FOREWORD
Dear friends and partners of the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT, dear reader,

Looking back at 2015, it was a year that was very much geared towards our customers: our researchers worked on numerous projects from a wide range of different industries and our cleanroom capacity was well used by external businesses and cooperation partners. We also focused on our service quality and were able to further optimize process stability and keep our projects on schedule.

There was a very positive response to our strategic focus and R&D priorities, which attracted great interest: our new micro-pump – currently the smallest in the world – caused a sensation among experts and is increasingly in demand from all quarters. New perspectives are constantly opening up for future areas of use. Interest in our flexible foil systems increased considerably in 2015 and we were able to initiate a number of exciting projects in this field with well-established customers. In terms of our ESD systems, we are currently involved in establishing a new industry standard for Charge Device Model Testing.

In September we also invited several experts from industry and research to critically review our strategy process. This audit confirmed our course in many aspects as well as providing us with valuable ideas as to how we can secure our success on a lasting basis.

However, scientific vision was by no means neglected in 2015 either: there are now 14 doctoral students working at Fraunhofer EMFT, all of them trying out new things with enormous enthusiasm. In the field of silicon technology this is leading us to fundamental new insights in epitaxy and characterization. Meanwhile in the field of foil technologies and micropumps, the primary focus was on the issue of reliability. In our “youngest” business area, Sensor Materials, our junior researchers have come up with exciting new approaches that allow us to consider integrating these sensor materials in our electronic sensors. The new area of Circuit Design has developed particularly impressively: we have succeeded in acquiring several large-scale EU projects, allowing us to advance the development of the group more quickly. We are currently developing analog-digital blocks for state-of-the-art wafer technologies that we can use for our sensor systems.

Collaboration with the Munich universities was further extended and we are now involved in a whole range of joint projects with Universität der Bundeswehr, TU München and Munich University of Applied Sciences.

Scientific highlights of 2015 included our established forum “Be Flexible” and the joint workshop with TechSearch. In fact there was so much interest in the TechSearch workshop on Panel Processing – Filling the Gap between Front-End and PCB* that we had to limit participant numbers.

Over the years, our workshop “Be Flexible” focusing on applications and technologies has become a very powerful brand of its own.

Dear reader, all that remains is for me to hope very much that you enjoy reading our 2015 annual report.

Best regards,

Prof. Dr. Christoph Kutter
Director of the Fraunhofer Institution for Microsystems and Solid State Technologies EMFT
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## Publishing Notes
Fraunhofer EMFT is engaged in top-level applied research into sensors and actuators for people and the environment.

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**History**

Fraunhofer EMFT was formed from the Fraunhofer Institute for Solid State Technology IFT, which was founded in 1974. Here, technologies were developed for the manufacture of semiconductors. Other areas of activity were sensor technology, communication technology and microstructure technology.

In 1999 the Fraunhofer IFT was dissolved and split into three independent sections. The section located in Hansastrasse, Munich – today’s Fraunhofer EMFT – initially became part of the Berlin-based Fraunhofer Institute for Reliability and Microintegration IZM. Fraunhofer EMFT itself was founded on July 1, 2010, as an independent institution once again, created from the Munich branch of the Fraunhofer IZM.

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**Profile**

In its research and development work, Fraunhofer EMFT focuses on sensors and actuators for people and the environment. Sensors already have a key role to play in our digitized world and will become increasingly important in the years to come as a result of the interconnection of devices (“Internet of Things”). People may not actually notice sensors, but the latter will make a significant contribution to improving the quality of living in areas such as health and nutrition, mobility and material analysis. Fraunhofer EMFT actuators will be used in micropumps and microvalves in medicine and industry, for example. In defining its research fields, Fraunhofer EMFT always attaches priority to practical application. The institution gets together with customers to assess areas which are important for the market where Fraunhofer EMFT can make a significant contribution with its expertise.

The aim of applied research is to create added value for society and for the economy. This added value consists of transferable work results, operational components and systems and qualifiable prototypes. Cutting-edge research means occupying a leading position in global competition. Fraunhofer EMFT is a sought-after guest on the relevant committees, conventions and conferences and is proactively involved in organizing such forums itself. The results of Fraunhofer EMFT’s work appear in a wide range of academic publications and attract a high level of interest in the world of science.

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 result in exceptional commitment and dedication, ultimately producing good results.
The institution in figures

Total budget

Fraunhofer EMFT once again performed successfully in fiscal 2015. The institution’s total budget amounted to approx. 11 million euros in 2015. Industry contracts generated a total volume of EUR 3 million, accounting for approx. 28.5% of the total budget.

Ongoing expansion of the institution is planned for 2016, involving a further increase in industrial revenue.

