</tr>
<tr>
<td>Semiconductor manufacturers</td>
<td>Industrial sensors and actuators</td>
</tr>
<tr>
<td>Contract manufacturers</td>
<td>Automotive</td>
</tr>
<tr>
<td>Testing facilities/ analysis labs</td>
<td>Test engineering</td>
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<tr>
<td>Internal clients</td>
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The business area’s main customers include both large corporations and SMEs, some of them leaders in their field.

The R&D activities in this business area are as follows:

- Development of integrated circuits and circuit blocks (IP): concept, circuit topology, development, layout, pre/ post-layout verification, test and validation
- Development of entire concentrated and distributed systems or subsystems (sensorics, actuator technology) also with wireless communication
- Development and evaluation of multiparametric, mainly electrical test concepts (focusing on ESD and high frequency technology)
- Development of ESD protection structures and concepts for integrated circuits and systems
- Customer-specific systems for ESD and reliability tests
- Analysis of the causes of complex errors and reliability problems of electronic components and systems (robustness)
COMPETENCES

FUNCTIONAL MOLECULES

SILICON TECHNOLOGIES, DEVICES AND 3D INTEGRATION

MICROPUMPS

FOIL TECHNOLOGIES

DESIGN, TEST & SYSTEM INTEGRATION

Foil package for thin and bendable MEMS pressure sensor strip
Fraunhofer EMFT clusters its research and development activities into five competences which meaningfully complement each other at their interfaces. Interdisciplinary collaboration between all five areas gives rise to novel sensor actuator solutions. In this way, Fraunhofer EMFT expertise feeds into the entire value creation chain – “from the molecule to the system”.

Functional Molecules

The competence Functional Molecules – in the business area Sensor Materials – permits selective synthesis of indicator molecules which react to different analytes in the environment by changing their properties. For this purpose, Fraunhofer EMFT scientists apply the relevant receptor groups to the sensor molecules, and these react selectively and sensitively with defined analytes. This reaction changes the properties of the sensor molecules, either producing a different color or fluorescence or else resulting in a change in the electrical parameters. The best detection method is selected depending on the concrete requirements of the application (electrical or visual) and the sensor molecule is adapted to the target analyte. For integration in sensor systems, these are embedded either in polymer materials or else in microparticles/nanoparticles. In this way it is possible to develop new types of sensor materials.

The competence covers the following research focus areas:
- Synthesis of sensor molecules for analyte detection
- Development of sensor polymers and sensor particles for analyte detection
- Development of detection strategies (assays) and methods for bacteria detection
- Integration of sensor materials/strategies/methods in systems

A look ahead

The unique position of the competence Functional Molecules is to be strengthened by the successful transfer of new research topics to applications. This will enable Fraunhofer EMFT to gain a leading edge that will establish it as a contact partner for material development in connection with new kinds of sensors.

The competence is to be extended by developing new materials for the detection of amines, carbon monoxide and cyanides as well as new strategies and methods for bacteria detection.

Silicon Technologies, Devices and 3D Integration

In future, sensor systems will be used more and more frequently in applications with particularly demanding requirements in terms of size, performance capacity and reliability. Extensive expertise is imperative in the field of silicon technologies so as to enable the research, development and manufacture of sensor and actuator components and in order to be able to provide services in this field. Silicon technologies are an area of expertise at Fraunhofer EMFT, allowing research and development relating to novel sensor and actuator concepts.

The competence covers the following technology areas:

Individual process and analytics
- CMOS technology
- MEMS technology
- Wafer thinning technology (together with the business area Flexible Systems)
- Integration of new materials and processes
- Characterization of materials and processes

Epitaxy and low-temperature processes are Fraunhofer EMFT USPs in this area:
- Epitaxy with silicon and germanium allows the manufacture of novel components and sensors, especially in nanoscale area
- Using low-temperature processes, plasma-supported epitaxy allows entire sensor components to be integrated on pre-structured CMOS wafers at temperatures <450°C
- In the area of analytics, the characterization of defects in silicon offers the unique opportunity to characterize components entirely based on their noise response and also analyze the causes

Components
- Simulation
- Layout
- Process integration and test

The development and manufacture of low-noise transistors are USPs of Fraunhofer EMFT. The institution possesses both the technological and the metrological expertise for JFETs, MOSFETs, diodes and sensors and this is used intensively for industry contracts.

Microsystem integration
- Add-on technologies
- Heterogeneous 3D integration

3D integration with tungsten-filled TSVs (Through Silicon Vias) has been applied successfully in research projects for many years.

A look ahead

The following strategic projects are already in progress and aim to establish new application fields for sensor and actuator technology in the coming years:
- Manufacture and test structures for 2D semiconductor materials (chalcogenides). These are expected to produce promising results in the area of biological sensors in particular
- Heterogeneous system integration of active components (e.g. optical sensors) on ready-processed CMOS wafers using low-temperature processes where the process temperatures do not exceed 450°C
- Novel sensor concepts based on nanogap structures
- Verified reliability of sensor and actuator components using specific test procedures
**COMPETENCES**

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**Micropumps**

Piezo-electrically powered micropumps are at the heart of microdosing systems. However, the technology requirements such as dosage precision, counter-pressure resistance, small size, low energy consumption, particle resistance, bubble tolerance and free flow protection require a series of technical solutions. The Fraunhofer EMFT team has longstanding experience in this area and has amassed substantial practical knowledge in the design of micropumps in particular.

Given the combination of design expertise and technology platforms (silicon, metal, plastic), there is currently no other development team in the world that is able to offer industry clients the same breadth of solutions for microdosing systems. The institution’s understanding of the requirements of industrial applications – the result of two decades of talking to industrial clients – enhances added value for the partner. The many disturbance variables are also well understood and in some cases have already been addressed, so new industry customers are able to benefit from the many lessons learned by the Micropumps competence. The competence also offers a good IP portfolio including key patents, some of which are by the Micropumps competence. The competence also offers customers the same breadth of solutions for microdosing systems. However, the technology requirements do not permit standardized handling. One potential solution to this problem is to combine capabilities in the area of thin silicon and foil technology: this allows realization of an IC with the appropriate assembly and interconnection techniques. Another central area of expertise for system integration on foils is the ability to produce and process ultra thin silicon ICs. Experience of development in the area of organic electronics to date suggests that this is the only way to realize electronic functions for flexible foil systems with the level of performance capacity that is necessary (and expected by customers). Fraunhofer EMFT therefore has a unique modular combination of various solid state technologies at its disposal.

The competence covers the following technology areas:

- Design of micropumps
  - Design methodology incl. influence of practical disturbance variables
  - Extensive libraries of analytical models, FEM models
  - System simulation

- Established technology platforms for low-risk implementation
  - Silicon development platform
  - Metal development platform
  - Assembly platform for piezo ceramics incl. parallel test integration of micropumps in systems

- Integration of micropumps in systems
  - Library of electronic activation systems
  - Broad range of flow sensors and dosage monitoring systems
  - Particles and bubble management

**A look ahead**

The main focus of the competence is on further miniaturization of silicon micropumps, which could significantly reduce manufacturing costs.

The first successful step was taken in 2015: miniaturization of the pump chip from 7 x 7 mm² to 5 x 5 mm². Further miniaturization to 3 x 3 mm² is currently being implemented. This is a necessary requirement in order to be able to produce micropumps in large volumes for mass applications.

In the area of metal micropumps, the main focus is the design of microdosing components, involving cooperation with industry partners who will manufacture the components themselves in high volumes subsequent to technology transfer. In future – as has been the case up to now – work in this area consistently aims to increase tolerance to particles and bubbles as well as further enhancing the quality and reliability of the micropumps.

**Foil Technologies**

The basis for the business area Flexible Systems is provided by the competence Foil Technologies. This includes both coating and structuring processes to produce electronic components in the specific conditions of the foil substrate as well as system integration with the appropriate assembly and interconnection techniques. Another central area of expertise for system integration on foils is the ability to produce and process ultra thin silicon ICs. Experience of development in the area of organic electronics to date suggests that this is the only way to realize electronic functions for flexible foil systems with the level of performance capacity that is necessary (and expected by customers). Fraunhofer EMFT therefore has a unique modular combination of various solid state technologies at its disposal.

The competence covers the following technology areas:

- Foil coating and structuring
  - Screen printing
  - Metallization (sputtering)
  - Photolithography
  - Etching techniques, plasma processing
  - Laser structuring
  - Ultra fine conductor manufacturing
  - Functional layers
  - Roll-to-roll processing

- Ultra thin silicon
  - Thinning techniques (grinding, spin etching, CMP polishing)
  - Separation (plasma dicing)
  - Handling techniques

- Hybrid foil integration
  - Chip-in-foil
  - Flat-to-flat
  - Modular systems, foil interposers

- Substrate handling
  - Reversible adhesive and bonding techniques
  - Electrostatic handling and carrier techniques

**A look ahead**

The obstacle to broader marketing of the technology field of ultra thin silicon is currently still the fact that users face high demands when further processing the thin ICs since these do not permit standardized handling. One potential solution to this problem is to combine capabilities in the area of thin silicon and foil technology: this allows realization of an IC packaged in foil and rewired, without abandoning the benefits of low mounting height and flexibility. Preparatory development has already led to excellent results and demonstrates here, and these are being used increasingly in industrial contract R&D.

The aim in future is not just to offer and manufacture a customer-specific foil casing but also to make an established roll-to-roll process for high-volume production available and transfer this to a commercial provider.
In realizing systems based on microsystems engineering, Fraunhofer EMFT provides its customers with extensive know-how along the entire value creation chain – from the initial design through to the finished system. Here, commercially available components can be flexibly combined with third-party circuit blocks and Fraunhofer EMFT’s own technologies. In this way, state-of-the-art microsystems are created that are specifically geared towards customer requirements and can then be credibly validated using suitable testing methods.

Development expertise includes IC design, hardware and software, electronics, mechanics, optics, testing and analysis, forming the basis for the range of services provided by the business area Circuits & Systems. This expertise is also crucial to other business areas, which benefit from the design of individually tailored ASICs, the creation of system demonstrators and the extensive testing and analysis facilities available in this area.

The competence area has achieved a unique international standing in its testing and improvement of the robustness of microelectronic systems and components to electrostatic discharge (ESD).

Capabilties, processes and technologies
- Definition and development of integrated circuit blocks (IP) and ASICs in low-power and high-voltage-capable mixed-signal technologies
- Circuit development in the area of sensorics and sensor networks
- Programming of microcontrollers and PC software
- Simulation, design, characterization, reliability
- Prototype manufacture
- Testing methods and systems, calibration
- Reliability studies
- ESD protection concepts and libraries
- ESD test methods and services, failure reproduction
- Generation and measurement of high-current impulses with ps accuracy
- High-frequency characterization of materials, components and systems
- Failure analyses and assessments of value creation chains

A look ahead

Circuit design
The capacity for fully-fledged circuit design using professional tools, covering the entire process from the system concept through to individual verified integrated circuit blocks (IP) in highly advanced mixed signal technologies including complete ASICs will be a universal key competence for the efficient realization of sensor/actuator nodes with high-frequency interfaces. The focus is on designing circuit blocks and complete ASICs and SoCs (systems on chip) for very high frequencies, low-noise amplifiers, power amplifiers and AD converters. Specialist expertise relating to high-voltage circuits will be used in numerous actuator and MEMS applications in future.