Personnel development

Fraunhofer EMFT currently employs a staff of 92. Of these, 60 work in the scientific area and another 32 in the areas of administration, marketing, IT and technology. On average there are also 23 students and research assistants from a wide range of institutions working on their doctoral thesis, dissertation or master’s degree assignment at any given time and also involved in the various research areas at Fraunhofer EMFT. Fraunhofer EMFT also employs two trainees.

Infrastructure

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 (1,477 m²)
- Office areas and meeting rooms: (1,852 m²)

In Regensburg Fraunhofer EMFT rents offices and labs for its Sensor Materials working group at Biopark, opposite the University of Regensburg. Staff also use the labs at the University of Regensburg itself. This ensures close scientific cooperation.

There are cleanrooms of varying cleanroom classes available in Munich. 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 enable intense professional dialog.
Advisory Board

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 Fraunhofer EMFT Advisory Board advise the 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

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Dr. Reinhard Fojt
KETEK GmbH

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Synergy Microwave Europe GmbH & Co. KG

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
BUSINESS AREAS
BUSINESS AREAS

SENSOR MATERIALS
SILICON TECHNOLOGIES AND DEVICES
MICRO DOSING SYSTEMS
FLEXIBLE SYSTEMS
CIRCUITS & SYSTEMS
At Fraunhofer EMFT, sensor materials are developed for applications in 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, such sensor materials 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 evaluation 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. In a cooperation with Fraunhofer IVV, e.g. sensor materials were developed for visual detection of oxidative quality changes in packaged (and opened) cooking oils and roasted nuts. 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. The insights gained will also be used as a basis on which to develop indicator systems for other types of food (e.g. meat, fish, ready-made products) and will be fed into the area of sensor technology.

In another current project Fraunhofer EMFT is looking into combining optical and electrical signal analysis. The aims are to achieve better exploitation of measurements and to extend the range of application. The combination of new sensor materials with Fraunhofer EMFT silicon technologies enables the creation of new energy-efficient systems here.

In the area of biosensorics, fluorescence-based sensor materials enable very sensitive analyte detection. Based on this type of materials, fluorescence-based assays are developed at Fraunhofer EMFT to specifically detect certain bacteria.

In combination with the relevant analysis systems, it is possible to selectively detect bacteria very quickly, making the systems well suited for use in the field of medicine and hygiene. Rapid, specific on-site tests are urgently needed to improve hygiene practices and the selection of suitable medication for therapy. 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 various 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 might be in 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:
Current projects in this business area concentrate on the following R&D focus areas:

- Development of new methods and materials for
  - gas detection
  - ion detection
  - the detection of neutral molecules
  - 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.

### Outstanding results of recent years

- Detection reactions to monitor the freshness of meat (BMBF, SensAmin)
- Test combining optical sensor materials with electronic signal analysis (Bavarian Ministry of Economic Affairs and Media, Energy and Technology)
- Reactions to detect multi-resistant pathogens (MST Bayern, MRSA Rapid Test)

<table>
<thead>
<tr>
<th>Customer group/industry</th>
<th>Application</th>
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<tbody>
<tr>
<td>Packaging industry,</td>
<td>Food safety</td>
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<tr>
<td>Food industry</td>
<td></td>
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<tr>
<td>Hospitals</td>
<td>Hygiene</td>
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<tr>
<td>Device manufacturers,</td>
<td>Occupational safety</td>
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<tr>
<td>Textile industry,</td>
<td></td>
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<tr>
<td>Chemical industry</td>
<td></td>
</tr>
<tr>
<td>Device manufacturers,</td>
<td>Water quality,</td>
</tr>
<tr>
<td>Chemical industry</td>
<td>Environmental monitoring</td>
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</table>
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. The institution also offers its customers a wide range of different services such as process development, small batch 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. Trends suggested by the communication of “things with things” were demonstrated at the “Trillion Sensor Summit 2014” in Munich, for example.

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 anticipate 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 measured very precisely by determining their physical properties (e.g. optical absorption, fluorescence etc.), but the measuring systems used tend to be very large and expensive. What is more, measuring is disrupted due to chemical reactions caused by the cross-sensitivities that occur. So there is great demand for the development of low-cost transducers that convert chemical signals into electrical ones.

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 then be covered by means of 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.