System integration
Here, application prototypes are to be realized in the areas of sensorics and sensor networks. Sensor elements developed at Fraunhofer EMFT will be used for this purpose as well as commercial sensors.

Analysis and testing
In addition to the development of pad cells and integrated ESD protection concepts, the CC-TLP method developed at Fraunhofer EMFT has enormous long-term potential to become the standard, replacing the load required for component qualification according to the Charged Device Model CDM.
The Oberpfaffenhofen Training & Analytics Center, which previously belonged to Fraunhofer IZM in Berlin, was integrated in Fraunhofer EMFT as of January 1, 2017. The new group’s expertise perfectly supplements the Fraunhofer EMFT portfolio.

The 10-strong team that has now joined the Munich research institution is made up of experienced experts in the areas of interconnect systems, mechanical connection technology, analytics and reliability. Based in Weßling/Oberpfaffenhofen, they focus on on-board connection technology in the areas of automotive, aerospace and plant engineering – industrial sectors that are heavily represented in the region and currently face the wide-ranging technological challenges of digitization (Industry 4.0). With this reinforcement from Oberpfaffenhofen, Fraunhofer EMFT is now in a better position to shape the trend of digitization in collaboration with industry users and customers.

Valuable synergies are available for developing innovative solutions, in particular with the Fraunhofer EMFT business areas Flexible Systems and Circuits & Systems. Thinned sensors and ICs on foil can be integrated in a connector housing, for example, so as to monitor degradations of the electrical contact and aging of the plastic housing. Another example is that of the new measuring and analysis techniques used to describe the reliability of on-board technology components as used in autonomous vehicles.

In addition to their research activities, the group in Oberpfaffenhofen runs a training center for electrical connection technology which is highly valued by industry. The focus here is on professional development for QS coordinators, specialists and manual workers. The Fraunhofer-Gesellschaft supported training activities by providing two practical lab programs – “Crimping for industry” and “Wiring harness finishing”.

The development and adaptation or optimization of cell-based sensors and/or assays was added to the Fraunhofer EMFT portfolio as of January 1, 2017. The team at the Fraunhofer EMFT site in Regensburg offers consultation as to suitable detection principles, selection of materials and their functionalization and integration in individual testing environments, including data analysis and feasibility studies for special assay formats and technologies.

Experimental tests on living human and animal cells (cell-based assays) have a key role to play in all areas of both basic and applied biomedical research. Isolated from various organs and tissues of the body and cultivated in the lab, the cells allow experiments to be carried out on living model systems on a high throughput basis without having to perform tests on animals.

In the area of cell-based sensors, physical signal converters such as metal or polymer electrodes are developed on which the cells can grow so that their reaction to an experimental stimulus (chemicals, pharmaceuticals, microorganisms) can be traced in a non-invasive manner and without the use of additional reagents (label-free). The physical principles used for measurement purposes and the materials are selected in such a way that there is no impact on the cells during measurement. The individual signal converters are integrated singly or in combination in the cell culture vessel, thereby allowing the cells to be observed without contact and with an individually adapted temporal resolution ranging from milliseconds to days.

The areas of application of these cell-based sensors are highly varied, ranging from fundamental issues of medical technology to active agent development, toxicity testing and regenerative medicine. They enable a very wide range of parameters of cell physiology to be measured under the influence of an external stimulus, including vitality, speed of cell division, speed of cell migration and changes in cell volume.
FROM RESEARCH AND DEVELOPMENT

EXAMPLES OF PROJECTS AND APPLICATIONS

Reliability testing of thin chip foil packages
Fraunhofer EMFT is involved in various projects, collaborating with organizations in science and industry to develop future-oriented solutions aimed at tackling some of the important challenges that face society today.

**3D integration technologies for IoT applications**

The trend towards the Internet of Things (IoT) makes heterogeneous 3D integration a key technology but also involves challenges in terms of the relevant process technologies, such as wafer bonding: the enormous pressure of competition in the area of IoT applications means that the systems have to be increasingly smaller but at the same time more capable and robust, too. In order to meet these demands, Fraunhofer EMFT signed a license agreement with Invensas Corp. in September so as to be able to incorporate ZiBond® and DBI® (Direct Bond Interconnect) in its portfolio - two of the most cutting-edge 3D integration technologies.

Both processes can be carried out at relatively low temperatures of approx. 200 °C, which impacts positively on component reliability and durability. DBI® technology involves the components being both mechanically and electrically connected after special preparatory treatment of the copper and oxide surfaces used. Since this avoids the elaborate process of through-connecting chips, the systems can be produced more cost-effectively – a basic requirement for access to mass markets such as consumer electronics. Another advantage: the “pitches” (structural width and spacing) between the connections are at best reduced to just 2 µm. This enables very highly integrated systems-on-chips with enormous performance capacity.

**Compact and energy-efficient power semiconductors**

In the EU project WAYTOGOFAST (Which Architecture Yields Two Other Generations Of Fully Depleted Advanced Substrates and Technologies) the aim is to develop improved chips based on FDSOI technology (Fully Depleted Silicon On Insulator), thereby laying the foundation for establishing an energy-efficient, future-oriented communication infrastructure. Here, the semiconductor manufacturer STMicroelectronics coordinates the research and development activities of the 33 project partners from research and industry.

Fraunhofer EMFT contributes its expertise in the simulation, design and measurement of analog, mixed-signal and millimeter wave circuits: the research team is developing innovative RF/mm wave circuitry in the 77 GHz range using novel 14-nm FDSOI CMOS technology. This permits the design of highly integrated, energy-saving circuits. The aim is to use the results to confirm the required performance capacity for RF applications as well as for automotive radar and terahertz telecommunications. Fraunhofer EMFT is working with Sony Germany GmbH on the development of a millimeter wave system-in-package (SiP) technology. This offers more benefits such as lower losses in the high-frequency range, cost-efficient manufacture at silicon wafer level, a high integration capacity (of both the passive and the active components) and improved heat dissipation.

The project is being funded as part of the EU program Electronic Components and Systems for European Leadership Joint Undertaking (ECSEL JU, project ID: 662175).

**Characterization of ESD protection structures**

On behalf of various industry customers, Fraunhofer EMFT researchers characterize ESD protection structures with high-current impulses on a transient and quasi-static basis in the automotive temperature range. The experts then use the analysis results to develop high-performance protection concepts for a variety of applications and requirements. This work is carried out using a modern, fully equipped HPPI001C TLP system in conjunction with a 300 mm Cascade PA300 or else the new HPPI ATS_8000A flying probe system in conjunction with the Agilent 62 GHz single shot oscilloscope DSOX960204Q.

For partners in areas such as automotive and LED lighting, ESD/EOS-induced fail scenarios are reproducibly recreated, with loads being measured into the picosecond range and robustness systematically increased.

**Better chips for groundbreaking communication infrastructures**

In the EU project 3D System-in-Package (3SIP) – compact, energy-efficient, and reproducible – the aim is to develop improved chips based on 300 mm PowerSOI technology. The second focus area is the development of new gallium nitride power semiconductor technologies suitable for mass production.

Fraunhofer EMFT is responsible for the detailed analysis of high-impedance 300 mm silicon substrates and partially processed components, looking at defects in the volume semiconductor and at the interfaces between the components. The aim is for the results to point the way forward to a diverse range of more energy-efficient products such as LED lighting systems,
The project being funded by the ECS (Electronic Components and Systems for European Leadership), the central funding instrument for microelectronics and nanoelectronics in the European Framework Programme for Research and Innovation HORIZON 2020 (GA no.: 692477-2) and the BMBF’s initiative IKT2020 – Research for Innovation (funding code 16ESE0121).

Electrostatic carrier foils for thin wafers

Electronic devices are getting smaller and flatter – one of the most obvious examples is the smartphone. This in turn requires microelectronic components and modules that are as space-saving and as flat as possible. For this reason, wafers and chips (ICs) are becoming increasingly thin for integration in electronic systems. Very thin semiconductor wafers are highly fragile, however, and their damage or destruction would mean a significant loss in value, so these sensitive items have to be handled with enormous care. Existing carrier techniques for fragile wafers are based on the use of removable adhesives. This method has its drawbacks, however: the thin wafer has to be detached and the polymer residue also has to be removed.

By contrast, electrostatic carrier techniques offer the advantage of adhesive-free, reversible attachment. In the project E-Foil, Fraunhofer EMFT researchers are working on a cost-effective method of making electrode structures – mounted on foil substrates – which can be electrostatically activated.

The e-foil itself is approx. 50 µm thick and contains an electrode structure on the inside which is connected to contact points on the outside. By applying an electric potential to the electrode contacts, an electrostatic field can be switched on or off. In the application, the e-foils are used as retention force agents between a substrate on the top (e.g. wafer, foil, chip) and carrier plate underneath. The e-foil can also be used as a replaceable and reusable electrostatic carrier foil, or optionally also permanently affixed to a rigid carrier substrate (e.g. ceramic, glass, silicon wafer).

The project “Electrostatic foil carrier for the processing of fragile and flexible substrates” is funded as part of the internal Fraunhofer program MEF (Application 115.2701).
Energy for smart objects

According to forecasts there will be as many as 24 billion networked objects by 2020 – more than a third of these being ‘smart’ everyday objects that communicate and interact as part of the Internet of Things (IoT). A key issue here is energy supply: the smart objects have to be energy self-sufficient in order to be able to operate for as long a period as possible. The EU project EnSO involves 39 partners from eight countries working on new solutions for an intelligent energy supply. The aim is to develop so-called AMES (Autonomous Micro Energy Sources). AMES combine various elements such as energy harvesting, energy management and micro-energy storage devices in order to ideally enable a lifelong operating period.

In the course of the project, Fraunhofer EMFT researchers will be developing concepts and technologies for the integration and embedding of electronic microchips in autonomous energy supply units. These compact packages are to be well under one millimeter in height, and the aim is also to make them mechanically deformable so that they can be adapted to different environmental shapes. For this purpose, the Munich experts are seeking to embed a very thin, bendable microchip in an ultra flat foil casing. Various technology concepts are to be tested for contacting purposes. In addition to flip-chip ideas where the chip is set face-down on a wiring foil, contacted and embedded, new technologies are also being used in which the chip is set face-up on a foil and embedded with a casting compound, for example. The electric contacting and the creation of a wiring level with the connections to the outside is then to be provided by means of established methods of thin film lithography.

The project is funded by the ECSEL initiative as part of the European Framework Programme for Research and Innovation HORIZON 2020 (grant agreement no. 692482) and by the BMBF.

Environment-friendly cleaning gas for the semiconductor industry

Many plasma coating systems used in the semiconductor industry have to undergo thorough cleaning on a regular basis after each stage of production. Currently this is mainly carried out using perfluorinated compounds (PFCs) and nitrogen trifluoride (NF3) gases, which are up to 17,000 times as damaging to the environment as the greenhouse gas CO2.

Solvay, Texas Instruments, Muegge and Fraunhofer EMFT are working on the project ecoFluxer to develop an environment-friendly alternative which only has the greenhouse potential of CO2: the gas mixture used by the cooperation partners – “Solvaclean” consisting of fluorine, nitrogen and argon – dispenses entirely with the highly environment-unfriendly gases PFCs and NF3. In the first year of the project, Fraunhofer EMFT was mainly responsible for optimizing the new gas mixture in terms of etching rate, process stability and particle contamination. This established a mix ratio of 30 % fluorine in nitrogen and argon as the best known method. At its production site in Freising, Texas Instruments has assembled a gas supply unit and tested the Solvaclean fluorine gas mixture on a number of production units. Initial tests show a slightly improved cleaning performance, and a reduction in the time required as compared to the standard process using CF3F. An initial durability test with more than 500 processed wafers and therefore approx. 250 cleaning cycles also showed that cleaning processes using the Solvaclean fluorine mixture do not cause increased particle contamination in the cleaning plasma source and the process chamber.