This business area covers the two market segments “Services and components” and “Microsystems and applications”, 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 many applications and sectors, including material analysis (e.g. characterization of semiconductor materials) process analytics (e.g. quality analysis of gases, novel purification methods), environmental analytics (e.g. room climate control), medical technology (e.g. identification of multi-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 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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**Outstanding results of recent years**

- **MRSA Rapid Test (Bayern MST Projekt):** A rapid detection method for identifying the methicillin-resistant pathogen Staphylococcus aureus (MRSA) is being developed in collaboration with the business area Sensor Materials and the Asklepios clinics.
- **e-BRAINS (EU project):** Manufacture of 3D TSV-based high-frequency components for RF-MEMS and RF-IC applications (including High-Q inductors and 60 GHz antennas)
- **MANpower (EU project):** Assembly of a miniaturized energy generation and storage system for pacemakers
- **HRFET (Bayern MST project):** Successful development of extremely low-noise Junction FETs (JFETs) and Depletion MOSFETs for highly sensitive sensors and low-noise oscillators in high frequency technology
- **SiPM (industry project):** Highly sensitive silicon photomultipliers (SiPM) were developed in collaboration with KETEK. The components are subject to ongoing optimization and improvement. The processes are subsequently transferred to a foundry for serial production
In the business area Micro Dosing Systems, individually tailored microdosing solutions are developed for the most diverse applications – from the concept 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 micro dosing systems offer considerable application potential:

In the area of medication dosage, externally portable micro dosing systems could be used for 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 disposable dosage components used have to be very low-cost.

Micro dosing technology is an interdisciplinary 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 how the system responds.

Meanwhile, there are a range of other interesting challenges in the field of micro dosing: 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 possibility of monitoring dosage
- Low level of material consumption
- Low level of energy consumption
- Miniaturization
- Low price, making the technology suitable for mobile devices and disposable applications in medicine
- Low weight
- Improved mobility
- Simpler integration

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

<table>
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<tr>
<th>Customer group</th>
<th>Application</th>
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<tbody>
<tr>
<td>Mobile phone manufacturers,</td>
<td>Micropumps in smartphones</td>
</tr>
<tr>
<td>System manufacturers, MEMS fabs</td>
<td></td>
</tr>
<tr>
<td>Mechanical engineering</td>
<td>Lubrication dosage</td>
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</table>
The R&D services in this business area are as follows:

- Solution of industrial problems in the area of micro dosing and consultation of industry clients
- Design of micro dosing systems taking into account disturbance variables
- Design of micro dosing components such as micropumps, microvalves, free flow stop, bubble separators, dosage monitoring
- Validated library of design tools for micro dosing 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 micro dosing systems incl. control and regulation
- Realization of customer-specific prototypes (components and systems)
- Consultation and support in realizing an industrial manufacturing chain for micro dosing systems
- Licensing, expertise and technology transfer

Outstanding results of recent years

- Creation of the smallest micropump in the world (chip measurements: 5 x 5 x 0.6 mm³)
- TUDOS: Medication dosing system with silicon micropump which offers a very large suction and pressure capability. (MAVO project, internal funding program as a cooperative venture between Fraunhofer EMFT, Fraunhofer IBMT, Fraunhofer ITEM, Fraunhofer IZM and Fraunhofer LBF)
- Mikroaug: Micro dosing system in the form of an implant for treating glaucoma and phthisis by means of permanent regulation of intraocular pressure. (Publicly funded project as part of “IKT 2020 - Research for Innovations” by the BMBF, joint innovative SME project)
- Nanolub: Nanoliter lubricant dosing system for tool machine spindles. (Publicly funded project of the Bavarian Ministry of Economic Affairs and Media, Energy and Technology as part of the R&D program “Microsystems Engineering Bavaria”)

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Application</th>
</tr>
</thead>
</table>
| Medical technology | Medication dosage  
Glaucoma therapy  
Sphincters  
Wound healing |
| Lab technology | Air displacement pipettes  
Microtiter plate dosage |
| Other | Scent dosage  
Micro fuel cells  
Tissue engineering |
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 unmistakable trend towards increasingly flat and flexible systems in electronics.

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 points in this connection are the extremely low installation height, the flexibility of the system with very small curvature radiiuses 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, the Internet of Things (IoT) with its demand for largely energy-autonomous, wirelessly networked and increasingly low-cost sensor systems will be one of the crucial driving forces behind developments in the business area Flexible Systems, too.

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)
- E-carrier (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. The area is 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>
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</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 electronics</td>
<td>Extremely flat electronics, Sensitive surfaces, Robotics</td>
</tr>
</tbody>
</table>

Measuring technology

Extremely flat electronics, Sensitive surfaces, Robotics
Outstanding results of recent years

- Chip integration technology for high-frequency applications (HF-SiP)
- Best Paper Award and Microwave Prize 2013 (European Microwave Conference, result of the customer project with Sony European Technology Center, Stuttgart)
- Self-assembly and self-alignment of silicon chips, demonstration of alignment precision (Best Paper Award MES Conference 2012, result of customer project with Panasonic Factory Solutions Europe GmbH)
- Functional product protective foil using roll-to-roll method (customer contract)
- Small-series production of sensor foil systems (temperature measurement/display/battery integrated in flexible substrate; customer assignment)

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// BUSINESS AREAS

<table>
<thead>
<tr>
<th>Customer group</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electronic components</td>
<td>Special flat casings (Foil casings)</td>
</tr>
<tr>
<td>Semiconductor industry</td>
<td>Thin wafer handling</td>
</tr>
<tr>
<td>Printed Circuit Board /</td>
<td>Processing of foil sheets</td>
</tr>
<tr>
<td>Flexible Printed Circuit</td>
<td>(Ultra thin circuit carriers), Foil interposers</td>
</tr>
<tr>
<td>industry</td>
<td></td>
</tr>
<tr>
<td>Special ceramics</td>
<td>Handling of fragile substrates</td>
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</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, demonstrators, small-series production
- Components with differing form factors, integration in utility objects
- Integration of thin ICs, wireless communication interface
- Handling techniques and systems for thin substrates
- Technology consultation and studies
CIRCUITS & SYSTEMS

The business area Circuits & Systems offers its customers individually tailored solutions and services, ranging from the development of integrated and discreetly structured circuitry through to complete modules and systems including 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 “Circuit 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 makes market entry easier. 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. The business area will benefit from this growth. Based on the high growth rates projected for semiconductor elements and electronics, the market for system development and integration will also grow. Fraunhofer institutions such as Fraunhofer EMFT are able to draw on the benefits of their excellent technical and technological facilities and 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 rough conditions. 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 require 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>
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<tr>
<th>Customer group</th>
<th>Application</th>
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<tbody>
<tr>
<td>System manufacturers and providers</td>
<td>Medical technology Diagnostics</td>
</tr>
<tr>
<td>Design companies</td>
<td>Aviation and aerospace</td>
</tr>
<tr>
<td>Component manufacturers</td>
<td>Industrial sensors</td>
</tr>
<tr>
<td>Semiconductor manufacturers</td>
<td>Actuator technology</td>
</tr>
<tr>
<td>Contract manufacturers</td>
<td>Automotive</td>
</tr>
<tr>
<td>Testing facilities/analysis labs</td>
<td>Test engineering</td>
</tr>
<tr>
<td>Internal customers</td>
<td></td>
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</table>

The business area's main customers include both large corporations and SMEs, some of them in leading competitive positions.

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, robustness
- 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)

Outstanding results of recent years

Circuit Design
- THINGS2DO: RF front-end specification, ASIC integration, A/D converter design for sensors and communication on a 28 nm FDSoI technology (funded by the Federal Ministry of Education and Research (BMBF) as part of the European initiative ENIAC, which is also supported by the European Commission)
- WAYTOGOFAST: mm-wave oscillator and package development with 22 nm FDX (funded by the Federal Ministry of Education and Research (BMBF) and the European Union)
- ADMONT: High-voltage driver concept and ASIC development (funded under the European Framework Programme for Research an Innovation HORIZON 2020)

Analysis & Test
- Customer-specific modular CDM test system (used by semiconductor manufacturers worldwide for qualification tests)
- Capacitive Coupled Transmission Line Pulsing method (CC-TLP) for the reproducible CDM-like exposure of integrated circuits (worldwide USP due to patent; now also sold on a customer-specific basis for the first time); its systematic investigation has also been funded since 2014 as ERC by the ESD Association, Cisco, IBM and TSMC
- Development of an ESD protection library for the mixed-signal high voltage process of an Asian contract manufacturing system level ESD co-design
- i-Tex: intelligent provision, characterization and reliability of a large-area intelligent LED lighting system on a textile basis
- Bending machine for flexible and rigid-flexible circuit boards up to 180°: developed from the i-Text project in collaboration with FED
- Various successful project for often multiphysical analysis and reproduction of failure causes

System Integration
- MRSA Rapid Test: Fluorescence measuring device based on a SiPM to detect methicillin-resistant pathogen Staphylococcus aureus
- Gamma detector with a SiPM and scintillator
- USB analysis electronics for capacitive sensors (e.g. CO₂, moisture sensors etc.)
- Measuring cell to detect bacteria in drinking water
- Measuring device to determine color values/color changes (e.g. using colorant test strips)
COMPETENCES
COMPETENCES

FUNCTIONAL MOLECULES

SILICON TECHNOLOGIES, DEVICES AND 3D INTEGRATION

MICROPUMPS

FOIL TECHNOLOGIES

DESIGN, SYSTEM INTEGRATION AND TEST

USB stick to measure air quality
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 and 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, which then 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 intensity of the change depends on the analyte concentration. 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.

The indicator molecules are either embedded in polymers or attached to microparticles or nanoparticles on surfaces. In this way it is possible to develop new types of sensor materials.