The new cleaning process went into pilot use in mid-November, with the aim of securing approval for industrial production by the end of 2017.

The project is funded partially under the BMBF’s “+imPuls – Innovative technologies for resource efficiency – Impulse for industrial resource efficiency”, which in turn is embedded as part of the framework program “Research for Sustainability” (FONA).

Europe-wide platform for FD-SOI technology

The project THINGS2DO involves 44 partners from research and industry working with Fraunhofer EMFT under the coordination of the French semiconductor manufacturer STMicroelectronics to establish a sustainable European and German ecosystem for the creation of FD-SOI semiconductor components. The aim of this ecosystem will be to offer SMES, industry partners and research partners a platform on which to combine, integrate and produce the relevant IP components. The THINGS2DO consortium provides design expertise, access to PDKs and IPs, EDA tool support and design services within a hosted design environment, providing support for successful FD-SOI designs by clustering all the competences, tools and IPs required.

The work of Fraunhofer EMFT focuses on new drafting techniques and circuits in the area of communication design that are optimized for FD-SOI technology; for example, the project involves a research team drawn from the Fraunhofer institutes IIS and IIS/EAS as well as Fraunhofer EMFT that is developing a fully integrated RF on-board communication module for data communication in collaboration with the Airbus Innovation Group.

FD-SOI technology has a key role to play in the development of extremely miniaturized, energy-saving and yet very high-performance circuits. Circuits with these properties are especially in demand for many applications in the fields of medical technology, environment monitoring, traffic technology and communication technologies.
THINGS2DO is funded by the EU as part of the technology initiative ENIAC and by the BMBF as part of the research program IKT 2020 – Research for Innovation (grant agreement no. 16ES0240).

**Extremely low-noise JFETS for the gigahertz range**

The internal Fraunhofer project “low-noise” builds on the HRFET JFET project which involved the development of novel, extremely low-noise FET transistors for use in the gigahertz range. In the follow-up project the aim is to adapt the HRFET JFET to the specific requirements of potential customers. The advantage of the low-noise JFET is that it reaches a cut-off frequency of 1 GHz – making it the “fastest” silicon-based JFET to date as compared to commercial products. By using self-adjusting processes, Fraunhofer EMFT researchers have been able to greatly reduce active channel length and thus advance into the gigahertz range.

The project seeks to optimize the low-noise JFET mainly in terms of robustness, cut-off frequency and noise. Initial samples of an improved batch are already being tested by the potential customers. The aim is to introduce the low-noise JFET to the application by the end of the project – in this case for the purpose of material analysis. In the medium term, it could potentially also be used in high-frequency oscillators and mixers.

**Impedimetric CO₂ sensor**

Energy efficiency and good air quality in indoor spaces – achieving these two goals requires intelligent air conditioning systems which ensure regular fresh air input without unnecessary heat loss to the outside. For this reasons, sensor-based systems are used increasingly frequently to monitor indoor air quality. One indicator of stale air is the gas CO₂: from a concentration of 1,000 ppm it can have a negative impact on our well-being. CO₂ sensors currently available on the market generally operate according to an optical measuring principle but they have several drawbacks: they are large, expensive and consume relatively large amounts of energy – which makes them not ideally suited for use in the growing smart home market.

A Fraunhofer EMFT research team has pursued an alternative approach, developing a CO₂ sensor based on an impedimetric measuring principle. A gas-related change in the capacity of a sensor layer provides the basis for the sensor signal. The researchers have now developed a new hybrid sensor layer consisting of a combination of organic and inorganic material which has produced promising results to date: the sensor detects CO₂ concentrations from 400 ppm and exhibits low response and regeneration times of less than 2.5 minutes. In long-term tests, the CO₂ sensor runs reliably and stably over several weeks without a signal drift occurring – even in fluctuating air humidity.

**Implantable microdosing system regulates intraocular pressure**

Current therapies to combat eye disorders such as glaucoma and eyeball atrophy generally only provide patients with brief alleviation of their suffering. As part of the BMBF-funded project MIKROAUG, researchers at Fraunhofer EMFT are working under the consortium leadership of the Heidelberg-based company Geuder AG in collaboration with Dualis MedTech GmbH, Binder Elektronik GmbH and jvi GmbH to develop an active microsystems technology implant system which will permanently stabilize the intraocular pressure of glaucoma and phthisis sufferers. It consists of a micropump system, a monitored pump control unit, a contactless energy supply and a telemetry module for data transfer and it can be attached directly to the eyeball.

A Fraunhofer EMFT research team is working with 19 European partners from industry and research on the EU project ADMONT to develop an integrated high-voltage driver (ASIC) for micropumps. A pilot line of the chip is to be realized in the cleanrooms of X-Fab in Dresden.

At the heart of the system is a tiny biocompatible silicon micromembrane pump measuring just 7 x 7 x 1 mm³ and with a flow rate of no more than 800 μl/min. The pump can either tone the eye or else pump intraocular fluid out of the eye, depending on the symptoms. By means of an external control module, the medical personnel providing treatment can set the flow rate of the micropump in relation to eye pressure.

The project was funded as part of the SME initiative “KMU innovativ” by the Federal Ministry of Education and Research BMBF (grant no.: 16SV5860).

**Integrated high-voltage driver for micropumps**

A Fraunhofer EMFT research team is working with 19 European partners from industry and research on the EU project ADMONT to develop an integrated high-voltage driver (ASIC) for micropumps. A pilot line of the chip is to be realized in the cleanrooms of X-Fab in Dresden.

The energy efficiency and response time of ASICs are significantly higher than is the case with the discrete type normally used nowadays. This enables pump accuracy to be increased and the electronics to be miniaturized without losing out on performance capacity – a key requirement for promising applications such as in medical implants or smartphones. The long-term project goal is to achieve an overall solution for microdosing systems which allows monitoring and control of the pump. The chip will monitor whether the pump is operating error-free, for instance, or adapt the pump function by means of various selectable program modes.
Increased manipulation security for electronic systems

Manipulation security of electronic systems is becoming increasingly important in the digitized world since chips and electronic components are easy prey for product counterfeiters and industrial spies nowadays. In order to improve IP protection of the firmware of such systems, a Fraunhofer EMFT research team is working on the internal Fraunhofer project Copycat, together with colleagues from Fraunhofer AISEC and Fraunhofer IMS (coordinator), to develop electronically analyzable structures based on product protection foils and physical unclonable functions (PUFs). Product protection foils serve to protect electronic systems from physical interference. The electronic system is encased entirely by a sensor foil so that any interference from the outside is instantly detected, thereby triggering an alarm. The project aims to develop new detection mechanisms and finer structures to increase copy and manipulation protection.

PUFs are based on small, unpredictable production fluctuations which inevitably occur in the manufacture of integrated circuits and are stably preserved in every chip or system, thereby constituting the chip’s unique fingerprint, so to speak. They do not actually impair functionality but can be used to generate a cryptographic key with which the individual chip is associated. The great advantage of such an intrinsic security system is that in the event of invasive attacks on the IC, the physical properties of the PUF are altered. It is then no longer possible to derive the original key. In this project, researchers intend to realize silicon and foil-based PUF structures and then evaluate their application for traceability, system integrity protection and IP protection. The task of the Fraunhofer EMFT scientists here is mainly to integrate the analysis structures and then evaluate their application for traceability, system integrity protection and IP protection. The project is being funded as part of the ECSEL initiative (Electronic Components and Systems for European Leadership), the central funding instrument for microelectronics and nanoelectronics in the European Framework Programme for Research and Innovation HORIZON 2020 (project reference: 661796).

Micropumps for gas sensors in mobile phones

Many recent smartphone models are fitted with environmental sensors, for example to measure the ambient CO₂ content, humidity or temperature. Existing environmental sensors in smartphones are subject to very long response times since the air first has to penetrate the inside of the sensor housing by means of slow diffusion. Special software algorithms can be used to speed up this process somewhat. Fraunhofer EMFT researchers are currently pursuing a different and more promising approach: By means of a tiny silicon micropump positioned near the housing opening, air can be actively fed to the sensor inside the smartphone. This has speeded up the response time by a factor of 50 – and measuring results were more precise, too. In the medium term it would also be conceivable to concentrate the air being fed to the sensor so as to increase sensor sensitivity.

Here a silicon membrane pump is used which was developed at Fraunhofer EMFT measuring just 5 x 5 x 0.6 mm³. The small size of the component, its low energy consumption and low production costs are key requirements for access to mass markets such as mobile devices. The application potential ranges from gases such as CO₂, alcohol and volatile organic compounds (VOCs) to particles such as allergens, particulate matter and fragrance dosage. An initial demonstrator for gas sensors in smartphones has already been realized and produces excellent results. The work is being funded by the Fraunhofer Future Foundation.

Microwave spectroscopic analysis of liquids

Among other factors, the physical and chemical response of many liquids is influenced by temperature. This is why for some applications, in the field of medicine for example, it is important to be able to measure and stabilize the parameter of temperature.

As part of an industry project, Fraunhofer EMFT researchers have developed a measuring station able to control the temperature of liquids to the nearest ±0.01 K and analyze them very precisely and reproducibly by means of microwave spectroscopy.

The automated measuring set-up was designed at Fraunhofer EMFT and realized in collaboration with Universität der Bundeswehr München. The measurements carried out on test liquids using a vector network analyzer (Keysight PNA N5247A) in the 110 GHz range showed the absolute necessity of temperature stabilization. It was also possible to detect impurities added to the liquid.

Miniaturized degassers for mobile applications

Dissolved gases in liquids can significantly disrupt chemical and biotechnological processes: pressure or temperature fluctuations can potentially lead to outgassing of the liquid, i.e. the formation of tiny gas bubbles. These can falsify sensor measurements, impair the compressibility of the liquid and at worst even cause system failure. To be on the safe side, the liquid should first be degassed. However, existing degassers are expensive and require a vacuum connection for operation – usually only available from a well-equipped laboratory.

Fraunhofer EMFT researchers have developed a self-sufficient micro-degger which is capable...
EXAMPLES OF PROJECTS AND APPLICATIONS

of removing both gas bubbles and dissolved gas from a liquid. The liquid is pumped in a porous tube through a low-pressure chamber in which the dissolved gas diffuses. A silicon micromembrane pump developed at Fraunhofer EMFT is integrated in the degasser. This can build up very high levels of negative pressure of up to -55 kPa – sufficient to generate the necessary negative pressure in the chamber and maintain this during degassing. Only a power connection is required for operation, which significantly expands the range of potential uses. The research team also integrated a pressure sensor in the chamber which ensures that the pump is not activated until a defined level of negative pressure is reached in the chamber. This saves energy and extends the service life of the pump.

On tests to date, a functional demonstrator of the micro-degasser has shown a degassing efficiency of approx. 50% at flow rates of 50 - 200 µl/min. It has two standard luer connections for input and output as well as a connector for voltage control of the micropump, enabling the system to be integrated in most units without undue effort.

The work was funded by the Fraunhofer-Gesellschaft as part of an MEF project.

In the EU-funded project MANPower, researchers at Fraunhofer EMFT are working with the partners Tyndall National Institute, University College Cork, Cork Institute of Technology, TU Eindhoven, KU Leuven, University of Paris South, 3D-Plus and LivaNova (previously SORIN CRM) to develop an innovative, autonomous pacemaker containing not just MEMS and IC elements but also an energy harvesting system that operates in the range of just a few hertz at extremely low frequencies. Here, new materials are used for the energy harvesting and 3D integration technologies so as to assemble and test an ultra miniature pacemaker as a completely self-contained system. There is a particular focus on studies into the reliability and biocompatibility of the system components and integration technologies.

Fraunhofer EMFT is in charge of the work package “System Integration”. Here, TSV (Through-Silicon-Via) based 3D integration technologies are mainly developed, applied and evaluated for reliability in collaboration with partners for the assembly of electronic subcomponents. Both silicon materials and flexible foil materials are integrated heterogeneously in order to integrate the individual components in the tube-shape system (capsule).

The project was funded by the 7th EU Research Framework Programme (grant agreement no. 604360). The future user of this innovative technology and project partner is the French company LivaNova, Europe’s leading manufacturer of pacemakers.

Mobile measuring device for gas detection

The EU project InForMed involves 42 European companies and research institutions coordinated by Philips GmbH who are seeking to establish a microfabrication pilot line for new medical technology products. The partners intend to realize six types of demonstrators to indicate the innovation potential in existing markets as well as laying the foundations for penetrating new markets. A Fraunhofer EMFT research team is collaborating with Dräger Safety AG, jsi GmbH and Philips GmbH to develop a mobile measuring device for gas detection. Worn directly on the human body, it increases occupational safety for those working in the chemical industry. What is especially interesting about the new system is that it has an integrated micropump which generates a high negative pressure, while this in turn serves to adjust the gas sensor. The sensor can be calibrated online if necessary. This means that the system is capable of operating quickly, reliably and stably even over extended periods of time.

The project is being funded as part of the ECSEL initiative (Electronic Components and Systems for European Leadership), the central funding instrument for microelectronics and nanoelectronics in the European Framework Programme for Research and Innovation HORIZON 2020 (grant agreement no. 662155).

Monitored dosage of minute quantities of lubrication oil

The project Nanolub involves Fraunhofer EMFT joining forces with GMN Paul Müller Industrie GmbH to develop a new method for monitored dosing of tiny quantities of lubrication oil (5 μg/s and less, approx. 5 nanoliters). This is integrated in a dosing system and used in a pilot application for the lubrication of ball bearings in high-speed spindles. The new dosing system saves up to 95% of the lubricant quantity previously required – thereby reducing production costs and environmental impact and increasing operational safety. In spite of the tiny quantity of oil, a continuous lubricant film is reliably ensured on the ball bearing surfaces at all times.

In the second year of the project, the work of Fraunhofer EMFT focused on an enabling abstraction of oil, a continuous lubricant film is reliably ensured on the ball bearing surfaces at all times. The partners intend to realize six types of demonstrators to indicate the innovation potential in existing markets as well as laying the foundations for penetrating new markets. A Fraunhofer EMFT research team is collaborating with Dräger Safety AG, jsi GmbH and Philips GmbH to develop a mobile measuring device for gas detection. Worn directly on the human body, it increases occupational safety for those working in the chemical industry. What is especially interesting about the new system is that it has an integrated micropump which generates a high negative pressure, while this in turn serves to adjust the gas sensor. The sensor can be calibrated online if necessary. This means that the system is capable of operating quickly, reliably and stably even over extended periods of time.

The project is being funded as part of the ECSEL initiative (Electronic Components and Systems for European Leadership), the central funding instrument for microelectronics and nanoelectronics in the European Framework Programme for Research and Innovation HORIZON 2020 (grant agreement no. 662155).
The project was funded through the Fraunhofer-Gesellschaft Discovery Program.

**New sensor for measuring gases and liquids**

As part of the ChemFET project, Fraunhofer EMFT has joined forces with LFoundry S.r.l. to develop and produce a field-effect transistor-based transducer to measure liquid and gaseous media. It can be used to measure charge changes in a Faraday cup via an electrode that is connected to the gate of a read-out transistor.

The new sensor principle was realized with the developed layout and a completely CMOS-compatible process. Several test measurements have already shown that the device can be used both as a pH sensor in liquids and as a gas sensor for CO₂ detection. The next stage will involve the development team testing the ChemFET for further applications, for example as a biosensor in the field of medical technology. Another aim is to further optimize the process cycle and design in terms of cost efficiency.

The project was funded through the Fraunhofer-Gesellschaft Discovery Program.

**Point-of-care system to detect MRGN bacteria**

Multi-drug-resistant Gram-negative rod-shaped bacteria (MRGN) have become increasingly widespread in recent years as a cause of nosocomial infections worldwide. Antibiotics used as a standard therapy are largely ineffective in the case of MRGN infections. This is why infections with multi-drug-resistant pathogens have to be identified very early on in order to initiate the right therapy with one of the few reserve antibiotics still available as soon as possible. MRGN bacteria can also survive on inanimate surfaces and spread via contaminated objects. Early detection is important so as to be able to take special hygienic measures and prevent these problematic pathogens from spreading.

A Fraunhofer EMFT research team is collaborating with the SME GBN Systems GmbH, the Institute of Microbiology and Hygiene at Regensburg University Hospital and Asklepios Kliniken GmbH to develop a compact, comprehensive system that will enable rapid on-site detection of MRGN bacteria. The detection system is to be fluorescence-based and capable of being carried out on the sample material without elaborate sample preparation. Smears from potentially contaminated surfaces and objects serve as test material, in addition to human samples. By using a highly sensitive measuring system combined with a fluorescence-based detection reaction, the aim is to achieve an enormous reduction in time between sample collection and test result. Unlike conventional, time-consuming methods using microbiological cultures, rapid on-site detection will provide feedback on the existence of MRGN bacteria in the sample material within a short period of time. In contrast to PCR-based methods, this phenotypic detection will be independent of the genetic variability of the MRGN bacteria, also allowing the pathogens to be detected where PCR-based methods would not be capable of identification. This constitutes a major step forward as compared to the methods currently in use.

This project is funded by the Bavarian Research Foundation (BFS).

**Sensor nodes and their networking for digital production**

Sensors have a key role to play in the Internet of Things (IoT), but they have to become more effective and cost-efficient in future in order to keep up with dynamic developments in this area. One critical point is the networking of the sensors: IoT applications in particular require the assembly of numerous cables and connectors. These components are sufficiently reliable but much too expensive for mass consumer markets. Wireless connectivity is not an option in many cases – the main obstacles are the energy supply to the sensor nodes and the often inadequate signal coverage in buildings (due to isolation by metal objects, for example).
The project SensNet therefore involves Fraunhofer EMFT researchers developing new concepts and experimentally verifying them so as to integrate sensors in a hierarchical information chain – from the detection of physical parameters through to data processing in a big data cloud environment. The sensors are to be networked effectively enough to be able to operate independently to a large extent. The project is supported by the funding initiative Bayern Digital.

**Sensor platform exemplified in an indoor climate sensor**

In office buildings, ventilators, humidifiers etc. often run continuously, even though the premises may not even been in use for many hours of the day. Yet when an office is fully occupied, an air conditioning system set to continuous operation is still inadequate. In order to regulate indoor climate based on needs while at the same time achieving greater energy efficiency, Fraunhofer EMFT researchers have joined forces with Mikrosysteme Wiedemann GmbH (KMW) of Kaufbeuren, Tapko Technologies GmbH and IS-LINE GmbH to develop a modular sensor platform. The aim is to use this as a basis for low-cost condition monitoring systems with an impedimetric sensor system. As an exemplary application, the partners are developing an HVAC sensor module – HVAC stands for heating, ventilation and air conditioning. The system with integrated sensors for temperature, humidity and CO₂ coordinates the three parameters and controls the air conditioning system according to needs. Sensor fusion allows low-cost serial production, thereby paving the way for use in the mass market.

The Fraunhofer EMFT science team involved in this project is developing a sensor platform for various capacitive, resistive sensors. They are also responsible for the low-cost electronics with standard interfaces and are working on optimizing the sensor components used. The project is funded by the program Electronic Systems in Bavaria (previously Microsystems Engineering Bavaria).

**Smart fire detector with multi-gas sensor and micropump**

The aim of the EU project SMOKESENSE is to bring about a radical change in fire detection technology by developing a smart, miniaturized fire detector. Conventional sensors are limited in terms of their performance capacity. They require a high level of maintenance and are generally at a disadvantage when it comes to speed of response because they are positioned a long way from the source of the fire.

The core components of the SMOKESENSE fire detection system are a multi-gas sensor and a micropump. The so-called electronic nose is capable of virtually eliminating false alarms by detecting specific combinations of gases ("fire-gas fingerprints"). The SMOKESENSE fire detection system is also able to trigger an alarm before a fire actually starts. The use of an air feed micropump being developed for this purpose by a Fraunhofer EMFT team enables a compact structure and the incorporation of a fire detector in the immediate vicinity of the potential safety hazard.

The project is being funded as part of the EU-FP7 project “Smokesense – Fire Fingerprint Sensor-on-a-Chip for early fire Detection” (grant agreement no. 605480) in the program “Research for the benefits of SME”.

**Solutions for an “electronic skin”**

The international network CONTEST (Collaborative Network for Training in Electronic Skin Technology) established by the European Commission aims to develop a ‘smart’ electronic skin. For this purpose, both silicon-based solutions and approaches using organic materials are to be studied in terms of the possibilities and benefits they offer. In the future, electronic skin is to be used for new applications in the field of robotics.

Fraunhofer EMFT is involved in two research projects as part of CONTEST. Firstly, a Munich research team is developing new packaging technologies for ultra thin silicon chips on flexible substrates and testing the reliability of these systems. The ultra thin chip foil packages have demonstrated a high degree of mechanical reliability in both simulations and tests. What is more, dynamic bending tests with several thousand bending cycles were carried out to evaluate what loads cause failure in the chip foil packages due to delamination of the electrical contacts or breaks in the wiring or else breakage of the chip itself.

In the second project the focus is on the electrical reliability of large-area flexible electronics, in particular in relation to electrostatic discharge. Tests at device level showed that organic photovoltaics, OLEDs and also organic field-effect transistors are not suitable for providing protection from electrostatic discharge. After this, tests were carried out at system level to look at the interference caused by electrostatic discharge to an “electronic skin”.