The competence covers the following research focus areas:

- Synthesis of new indicator 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 scientific edge that will establish it as a contact partner for material development for new kinds of sensors. The role of the competence for innovative sensor development is to be extended by developing new materials for the detection of amines, carbon monoxide and cyanides and by means of 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 for research, development and manufacture of sensor and actuator components and in order to provide services in this business area. Silicon technologies are a longstanding area of expertise at Fraunhofer EMFT, allowing research and development of 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 the field of nanostructures
- With low-temperatures, 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 complete characterization of the noise characteristics of components and to analyze the reasons behind it

**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 metrological expertise for JFETs, MOSFETs, diodes and sensors and uses this 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 at Fraunhofer EMFT.

**A look ahead**
The following strategic projects are already in progress, aiming at establishing 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

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 a lot of 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 this breadth of solutions for microdosing systems. The institution’s understanding of the requirements of industrial users – the result of two decades of talking to industrial clients – enhances the added value to the customer. The many disturbance variables are also well understood and in some cases already 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 with some broad and central key patents.

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

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
- Library of electronic activation systems
- Broad range of flow sensors and dosage monitoring systems
- Management of particles and bubbles

A look ahead

The main focus of the competence is on further miniaturization of silicon micropumps, in order to significantly reduce the manufacturing costs of silicon pumps.

The first successful step was taken in 2015: miniaturization of the pump chip from $7 \times 7 \text{ mm}^2$ to $5 \times 5 \text{ mm}^2$. Further miniaturization to $3 \times 3 \text{ mm}^2$ is currently being implemented. This is a necessary requirement in order to be able to produce micropumps in large volumes for mass applications.

The current focus in terms of the metal platform is the design of microdosing components, involving cooperation with industry partners who are to 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 to further enhance the quality and reliability of the micropumps.
The basis for the business area Flexible Systems is provided by the competence Foil Technologies. This includes both coating and structure processes to produce electronic components under the specific conditions of foil substrate as well as system integration with the appropriate assembly and interconnection techniques. Another central 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 the customer). As such, Fraunhofer EMFT 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

**Hybrid foil integration**
- Chip-in-foil
- Foil-to-foil
- 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 demonstrators 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 engineering solutions are created at Fraunhofer EMFT that are specifically geared towards customer requirements and can then be credibly validated using suitable testing methods. Cross-departmental collaboration allows both R&D customers and licensees to be offered efficient and sustainable options.

Development expertise includes IC design, hardware and software, electronics, mechanics, optics, testing and analysis – from the first feasibility demonstrator through to the prototype, providing the basis for the range of services provided by the business area Circuits and 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). Here, investments in an ultra fast oscilloscope (63 GHz) and modular test systems (modular 2-pin test systems) as well as various in-house developments (modular CDM, CC-TLP) continue to create the basis for ongoing positioning among the leaders in this field.

**Design, System Integration and Test**

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**Capabilities, processes and technologies**

- Definition and development of integrated circuit blocks (IP) and ASICs in low-power and high-voltage-mixed-signal technologies (28 nm FDSOI and 22 nm FDSOI or XU035 CMOS) in the areas of RF, waves and signal processing
- Electronics: circuit development in the area of sensorics and sensor networks
- Programming of microcontrollers and PC software
- Optics/LED: simulation, design, characterization, reliability
- Mechanics: mechanical design and assembly
- Prototype production
- Testing methods and systems, calibration (standardize and specific to particular applications/technologies)
- Reliability studies
- ESD protection concepts and libraries
- ESD test methodology (modular CDM test, CC-TLP, Ultra fast TLP, system level ESD, secondary discharge (USP))
- ESD test services and failure reproduction (CDM, HBM, modular 2-pin test for components and wafers)
- 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 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. This includes concept, design draft, circuit simulation/verification, layout, physical verification and validation. Third-party circuit blocks (IP) are integrated in addition to in-house developments.

The focus is on designing circuit blocks and complete ASICs and systems on chip for very high frequencies, low-noise amplifiers, power amplifiers and AD converters. The specialist expertise acquired in relation to high-voltage circuits will be used in numerous actuator and MEMS applications in future.

System integration
In the near future, developing and building application prototypes for sensorics and sensor networks will be the main focus in the area of system integration. Sensor elements developed at Fraunhofer EMFT will be used for this purpose as well as commercial sensors

Analysis and test
In the years to come there will be continued expansion of the range of expertise amassed over years of work in collaboration with well-known customers – from the technology to the system and back to the latter’s causes of failure. Synergies with IC design provide the opportunity to establish expertise in the development of application-specific ESD-robust pad libraries for high voltage and mixed signal technologies. By establishing a circuit design environment, the basis is provided for efficient in-house development of pad cells and integrated ESD protection concepts.