The network was funded by the European Commission as part of the Marie Curie Actions of the 7th EU Framework Programme (grant agreement no. 317488).
ESD system test with broadband measurement of the secondary discharge current
Companies benefit from collaborating with Fraunhofer EMFT in that they are able to draw on the very latest research insights and innovations for their product development. Here, Fraunhofer EMFT supports its customers throughout the entire development process – from the idea through to implementation. Fraunhofer EMFT offers its customers and partners the following services:

**Studies**
- Technology analyses
- Feasibility studies
- Assessment in the case of damage claims

**Modeling & Simulation**
- Whole process
- FEM simulation
- System response

**Customer-Specific Development**
- Advance development
- Single process modules and overall process
- Chip design
- Components and systems

**Prototypes and Small Series Production**
- System design
- Layout
- Device design and construction

**Analysis & Test**
- Risk and problem analysis
- Development of test methods and equipment

**Professional development**
- Seminars and training programs
- Conferences

**R&D as part of publicly funded projects**
- Joint projects funded by industry or publicly, e.g. BMBF, German states, the EU
- Coordination of industrial project consortia
- Consultancy for national and EU research applications

**Start-Ups & Joint Ventures**
- Spin-offs for the commoditization of products and systems
- Participation of industrial partners via joint ventures
FRAUNHOFER EMFT RANGE OF TECHNOLOGIES

An extensive infrastructure, a broad range of technologies and a well-developed network of partners in industry as well as among research institutes, universities and public-sector organizations make Fraunhofer EMFT an attractive partner in research and development, of interest to small and medium-sized companies as well as larger-scale industrial enterprises. Marketing the results of research is generally the responsibility of the corporate partner. Since 2007 Fraunhofer EMFT has also offered high-tech companies the opportunity to hire its high-quality facilities (such as cleanrooms, laboratories and equipment). Several companies have entered into strategic cooperation with Fraunhofer EMFT. Here is a selection of the technological facilities available at Fraunhofer EMFT:

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200 mm CMOS technology
- Wet chemical cleaning and etching processes
- Photolithography
- Epitaxy (Si, SiGe)
- Ion implantation and annealing
- Dielectric layers (thermal oxidation, LPCVD deposition of SiO₂, and Si₃N₄)
- Highly conductive layers (Au, Pt, W, doped poly-Si)
- Plasma processing (Si, SiO₂, Si₃N₄, Al, W)
- Electroplating (Cu, Sn)

200mm lithography cluster
- Proximity exposure
- Double-sided exposure
- Contact exposure
- Electron ray exposure
- i-Line stepper
- Nanoimprint

Si-MEMS technology
- Cleanroom technology for 150 mm wafers (silicon, ceramics, glass)
- Metal coating (Cu, Ti, TiW, Pt, Au, Ni)

Dielectric layers (SiO₂, Si₃N₄, SiC, polyimide)
- Wafer bonding, bonding techniques by means of adhesion
- Structuring with mask aligner 2 μm

Substrate processing
- Wafer grinding
- Spin etching
- Chemo-mechanical polishing (CMP)
- Wafer cleaning
- Contactless wafer thickness measurement
- Flexural and breakage test devices for thin substrates and chips

Processing of large-area electronics and flexible substrates as foil sheets and using the roll-to-roll method
- Hot roll laminator for double-sided lamination
- In-line coating system for liquid coatings such as photoresist, dielectrics and passivation
- Sputter system for double-sided metalization of chrome and copper
- UV lithography with high resolution (5 – 15 μm structure width)
- Wet-chemical etching techniques for structuring metals
- Screen printing on foil sheets
- Screen printing using the roll-to-roll method
- Galvanic deposit of copper on premetallized foils
- Laser processing for cutting, marking and drilling various materials
- Plasma process for surface conditioning and reactive etching of polymers with nitrogen, oxygen and CF₄
- Foil mounting and bonding technology

Analytics and material characterization
- Atomic force microscope (AFM): measurement of surface roughness and step measurements up to max. 6 μm
- Scanning electron microscopy (REM) incl. energy-dispersive x-ray spectroscopy (EDX)
- In-line REM (Schottky emitter) and focused ion beam (Ga-FIB) with EDX and gas injection system (GIS)
- Spectral ellipsometer: measurement of thin layers and transparent materials
- Spectrometer: measurement of layer thickness of silicon (thick layers) and infrared permeable layers
- Target grinding device for sample preparation (grinding accuracy: ±2 μm)
- X-ray diffractometry (XRD): measurement of silicon-germanium content
- CVD epitaxy facility: quality control of high purity gases
- Plasma-supported etching and deposition systems to test gas compounds
- Wafer prober for electrical characterization

Analysis and testing
- Semi-automatic wafer prober up to 300 mm using thermo chuck (-55 °C to +300 °C) and laser
- Semiconductor parameter analyzers
- Network analyzers in the megahertz range up to 110 gigahertz and Simulator Agilent ADS
- Generation and measurement of high-current pulses in the picosecond and nanosecond range
- Electrostatic discharge characterization and load (CDM, HBM, TLP, VF-TLP, CC-TLP)
- 160 cc climate chamber for chemical and biochemical sensors: gases and liquids
- Electrochemical impedance spectroscopy
- Environmental test chamber 100 cc – humidity and gases
- Oscilloscope
Fraunhofer EMFT staff member working on the design and simulation of an analog-digital converter.
Cooperation with national and international partners from research and industry is a central element of the work done at Fraunhofer EMFT. The institution is currently collaborating with the following companies, associations and research facilities:
In order to enable efficient collaboration with industry and develop product ideas into concrete applications more swiftly, Fraunhofer EMFT has established three technology networks for specific themes and research areas. These are aimed at longstanding customers and development partners as well as new customers who wish to draw on expert support to put their innovative product ideas into practice.

**Multifunctional on-top technologies (MOTT)**

The development center for Multifunctional On-Top Technologies (MOTT) for standard silicon and CMOS processes was founded in 2009. Building on the results of previous research into CMOS circuits and 3D system integration, the infrastructure combined with the Munich-based Fraunhofer EMFT expertise provides a technology platform enabling industry to carry out rapid system development that is closely geared towards end products in the area of semiconductor technology. The platform supports modular integration of new functions and components in existing silicon standards technologies, resulting in cost-effective solutions even for small and medium-sized companies.

**Center for Microsystem Integration Munich (CMM)**

Fraunhofer EMFT initiated the founding of the Center for Microsystem Integration Munich (CMM) in 2010 in collaboration with leading Bavarian companies. By pooling the extensive expertise of prestigious partners in the field of technology and product development, the CMM provides a high-performance and efficient technology network in the field of microsystems engineering. The CMM acts as the nucleus for a microsystems engineering center and is looking forward to ongoing expansion as it is joined by further experts.

**Bavarian Polytronic Demonstration Center (BDP)**

The Bavarian Polytronic Demonstration Center was founded to facilitate low-cost production of electronic systems in substantial quantities on large-area substrates. A wide range of coating and structuring processes for foils are developed in collaboration with industry as part of research projects and development activities for flexible, organic and large-area electronics (FOLAE). The equipment used is consistently designed to process rolls of foil. Current focus areas include the functional integration of organic materials, the assembly of sensors in polymer technology and the creation of large-area, flexible wiring systems.

**Innovation Flex**

The center enables industry users to create and test new technologies, processes and demonstrators for various areas of application. It gives project partners access to Fraunhofer EMFT’s cutting-edge roll-to-roll infrastructure and they benefit from support provided by the experienced and highly qualified specialists at the institution. In future the aim is to develop a self-contained pilot line for preliminary production stages and a ramp-up for flexible electronic components. Participants are able to influence the concept directly. In return for a fee, they receive:

- Exclusive information on the results
- Individual consultation
- Involvement in defining applications and the resulting demonstrators, prototypes and/or pilot production facilities
- Involvement in specifying any equipment, processes and materials required
In order to pursue its research goals consistently, Fraunhofer EMFT engages in collaborative research and projects with a number of universities in Germany and elsewhere in Europe.

Universität der Bundeswehr München

There is a close link between the Faculty of Electrical Engineering and Information Technology of the Universität der Bundeswehr München and Fraunhofer EMFT, not least as a result of staff connections: Prof. Linus Maurer (Professorship for Integrated Circuits and Electronic Components) has taught at the university since 2012, along with Prof. Christoph Kutter (Professorship for Polytronics). The cooperation originated under Prof. Ignaz Eisele, who was appointed the university’s first Emeritus of Excellence and today heads up the business area Silicon Technologies and Devices at Fraunhofer EMFT.

Dr. Sabine Trupp joined Universität der Bundeswehr as a habilitation candidate last year and is working in the field of gas sensors there. The Fraunhofer EMFT and Universität der Bundeswehr München complement each other ideally due to the nature of their respective cleanroom facilities. The two institutions aim to intensify their collaboration in future.

Technische Universität München

In the spring of 2016 Prof. Marc Tornow joined Fraunhofer EMFT to head up the Silicon Technologies and Devices department together with Prof. Ignaz Eisele. Marc Tornow holds the Professorship in Molecular Electronics at TU München and is involved in research into nanoscale components in molecular electronics and biosensors.

Through the Chair for Technical Electrophysics there is also close collaboration with Dr. Gabriele Schrag and Prof. Gerhard Wachutka. Research there focuses on physically based modeling, numerical simulation and the characterization and diagnosis of production processes and the operating response of microstructured components. Collaborative research aims to further strengthen Fraunhofer EMFT expertise in this area. There are plans for joint doctoral dissertations on various preliminary research topics.

Universität Regensburg

Fraunhofer EMFT has a longstanding collaboration with the Institute for Analytical Chemistry, Chemo- and Biosensors at the Universität Regensburg. As of 01.01.2017, Prof. Joachim Wegener will be in charge of the Fraunhofer EMFT group Cell-Based Sensors (ZBS) in Regensburg. Joachim Wegener is Professor of Bioanalytics and Biosensors at the Universität Regensburg, and the work he does with his group mainly focuses on developing physical sensors that allow living cells to be examined non-invasively and label-free. The aim of this new initiative is to harness Fraunhofer EMFT expertise in the areas of microanalytics and polymer electronics for cell-based sensors, thereby penetrating new areas of application in bioanalytics and biotechnology.

Technische Universität Dresden

Technische Universität Dresden has been one of Germany’s eleven Universities of Excellence since 2013. The honorary professorship of Prof. Peter Kücher at the Faculty of Electrical Engineering forms the basis for cooperation with Fraunhofer EMFT.

In his courses at the Institute for Semiconductors and Microsystems Technologies (IHM), Prof. Kücher focuses mainly on the connection between technological and economic challenges, since globalized competition leads to changes such as specialization and resegmentation of the supply chain. This requires manufacturers of materials, production facilities and chips to adopt new strategic approaches. For this reason, current trends in microelectronics/nanoelectronics – from “More Moore” to “More than Moore” – need to be viewed from the perspective of the overall economic context.

Fraunhofer EMFT also cooperates closely with the Electronics Packaging Laboratory (IAVT) on scientific topics.

Politehnica Universität Bukarest, (Universitatea Politehnica Bucuresti, UPB), Romania

Politehnica Universität Bukarest developed from a polytechnic school dating back to 1864 and is now the most important technical university in Romania. There are long-standing collaborative links between Fraunhofer EMFT and the university’s Faculty of Electronics, Telecommunications and Information Technology (ETTI) as well as its Department of Electronic Technology and Reliability (TEF) and Center for Assembly and Interconnection Technology (CETTI). This cooperation allows several staff of the TEF/CETTI department to undertake scientific internships at Fraunhofer EMFT. A number of doctoral students from the TEF/CETTI department also use the experimental facilities at Fraunhofer EMFT. Collaboration between the two institutions has resulted in joint conference presentations and publications.
The Bavarian government runs a cluster offensive to support the competitive capacity of Bavarian companies in 19 key sectors. For this purpose it has set up cluster platforms throughout Bavaria to promote networking among companies and research institutions. The clusters and alliances in general help companies become involved in joint product development, optimize internal processes and jointly penetrate markets.

**Strategic Partnership Sensors Cluster**

The partnership organization Strategische Partnerschaft Sensork e.V. in Regensburg is the platform for sensors as part of the cluster offensive of the state of Bavaria. More than 70 companies and institutes now belong to this association, some of which are among Fraunhofer EMFT’s customers and cooperation partners.

Fraunhofer EMFT is a founding member of the cluster and its ZIM network SensoIT, which focuses on the use of sensor-supported IoT applications in all walks of life.

In May 2016 it co-exhibited at the joint cluster stand presented at the trade fair Sensor + Test in Nuremberg. What is more, Fraunhofer EMFT staff are able to use the excellent professional development program offered by the Sensor Cluster.

The aim of NeZuMed is to establish an innovative organization for research and development among medtech suppliers. The focus is geared specifically towards promoting SMEs in Franconia, Bavaria and Thuringia by providing specialist expertise built up over many years. Network cooperation seeks to make it easier for such companies to become established in the interdisciplinary medtech market on a lasting basis.

**Microsystems Engineering Cluster**

Fraunhofer EMFT has been very involved in the wide-ranging activities of the Microsystems Engineering Cluster (MST) ever since it was founded. Scientists and experts from the Fraunhofer institution regularly support cluster events by providing expert talks and exhibition stands, as at the MST symposium in Landshut, for example. Fraunhofer EMFT also becomes involved in cooperative ventures and project partnerships with some of the companies.

The Microsystems Engineering Cluster offers cross-sectoral communication and collaboration as well as support for cluster partners on the future-oriented development of products and value creation processes.

**NeZuMed – Network for innovative suppliers in medical technology**

Fraunhofer EMFT has been a member of the NeZuMed network since the end of 2012. This membership enables scientists to take part in events, trade fairs, workshops, forums, symposiums and conferences. In engaging in this type of activity, Fraunhofer EMFT seeks to intensify dialog and scientific exchange with potential project partners so as to generate ideas for technological innovations and R&D projects.

The aim of NeZuMed is to establish an innovative organization for research and development among medtech suppliers. The focus is geared specifically towards promoting SMEs in Franconia, Bavaria and Thuringia by providing specialist expertise built up over many years. Network cooperation seeks to make it easier for such companies to become established in the interdisciplinary medtech market on a lasting basis.

The network provides a platform on which to define and implement measures to serve the advancement of medical technology and related fields. By involving all industrial partners and the user side very early on, the goal is to promote the development of market-oriented and innovative components and products in medical technology. The organization serves as an efficient information network for tackling interdisciplinary challenges and generating low-cost, market-oriented solutions by tapping into synergies.

**Forum MedTech Pharma e.V.**

The Forum MedTech Pharma e.V. is the biggest network of the healthcare sector in Germany and Europe. It promotes cooperation between partners, facilitates contacts and provides information on the sector’s latest trends and innovations at workshops, conferences, congresses and professional development courses. The network has approximately 600 members from the area of science, business and the healthcare sector throughout Germany and 14 other countries.

The main focus areas include electronics and IT, medical imaging, minimally invasive technologies, biomaterials and substances, diagnostics and pharmaceuticals, hospitals and processes, markets and products, regulatory affairs and industrial property rights. The network acts as a neutral, independent and non-profit body which is able to provide individual support.

Fraunhofer EMFT has been a member of the network since 2016, regularly attending events and conferences.

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Micropump driver ICs realized with a 0.35 µm high-voltage process
Sonia Marin, Fraunhofer EMFT trainee, scored the best grades in Bavaria on her Chamber of Industry and Commerce examination in microtechnology. She started training as a microtechnologist at Fraunhofer EMFT in September 2013, specializing in microsystems engineering – a decision she does not regret: “The job is incredibly varied and includes a wide variety of disciplines such as materials science and electrical engineering.”

Out of more than 18,000 trainees taking their final exams at the Chamber of Industry and Commerce in Munich/Upper Bavaria, she received a distinction as one of the 117 best. The Fraunhofer-Gesellschaft awarded the 14 best Fraunhofer trainees a prize for their achievement – and Sonia Marin was one of them.

Fraunhofer EMFT team receives ERC 2016 grant

The Analysis & Test group withstood tough international competition in September 2016 and received a grant from the 2016 Educational Research Council of the American ESD Association Inc. promoting outstanding industry-related research in the area of electrostatic discharge.

The set topic was “Study of Critical Stress Factors in CDM and Alternative Contact Methods”. Among other things, the researchers aim to examine cutting-edge CDM-sensitive modules for multi-Gbit/s data transfer.

The sponsors are Cisco Corp, GlobalFoundries Corp. and the ESD Association. The grant funds are to be explicitly used to support a doctoral candidate at Fraunhofer EMFT. The research can be freely designed, the only condition being that initial publication is at the EOS/ESD symposium in the USA.
Fraunhofer EMFT organizes science events each year on its own premises as well as presenting at numerous external events. The institution’s latest research and development work is regularly featured at national and international trade fairs and congresses. Here is an overview:

**Fraunhofer EMFT Annual Event**

Once a year, Fraunhofer EMFT invites representatives of business, science and politics to an annual event held on its own premises to provide information on the institution’s current activities. The motto of the event on March 15, 2016 was: “Materials in microelectronics”.

Materials have a key role to play in microelectronics and sensorics. Microelectronics is based on the thermal and electrical conductivity of semiconductor materials such as silicon and germanium. In chemically and biologically based sensor systems, analytes can be detected as a result of change they cause in the optical, electrical, magnetic, mechanical or thermal properties of the material used.

The development and use of new materials and combinations of materials is therefore a key innovation driver in semiconductor technology and sensorics and a key focus of research activities at Fraunhofer EMFT.

**Smart Home Congress**

The market for intelligent living in the future promises huge growth potential and is of increasing interest to developers, manufacturers and users in the field of electronics. The congress “Smart Home/ Smart Living” took place on October 5 - 6 in Würzburg, organized jointly by Bayern Innovativ, Fraunhofer EMFT and Vogel Verlag. It offered decision-makers from business and science the opportunity to identify market opportunities and establish contacts for cooperative ventures.

The event primarily focused on the latest insights and developments in the area of electronics – trendsetters for innovative technologies used in the automation and networking of buildings as well as for new products. Potential application scenarios were to be found in the areas of energy, security, comfort and health.

**Forum be-flexible**

Fraunhofer EMFT has organized the international workshop Forum be-flexible for over 10 years now, inviting researchers, scientists, industry partners and users to engage in a lively exchange. In 2016 the event took place on November 21 and 22, focusing once again this year on the latest technologies and applications in the areas “Thin Semiconductor Devices” and “Flexible Electronic Systems”, with particular attention being paid to the Internet of Things (IoT).

The international audience included end users, scientists, developers and visionaries who met on the Fraunhofer EMFT premises to engage in lively and inspiring debate.

In 2016, Fraunhofer EMFT once again provided a wide-ranging service portfolio at trade fairs in the most diverse fields, aimed at a practically oriented exchange of information and expertise as well as seeking to attract new customers.

**Trade fairs in 2016**

- **Landshut Symposium for Microsystems Engineering**
  Landshut, March 9 - 10

- **Smart Systems Integration**
  Munich, March 9 - 10

- **Sensor + Test**
  Nuremberg, May 10 - 12

- **Semicon Europa**
  Grenoble, October 25 - 27

- **COMPAMED**
  Düsseldorf, November 14 - 17
TALENTA is an instrument established by the Fraunhofer-Gesellschaft to support young female scientists in developing their individual careers. Four Fraunhofer EMFT scientists who were involved in the program in 2016 report on their experiences.

What were the focus areas of your research?

Anna Ohlander: I work in the area of flexible electronics and have been involved in a range of different projects relating to foil-based electronic systems since I joined Fraunhofer EMFT in 2010. My specialist area is now, foil-based lab-on-chip applications – and this is what my doctoral dissertation is about.

Bernadette Kinzel: I work in the Circuit & Systems department where I design integrated circuits. My focus here is on power management: at the moment, for example, I’m developing an integrated high-voltage driver which will power micro-pumps – this is part of the ADMONT project and our work on gas sensors in mobile phones. This is also the subject of my doctoral dissertation.

Jennifer Schmidt: I’ve been in charge of the Sensor Materials business area at Fraunhofer EMFT since 2010. One of the things we’re currently working on is to develop new detection methods for bacteria. We’ve just successfully completed a project on the detection of MRSA bacteria and in our current project we’re developing detection methods for MRGN bacteria.

Sabine Trupp: I’ve been working in the Sensor Materials business area at Fraunhofer EMFT since 2010. One of the things we’re currently working on is to develop new detection methods for bacteria. We’ve just successfully completed a project on the detection of MRSA bacteria and in our current project we’re developing detection methods for MRGN bacteria.

Are there aspects or areas you believe should be given greater emphasis as part of the TALENTA program?

Bernadette Kinzel: I think for young scientists in particular it would be nice to be able to learn from the experience of others. As TALENTA members you have a certain role-model function for young female scientists at Fraunhofer. What is your advice to young women who wish to pursue a career in science with Fraunhofer? What do they need to have?

Anna Ohlander: It’s important to be proactive. If you’re interested in something, take matters into your own hands and get things going. From my experience I can say that project work gives you good ideas for your own doctoral dissertation. Sometimes it’s a challenge to strike a balance between the two.

Bernadette Kinzel: It’s a good idea to set yourself milestones and define what objectives you want to achieve by when.

What is your career goal with Fraunhofer? What would you like to achieve in the next five years?

Anna Ohlander: My date for the defense of my dissertation is at the end of April 2017. After that I would like to carry on developing lab-on-a-chip applications here at Fraunhofer EMFT. This primarily means doing a lot of acquisition work. Also, a colleague and myself have been working on launching a start-up for some time.

Bernadette Kinzel: The main goal my sights are set on is getting my doctorate. Since this will definitely take some time, I’m not yet making any detailed plans for what comes afterwards.

Jennifer Schmidt: I’d like to do more in the area of biosensors, specifically looking at bacteria detection – so that means acquiring and heading up more projects. I’ve already gained lots of new insights from the projects I’ve worked on to date and I’d like to be able to put this knowledge to use in new projects. In this way I’m building up my specialist expertise, which is also helping my career and my habilitation.

As TALENTA members you have a certain role-model function for young female scientists at Fraunhofer. What is your advice to young women who wish to pursue a career in science with Fraunhofer? What do they need to have?

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CAREERS AT FRAUNHOFER EMFT

Many young people opt to start their working life at Fraunhofer EMFT. The institution offers an excellent start to a career for trainees in research, science, technology and administration. Students of physics, electrical engineering, process engineering, biochemistry and related areas have the opportunity to get involved in applied research at a practical level. They can take an internship, work as a research assistant, write their diploma/ bachelor’s/ master’s assignment and undertake doctoral studies.

I’ve been working as a student trainee at Fraunhofer EMFT since February 2016 in the area of design, testing and systems integration. My main focus is a project that involves further development of a gamma radiation sensor with a silicon photomultiplier. Communication channels are short and straightforward here, and the atmosphere among us student trainees is very family-like. I also find it highly motivating that you can contribute your own ideas at Fraunhofer EMFT without being confronted with major obstacles.