What is more, it is possible to refine ESD testing methods on an ongoing basis drawing on industrial problems and familiarity with the weak points of existing methods. Examples here include the CC-TLP method, which has enormous long-term potential to replace the load required for component qualification according to the Charged Device Model (CDM). Nonetheless, modular CDM test platforms can still be created to industry order based on a commercial positioning system so as to continue to qualify components based on the existing CDM standard. Experience of various industry projects shows that only a correct assessment of load scenarios and precise measurement of the load allow systematic validation and improvement.

The modular 2-pin ESD test system already put out to procurement tender will create new possibilities for a system-efficient ESD design SEED and system level ESD co-design, supporting work on secondary discharge robustness using in-situ current measurement methods. System integration expertise is used to develop and realize the test systems.
FROM RESEARCH AND DEVELOPMENT
EXEMPLARY OF PROJECTS AND APPLICATIONS

HEALTH AND ENVIRONMENT
SECURITY AND PROTECTION
ENERGY AND RESOURCES
PRODUCTION AND SUPPLY OF SERVICES
Examples of Projects and Applications

Fraunhofer EMFT is involved in various projects, collaborating with organizations in science and industry to develop future-oriented solutions aimed at tackling major challenges facing society today.

**MANpower**

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

The future user of this innovative technology and the French project partner LivaNova, Europe’s leading manufacturer of pacemakers.

**Mikroaug**

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 or 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.

At the heart of the system is a tiny biocompatible silicon micromembrane pump measuring just 7x7x1 mm³ and a flow rate of no more than 800 μl/min. This 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 doctor providing treatment can set the flow rate of the micropump in relation to eye pressure.

**MRSA Rapid Test**

Multi-resistant pathogens are becoming an increasing problem for hospitals and doctors’ surgeries. Infections that are not detected in time can spread quickly and become a serious health risk to individuals who are already in a weakened state. MRSA (methicillin-resistant Staphylococcus aureus) tests are currently only carried out on suspected patients since the methods are either very time-consuming (microbiological culture detection) or very cost-intensive (molecular biological or antibody-based detection).

A research team at Fraunhofer EMFT is currently working with Asklepios Kliniken GmbH and KETEK GmbH to develop a low-cost MRSA Rapid Test which is suitable for routine access control at hospitals or doctors’ surgeries. In this way it would be possible to significantly reduce the risk of transmission to other patients. The rapid test requires only a nose smear to be taken from the patient. Whether or not multi-resistant pathogens are contained in the sample is shown by fluorescence indicators, which are detected by a highly sensitive measurement system within a short period of time.

In order to be able to offer this innovative rapid test method as a product in future, the entire system is being assembled as a mobile hand-held device for on-site analytics. The new detection method is to be verified in clinical tests carried out at selected Asklepios clinics.

The project is funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology as part of the program “Microsystems Engineering Bavaria”.
COPYCAT

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 in terms of the firmware of such systems, a Fraunhofer EMFT research team is working on the MAVO 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 fully encased 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. 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 electronics for internal and externally connected PUF structures in a microchip.

InForMed

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. Here, a Fraunhofer EMFT research team is collaborating with Dräger Safety AG, jvi 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.

SMOKESENSE

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.

HRFET

In the project HRFET (low-noise field-effect transistors with high-frequency capability), a Fraunhofer EMFT research team is working with KETEK GmbH to develop novel FET transistors which are suitable for use in the Gigahertz range and are extremely low-noise. At the moment it is not possible to combine these two properties. The project partners are essentially pursuing two different potential solutions. Firstly they are advancing the development of so-called JFETs (Junction FETs), which already demonstrated excellent properties in the Megahertz range in a predecessor project. The second approach is a new type of CMOS concept with so-called “buried channel” MOS transistors. The two concepts are based on self-adjusting processes that allow the active channel length to be heavily reduced. This in turn enables an advance into the Gigahertz range, since a shorter channel length also means a higher transit frequency. The field-effect transistors to be developed are to be used for a pre-amp stage in the field of x-ray spectroscopy, and application is also planned in high-frequency oscillators and mixers.
The project is funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology as part of the MST Bavaria program.

Nanolub

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 enabling absolutely reliable operation of the dosing system. The focus was on advancing development of the dosing and sensor algorithms, achieving deeper understanding of the fluid mechanical properties of the concept, a precision model that allows for the influence of signal processing and – derived from this – a proposal for the next generation of the sensor microchannel to be produced. The next will be to set up an infrastructure to manufacture and install pump and flow sensor modules in series.

ADMONT

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 micro dosing 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.
CONTEST

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 due to delamination of the electrical contacts in the chip foil packages or breakage in the wiring 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’.

NanoFET

In the project “NanoFET”, Fraunhofer EMFT researchers are collaborating with Infineon, Siemens and Micro-Epsilon to develop highly-sensitive sensors. The core is a nanogap field-effect transistor with a mechanically movable gate.

Mechanically oscillating tongues and membranes have been established in MEMS technology as sensors for acceleration and pressure for some time. The aim of “NanoFET” is to increase the sensitivity of such sensor systems significantly by means of miniaturization: since the oscillation structures of the NanoFETs are just a few nanometers above the channel area, even the slightest mechanical deflections of the gate result in significant changes in the electrical properties of the field-effect transistor. Miniaturization to nano scale is thus a key factor in order to achieve a significantly higher level of sensitivity as compared to conventional solutions. The principle can be scaled down to well below one micrometer.

The scalability of this technology in particular as well as its full compatibility with CMOS proces-
The research team developed a gas sensor as a demonstrator which could be used to monitor room climate, for instance. A gas-sensitive layer is applied to the oscillator for this purpose. If gas molecules from the ambient air are present – in this case CO$_2$, for instance – the normal frequency of the oscillators is altered. The project is funded by Infineon Technologies and the state of Bavaria.

**POWERBASE**

Compact and energy-efficient power electronics is a key technology in being able to face up to central challenges of our age – such as climate change, energy supply, nutrition, health and demographic change. The ECSEL project POWERBASE involves 39 partners all over Europe, including Fraunhofer EMFT, who are collaborating on a new generation of compact and energy-efficient power semiconductors. Two approaches are essentially being pursued here. Firstly, the development of silicon technologies is being advanced based on cutting-edge 300 mm power semiconductor technologies. The second focus area of research work is the development of new gallium nitride power semiconductor technologies suitable for mass production.

In this project, 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 project results to point the way forward to a diverse range of more energy-efficient products such as LED lighting systems, solar inverters and charging devices. The project is funded by the European research program “HORIZON 2020” and the BMBF as part of the ECSEL initiative.

**THINGS2DO**

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”.

WAYTOGOFAST

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. The semiconductor manufacturer STMicroelectronics is coordinating the research and development activities of the 33 project partners from research and industry.

Here, Fraunhofer EMFT contributes its expertise in the area of 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 Gigahertz 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 development of a millimeter wave system-in-package technology (SiP). This offers more benefits such as lower losses in the high-frequency range, cost-efficient manufacturer at silicon wafer level, a high integration capacity (of both the passive and he active components) and improved heat dissipation.
RANGE OF SERVICES AND TECHNOLOGIES
RANGE OF SERVICES AND TECHNOLOGIES

FRAUNHOFER EMFT RANGE OF SERVICES

FRAUNHOFER EMFT RANGE OF TECHNOLOGIES

Staff members in the cleanroom
FRAUNHOFER EMFT RANGE OF SERVICES
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. The range of services Fraunhofer EMFT is offering its customers and partners includes:

**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
- Special conferences

**R&D as part of publicly funded projects**
- Joint projects funded publicly or by industry, 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
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 the institution 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 and utilize its high-quality facilities (such as cleanrooms, laboratories, workshops and equipment). Several companies have entered into strategic cooperation with Fraunhofer EMFT. Here is a selection of the technological facilities available at Fraunhofer EMFT:

### 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, PECVD of SiO₂ and Si₃N₄)
- Highly conductive layers (Al/Si, Ti, W, doped poly-Si)
- Plasma etching processes (Si, SiO₂, Si₃N₄, Al, W)
- Electroplating (Cu, Sn)

### 200 mm lithography cluster
- Proximity exposure
- Double-sided exposure
- Contact exposure
- Electron ray exposure
- Ion 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, Polyimid)
- Wafer bonding, adhesion bonding techniques
- 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
Application of large-area electronics and flexible substrates to foil sheets and using the roll-to-roll method

- Hot-roller laminator for two-sided lamination
- In-line coating system for liquid coatings such as photoresist, dielectrics and passivation
- Sputter system for double-sided metallization 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 roll-to-roll processing
- Galvanic deposit of copper on pre-metallized foils
- Laser processing for cutting, marking and drilling various materials
- Plasma process for surface conditioning and for reactive etching of polymers with nitrogen, oxygen and CF₄
- Foil mounting and bonding technology

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 GHz and Simulator Agilent ADS
- Generation and measurement of high-current pulses in the pico- and nanosecond range
- Electrostatic discharge characterization and load (CDM, HBM, TLP, VF-TLP, CC-TLP)
- 160 cm³ climate chamber for (bio-)chemical sensors gases and liquids
- Foil mounting and bonding technology

Analytics and material characterization

- Atomic force microscope (AFM): Measurement of surface roughness and step measurement up to max. 6 µm
- Scanning electron microscopy (REM) inkl. energy-dispersive x-ray spectroscopy (EDX)
- Inline SEM (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
SCIENCE TRANSFER
Foil-based lab-on-chip for blood analysis
It's a long journey from the initial sketch of an idea through to the finished product. But Anna Ohlander and Ronnie Bose were not put off by this: the young research team is currently busy setting up a spin-off to market an MRSA rapid test they developed themselves.