Rupert Amann

I did an internship at Fraunhofer EMFT as part of my bachelor’s degree in chemical engineering at Munich University of Applied Sciences. As well as carrying out chemical measurements for various projects in the Silicon Technologies and Devices department, I was also involved in producing and characterizing thin films on FTO electrodes. The work was very varied and my colleagues were very friendly and supportive, so I was able to benefit a lot in terms of acquiring practical skills.

Julian Hohendorf

I’ve been working as a student trainee at Fraunhofer EMFT for my master’s assignment since October 2016. My topic is developing a Bluetooth-controlled app for the purpose of microdosing. It will be part of a planned microdosing system used to train dogs for the early detection of lung cancer. I find it really exciting to be involved at the forefront of current research and that makes the work here very varied and interesting.

Bassem Badawi

Since August 1, 2016 I’ve been working on a project that involves multi-gas analysis using a MEMS Fabry-Perot infrared interferometer and creating a compact system for gas analysis. Fraunhofer EMFT gives me the opportunity to get proactively involved at the forefront of applied research and that makes the work here very varied and interesting.

Büşra Tas

I joined Fraunhofer EMFT as a trainee student in October. Since then I’ve been working in the Silicon Technologies and Devices department on a system set-up for chemical sensors. The goal is to develop a gas concentrator. My job ranges from building a heat current control unit complete with measuring system including Arduino microcontroller through to gas analyses with metal oxide sensors and an ion mobility spectrometer. The focus is on programming, carrying out measurements and then analyzing the data. The work here is very diversified, interdisciplinary and independent. All my colleagues are extremely supportive, too, and there’s lots of sharing of ideas among students.

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Lorenz Grünerbauer

From basic research to practical projects for industry and commerce: where else would you find such a wide range? The broad Fraunhofer portfolio perfectly matched my master’s assignment in engineering and applied physics at Technical University of Munich, and through this I got involved in developing gas sensors. The key questions here were: how can I functionalize plastics in such a way that they react to certain gases in the environment? How can I integrate this effect in a sensor that is valid and offers long-term stability? The work on this project was really fascinating and I’d like to thank my colleagues for allowing me to learn so much from them in different disciplines.

Matthias Steinmaßl

I’m working as a RF Design Engineer in the Circuit & Systems department. My tasks encompass to manage the REFERENCE project at Fraunhofer EMFT and to design integrated circuits for wireless aeronautics systems. During this project, I will develop new and innovative IP for the Circuit Design department. My job is very versatile and challenging, what I appreciate a lot. Moreover, I have a supportive group manager and enjoy working in an international team.

My next goals are to complete the REFERENCE project successfully, to obtain my PhD degree at the end of the forthcoming 3 years, and to develop my personal and technical skills.

Kai Hollstein

I’m working on part of the “Smart Pump” project. We’re developing a new manufacturing concept for the automated production of micro-pumps. The aim is to define a process that is suitable for the mass market, and then select and design the components required. Fraunhofer EMFT offers us students a fascinating combination of scientific research and industrial application. We can develop concepts and potential solutions that are not just theoretical but actually get put into practice.

Since 2016 I’ve been working as a trainee in the Micromotion Dosing Systems department and I’m working on part of the “Smart Pump” project. We’re developing a new manufacturing concept for the automated production of micro-pumps. The aim is to define a process that is suitable for the mass market, and then select and design the components required. Fraunhofer EMFT offers us students a fascinating combination of scientific research and industrial application. We can develop concepts and potential solutions that are not just theoretical but actually get put into practice.

Vanessa Roth

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Xaver Lampricht
Fraunhofer EMFT has promoted the development of up-and-coming talent in the area of science and technology for over 15 years. Since 2009 the institution has been a member of the initiative “National MINT Pact – more women in MINT careers”, offering young people an insight into the prospects offered by technical professions in terms of training and university study (MINT = STEM = Science, Technology, Engineering, Math).

The tech caching Parcours were developed in collaboration with experienced practitioners and researchers working in high tech with the aim of inspiring interest in MINT topics among girls at various grade levels at an early age. The stations specifically reflect career-related aspects as well as typical materials and tools associated with the various professions.

The mobile tech caching Parcours are not just available to educational institutions but also to companies for recruitment purposes. The stations offer the following:

- Conceived and designed specifically to appeal to school girls
- Hands-on activities at 16 stations, all relating to everyday life
- Discovery of unfamiliar phenomena
- Independent error monitoring
- High-tech topic areas covered: microsystems engineering, nanotechnologies, optical technologies
- Trained supervisors
- Group size: 12 - 16 school students
- Total duration approx. 2 - 2.5 hours

“GO MINT – National Pact for Women in MINT Careers” is nationwide initiative in Germany which aims to counteract the shortage of specialists in scientific and technical professions, as well as tapping into the innovation potential of women in science and technology.

The atmosphere was great and it was a lot of fun.”

“I thought it was a great day. It was fascinating, great fun and everyone was really nice.”

“Name tags with QR code”, “Cool LEDs”, “Solar music”, “Smartly dressed in the cleanroom” – these and other themes occupied 16 7th grade students from the girls’ school Erzbischöfliche Mädchenschule Erding Heilig Blut on Girls’ Day 2016 at Fraunhofer EMFT. The students had the opportunity to carry out experiments independently in small teams and get a taste of everyday working life at a research institute. They also passed through various stations of the tech caching Parcours, where the young researchers even spent their lunch break testing and exploring.

Girls in the lab

Girls’ Day on April 28, 2016

The atmosphere was great and it was a lot of fun.”

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“The atmosphere was great and it was a lot of fun.”
to financial sta...
PRESS AND MEDIA RELATIONS

SAFETY

Data security makes only sense in Europe
[Elektronik – November 2, 2016]

Digitalisation – California entrepreneur calls for “German Angst”
[Elektronik Praxis – November 8, 2016]

Internet of Things – That’s how surveillance cameras protect against double life
[Deutschlandfunk – November 9, 2016]

MEDICINE, HEALTH AND THE ENVIRONMENT

Future Hospital Room
[Hamburger Abendblatt – March 12, 2016]

Diagnosis Hotel Envy
[Frankfurter Allgemeine – March 20, 2016]

[Deutsches Ärzteblatt – April 2016]

Diagnostic Air Quality Monitoring on its way to the mass market
[Elektronik Praxis – August 31, 2016]

Emissions measurement with the smartphone
[Elektronik Praxis – August 31, 2016]

Verbund project with Fraunhofer EMFT
[GreenHospital – September 2016]

Medication dispensing system in miniature form
[Laboronline – November 2, 2016]

Concept for an integrated one-time module for monitored medication dispensing
[DeviceMed – November 17, 2016]

[Elektronik – November 2, 2016]

Digitalisation – VDE calls for Californian entrepreneur instead of “German fear”
[Elektronik Praxis – November 8, 2016]

Security in the Internet of Things – So that surveillance cameras don’t lead a double life
[Deutschlandfunk – November 9, 2016]

FOOD

Pack to the future
-Packaging News – March 2016

Smart Pack for the Ultimate Cool Beer!
[APIA Active & Intelligent Packaging Industry Association – May 9, 2016]

Smart packaging for the ultimate cool beer!
[yumda – May 25, 2016]
[Mikroelektronik Nachrichten – June 2016]

Freshness check for food
[Landshuter Zeitung – June 25, 2016]
[Moosburger Zeitung – June 25, 2016]
[Straubinger Tagblatt – June 25, 2016]

Freshness check for food
[DIE WELT – June 29, 2016]

MICROPUMPS

Zwerg mit viel Potential
[Mikroelektronik Nachrichten – March 2016]
[Labortests – May 2016]

Smallest micropump into mobile phone
[Sensortechnik + Test Messezeitung – May 2016]

The smallest pump in the world
[DeviceMed – August 7, 2016]

Die kleinste Pumpe der Welt
[DeviceMed – August 7, 2016]

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[DeviceMed – August 7, 2016]
Tessera Technologies’ Invensas unit signs licensing agreement with Fraunhofer EMFT
[thepatentinvestor – September 15, 2016]

Fraunhofer EMFT Signs Agreement to Implement ZiBond and DBI Technologies in MEMS Applications
[BUSINESS WIRE – September 15, 2016]

Braucht irgendjemand 450-mm-Wafer?
[Markt & Technik – September 16, 2016]

Chips on wafer connected by means of flip chip technology

2016 MEMS and Sensor Congress 2016 in Munich in March
[channel-e.de – February 5, 2016]

Was geht denn hier App?
[DIE WELT – November 7, 2016]

Superhirne für das IoT-Zeitalter
[Mikroelektronik Nachrichten – December 2016]
High-precision Kelvin measurement of current-voltage characteristic
Communicative exchange is especially important in science and research. This is why Fraunhofer EMFT scientists once again published their insights in various forms in the course of 2016. The following list provides a small selection of their academic publications and talks.

**Publications**

- P. Ramm, A. Klumpp, J. Weber, P. Schneider, R. Pufall, M. Engelhardt
  Our early and ongoing work in 3D integration
  3D InCites Resource Library, Phoenix & San Francisco, USA, January 2016

- Pragoti Pran Bora, David Borggreve, Erkan Isa, Linus Maurer
  Design of Analog-to-Digital-Converters in 28 nm Fully Depleted Silicon On Insulator CMOS Technology
  Cadence, Munich, January 29, 2016

- Christof Landesberger, Nagarajan Palavesam, Andreas Drost, Waltraud Hell, Robert Faul, Christoph Kutter
  Thin chip foil packaging: An enabling technology for ultra-thin packages
  Chip Scale Review, March – April 2016

- Nagarajan Palavesam
  Mechanical Reliability Analysis of Ultra-thin Chip-on-Foil Assemblies under different types of recurrent bending

- P. P. Bora, M. Roner, D. Borggreve, A. Hurni, E. Isa, L. Maurer
  Development of a Digital Temperature Transducer ASIC in a 28 nm FD-SOI CMOS Process for a Spaceborne Low Power Sensor Bus
  European Space Agency (ESA), Gothenburg, Sweden, June 13, 2016

- Stephan Altmannshofer, Ignaz Eisele, Alexander Gschwandtner
  Hydrogen microwave plasma treatment of Si and SiO2

- Bernadette Kinzel, Detlef Bonfert, Siegfried Röhl, Florian Lippert, Frank Vanselow, Erkan Isa, Doris Schmitt-Landsiedel, Linus Maurer
  A novel test method for robustness assessment of very small, functional ultra-thin chips embedded in flexible foils
  IEEE Sensors Conference, Orlando, USA, November 9 - 10, 2016

- Lars Nebrich, Franz Wenninger, Thomas Ganka, Ignaz Eisele
  Gamma detector module with silicon photomultiplier sensor and BLE communication
  5th Landshut Symposium for Microsystems Engineering, Landshut, March 9 - 10, 2016

- Martin Richter
  Miniaturization of Silicon Micropumps

- Peter Ramm
  An Overview on Silicon Technologies, Devices and 3D-Integration
  Fraunhofer EMFT Munich, Sendai, Japan, November 24, 2016

**Talks**

- Nagarajan Palavesam
  Smart capacitive CO₂ sensor
  Proceedings IEEE sensors, USA, 2016 (776-777)

- Bernadette Kinzel
  An integrated dual-polarity high-voltage driver concept for micropump applications
  Smart Systems Integration, Munich, March 9 - 10, 2016

- Martin Heigi
  CMOS Compatible Nanogap-Field-Effect-Transistor for Integrated NEMS Application
  Smart Systems Integration, Munich, March 9 - 10, 2016

- Martin Richter
  Applications and technology of piezo driven micropumps

- Martin Richter
  Cost-efficient miniaturized silicon micropumps for medical applications
  Compamed, Düsseldorf, November 14 - 17, 2016

- Peter Ramm
  Microfluidic Systems and their Applications in the Life Sciences

- Peter Ramm
  An Overview on Silicon Technologies, Devices and 3D-Integration at Fraunhofer EMFT Munich
  Fraunhofer Symposium, Sendai, Japan, November 24, 2016
DOCTORATES

Julia Linhardt

Colorimetric detection of selected gases for work and food safety applications

Doctoral dissertation in natural sciences (Dr. rer. nat.) at the Faculty of Chemistry and Pharmacy, University of Regensburg

The doctoral dissertation was completed from January 2013 to December 2015 at Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT in collaboration with the Institute of Analytical Chemistry, Chemical and Biosensors at the University of Regensburg. The dissertation was submitted to the Faculty of Chemistry and Pharmacy at the University of Regensburg on January 29, 2016 and successfully defended on March 18, 2016 ("magna cum laude").

The dissertation was supervised by Prof. Dr. Joachim Wegener.

Indranil Ronnie Bose

Organic Semiconductor based Disposable Bio-Chemical Sensors Manufactured in a Roll-to-Roll Compatible Process

Doctoral dissertation in engineering (Dr.-Ing.)

The doctoral dissertation was completed from 2011 to 2014 at Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT in Munich. The dissertation was submitted to the Faculty of Electronics and Information Technology at Technical University of Dresden on July 13, 2015 and successfully defended on January 14, 2016 ("summa cum laude").

The dissertation was supervised by Prof. Dr.-Ing. Dr. h.c. Karlheinz Bock.

PATENTS

Carrier wafer, method for holding a flexible substrate and method for producing a carrier wafer
Christoph Kutter, Christof Landesberger, Dieter Bollmann
DE 10 2014 215 333 B3

Measuring device and system for the melting curve analysis of a DNA microarray, and use of a fluorescence detector array for analysis
Anna Ohlander, Thomas Ganka, Karlheinz Bock
DE 10 2014 221 734 A1

Circular accelerator to accelerate charge carriers and method of producing a circular accelerator
Karl Haberger
DE 10 2015 200 739 B3

Device and method using a microfluid chip to detect the resistance of bacteria to an active agent under analysis
Jennifer Schmidt, Anna Ohlander
DE 10 2015 202 353 B2

Device with foil for the electrostatic coupling of a substrate to a substrate carrier
Christof Landesberger
DE 10 2015 210 736 B3
Fraunhofer EMFT staff promote the transfer of knowledge through various memberships of networks and collaborative ventures. This enables them to tackle interdisciplinary tasks that go beyond the confines of the institution itself.

### MEMBERSHIPS

<table>
<thead>
<tr>
<th>Organization</th>
<th>Scientist</th>
<th>Position</th>
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<tr>
<td>CeNS/LMU, Center for Nanoscience</td>
<td>Marc Tornow</td>
<td>Member</td>
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<td>Cluster-Offensive Bayern:</td>
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<tr>
<td>- Power electronics</td>
<td>Christof Landesberger</td>
<td>Members and technical consultants</td>
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<td>- Microsystems engineering</td>
<td>Robert Faul</td>
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<td>- Sensors</td>
<td>Hanns-Erik Endres</td>
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<td>Cosima Student Competition</td>
<td>Martin Richter</td>
<td>Jury member</td>
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<td>Critical Manufacturing, Portugal</td>
<td>Peter Kücher</td>
<td>Member of the Advisory Board</td>
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<td>db, deutscher ingenieurinnenbund e.v.</td>
<td>Sabine Scherbaum</td>
<td>Member</td>
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<tr>
<td>German Physical Society</td>
<td>Hanns-Erik Endres, Christoph Kutter, Peter Kücher, Marc Tornow, Johannes Weber, Axel Wille</td>
<td>Members</td>
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<tr>
<td>ECTC, Electronic Components and Technologies Conference, USA</td>
<td>Peter Ramm</td>
<td>Member of the Subcommittee Advanced Packaging</td>
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<tr>
<td>Eduard Rhein Foundation</td>
<td>Christoph Kutter</td>
<td>Member of the Board of Curators</td>
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<tr>
<td>EOS/ESD Association, USA</td>
<td>Horst A. Gieser</td>
<td>Member</td>
</tr>
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<td>EOS/ESD Symposium, USA</td>
<td>Heinrich Wolf</td>
<td>Member of the Technical Program Committee</td>
</tr>
<tr>
<td>ESD Association</td>
<td>Horst A. Gieser, Heinrich Wolf</td>
<td>Members, standardization, experts</td>
</tr>
<tr>
<td>ESD-FORUM e.V.</td>
<td>Horst A. Gieser</td>
<td>Board Chairman and Founding Member, Conference Chair of the 13th ESD-FORUM</td>
</tr>
<tr>
<td>EuMV, European Microwave Week</td>
<td>Christoph Kutter</td>
<td>Advisory council of the cross-sectoral consultation body</td>
</tr>
<tr>
<td>GMM, Division 4 Microsystems Engineering and Nanotechnology, Committee on Microactuators</td>
<td>Martin Richter</td>
<td>Member</td>
</tr>
<tr>
<td>University of Applied Sciences Landshut Microsystems Engineering Cluster</td>
<td>Robert Faul</td>
<td>Technical Consultant</td>
</tr>
<tr>
<td>IEEE, Institute of Electrical and Electronics Engineers, USA</td>
<td>Peter Kücher, Christoph Kutter, Linus Maurer, Peter Ramm</td>
<td>Members</td>
</tr>
<tr>
<td>IEEE (CPMT), Components, Packaging and Manufacturing Technology, USA</td>
<td>Detlef Bonfert, Christoph Kutter, Peter Ramm</td>
<td>Members</td>
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<tr>
<td>IEEE (EDS), Electron Devices Society, USA</td>
<td>Detlef Bonfert, Peter Ramm</td>
<td>Members</td>
</tr>
<tr>
<td>IEEE (ComSoc), Communication Society, USA</td>
<td>Detlef Bonfert</td>
<td>Member</td>
</tr>
<tr>
<td>IEEE, International NEWCAS Conference USA</td>
<td>Erkan Isa</td>
<td>Member of the Steering Committee</td>
</tr>
<tr>
<td>IEEE (ISCDG), International Semiconductor Conference Dresden – Grenoble</td>
<td>Christoph Kutter</td>
<td>Head of the Technical Program Committee</td>
</tr>
<tr>
<td>IEEE Transactions on Electron Devices</td>
<td>Peter Ramm</td>
<td>Regular Consultant</td>
</tr>
<tr>
<td>IEEE (MTT), Microwave Theory and Techniques Society, USA</td>
<td>Detlef Bonfert, Linus Maurer</td>
<td>Members</td>
</tr>
<tr>
<td>IEEE (SDIC), International 3D System Integration Conference</td>
<td>Peter Ramm</td>
<td>Head of the Organizing Committee Europe and Founding Member</td>
</tr>
</tbody>
</table>
## MEMBERSHIPS

<table>
<thead>
<tr>
<th>Organization</th>
<th>Scientist</th>
<th>Position</th>
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</thead>
<tbody>
<tr>
<td>IEEE Sensor Council</td>
<td>Peter Kücher</td>
<td>Member</td>
</tr>
<tr>
<td>IEEE (SIU), Signal Processing and Communications Applications Conference</td>
<td>Erkan Isa</td>
<td>Member of the Technical Committee</td>
</tr>
<tr>
<td>IEW, International Electrostatic Workshop, USA</td>
<td>Heinrich Wolf</td>
<td>Member of the Technical Program Committee</td>
</tr>
<tr>
<td>iMAPS, International Microelectronics Assembly and Packaging Society, USA</td>
<td>Detlef Bonfert</td>
<td>Member</td>
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<tr>
<td>iMAPS DPC, iMAPS Device Packaging Conference, USA</td>
<td>Peter Ramm</td>
<td>Fellow of Society and Member of the Awards Committee</td>
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<tr>
<td>Industry Council on ESD Target Levels</td>
<td>Horst A. Gieser</td>
<td>Member</td>
</tr>
<tr>
<td>Innovationspreis der deutschen Wirtschaft</td>
<td>Christoph Kutter</td>
<td>Member of the Board of Trustees</td>
</tr>
<tr>
<td>ISSE, International Spring Seminar in Electronics</td>
<td>Detlef Bonfert</td>
<td>Member of the Steering Committee</td>
</tr>
<tr>
<td>IWLPC, International Wafer-Level Packaging Conference</td>
<td>Peter Ramm</td>
<td>Chairman of the Subcommittee 3D Integration</td>
</tr>
<tr>
<td>MOVE – service point at Frauenakademie München</td>
<td>Sabine Scherbaum</td>
<td>Mentor</td>
</tr>
<tr>
<td>mst</td>
<td>femNet meets Nano and Optics in the National Pact for Women in MINT Careers</td>
<td>Sabine Scherbaum</td>
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<tr>
<td>MST Congress</td>
<td>Martin Richter</td>
<td>Member of the Program Committee</td>
</tr>
<tr>
<td>NERGID, NanoElectronics Roadmap for Europe</td>
<td>Peter Ramm</td>
<td>Member of the Advisory Committee</td>
</tr>
<tr>
<td>Robert Bosch Zentrum Reutlingen</td>
<td>Ignaz Eisele</td>
<td>Member of the Advisory Board</td>
</tr>
<tr>
<td>SEMI Heterogeneous Integration Roadmap (HIR)</td>
<td>Peter Ramm</td>
<td>Contributing Member</td>
</tr>
<tr>
<td>SEMI North America</td>
<td>Peter Ramm</td>
<td>Member of the Standards 3DS-IC Committee and the Technical Program Committee</td>
</tr>
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<thead>
<tr>
<th>Organization</th>
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<tbody>
<tr>
<td>SiTME, International Symposium for Design and Technology in Electronic Packaging</td>
<td>Detlef Bonfert</td>
<td>Members of the Steering Committee</td>
</tr>
<tr>
<td>SMITA, Surface Mount Technology Association</td>
<td>Peter Ramm</td>
<td>Member of the Technical Program Committee</td>
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<tr>
<td>TIE, Interconnection Techniques in Electronics</td>
<td>Detlef Bonfert</td>
<td>Members of the Steering Committee</td>
</tr>
<tr>
<td>University College Cork</td>
<td>Peter Ramm</td>
<td>Expert Consultant Research Quality</td>
</tr>
<tr>
<td>VDE ITG, Informationstechnische Gesellschaft</td>
<td>Linus Maurer, Werner Muth</td>
<td>Members</td>
</tr>
<tr>
<td>VDE/VDI-Gesellschaft Mikroelektronik, Mikro- und Feinwerktechnik, GMM</td>
<td>Christoph Kutter</td>
<td>Deputy Chair</td>
</tr>
<tr>
<td>VDI Verein Deutscher Ingenieure (Association of German Engineers)</td>
<td>Christoph Jenke, Axel Wille</td>
<td>Members</td>
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<tr>
<td>VDI VDE IT GmbH</td>
<td>Christoph Kutter</td>
<td>Member of the Supervisory Board</td>
</tr>
<tr>
<td>Robert Wieland</td>
<td>Member</td>
<td></td>
</tr>
</tbody>
</table>

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