**What is the aim of your spin-off?**

*Ronnie Bose:* We are developing an on-site diagnosis system for MRSA detection which consists of a disposable test card and a portable reading device. The test card is a microfluidic chip on foil in which we have additionally integrated a micro-heater. In this tiny chip it is possible to carry out a high-quality DNA analysis of sample material as was previously only possible in a lab. The result is available within one hour. The system is designed for use at doctors’ surgeries and hospitals and can be applied without significant expertise and quite straightforwardly by doctors or nursing staff.

**What are the advantages of your product or what technological innovation does it embody?**

*Anna Ohlander:* Current DNA-based MRSA tests can only show whether the pathogen is present or not. Our test allows us to identify the specific pathogen subtype. This has two very significant benefits. Firstly, each strain responds to different antibiotics. If the subtype is not known, the standard procedure is to treat the patient with a broad-spectrum antibiotic – but it is precisely this mass-scale usage that is increasingly leading to the formation of dangerous resistance. Our test enables a very specific therapy to be applied. What is more, the subtype provides valuable information as to potential infection sources and transmission routes. This is helpful in terms of hygiene management in a hospital or for health authorities who wish to get an MRSA outbreak under control more quickly. Of course, methods already exist which allow the pathogen subtype to be defined – but this generally requires lengthy and involved lab investigations. The key USP of our test is that it combines high information content with speed. At the same time, it is inexpensive to make and simple to use.

**At what point did you decide it was time to put your research activities on the market in the form of a spin-off?**

What were the main factors affecting your decision?

*Ronnie Bose:* There was no one specific point in time – it was actually quite a long drawn-out process. Our decision to market our lab-on-foil DNA test ourselves ultimately arose from the question of what was going to happen to our research area after we had gained our doctorates. At some point we realized: if we wanted our findings to be pursued further, we’d have to do something about it ourselves.

**What are the main challenges along the way from being a researcher to becoming an entrepreneur?**

*Ronnie Bose:* We had to learn adopt an entirely new perspective and a view the whole thing from the point of view of the market. Where are promising applications? Who are our potential customers? What product benefits can we use as selling points? Up to then we’d only viewed the project from a scientific angle. We had a technological platform but we hadn’t envisaged a specific application. The last year was an important learning process for us: ultimately, users are not interested in how our test works – it simply has to do the job...
and offer additional benefits as compared to rival products. We found this rather disconcerting at first – in fact we took it as something of an insult to our sense of pride as researchers (laughs).

Anna Ohlander: The same was true when we looked at the competition – from the market point of view, the technology itself is not initially the primary focus: the five leading providers all use technologies derived from the same family of patents, for instance. The difference lies in aspects such as speed, precision, cost etc. Those are the points that clinch the success of a new product, so that is what our market strategy is geared towards.

What tips would you give your colleagues who are considering setting up their own company?

Ronnie Bose: Well, we’re in the middle of the process ourselves, of course. But there is one aspect we can definitely share: it’s never too early to take an idea to your institute management or the central Fraunhofer organization. We originally thought we’d need a ready-made product and market strategy before doing this, but we now know that this is not true. On the contrary: the earlier on you seek out support, the lower the risk of investing a lot of in what might turn out to be the wrong areas.

How do you rate the support provided by the Fraunhofer-Gesellschaft in this connection?

Anna Ohlander: Manfred Stöger, our mentor from the venture group, and Dr. Volker Rürup, our mentor from the business model development group, were incredibly supportive in helping us elaborate our business plan and our market strategy. Looking back, I would actually have involved the people at central office even earlier that we did so as to be fully on course from the start. We also had a lot of backing from our management, so that was crucial too.

What are the next steps you’ll be taking towards setting up your own company?

Ronnie Bose: Our aim is to refine our test card within the next two years to create a complete sample-to-answer system. This would then be a good time for another round of funding talks with interested investors. If that goes well we could officially register the spin-off and start business operations. In terms of our premises we’d very much like to stay at Fraunhofer EMFT.
CUSTOMERS AND COOPERATION PARTNERS
CUSTOMERS AND COOPERATION PARTNERS

INDUSTRY REFERENCES
PARTNER COMPANIES
TECHNOLOGY NETWORKS
UNIVERSITIES
BAVARIAN INNOVATION CLUSTERS

Flow sensors
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:

"I’m very impressed by the enormous expertise of the Fraunhofer staff. I should particularly like to single out the institution’s excellent and very amenable collaborative approach."
“Very nice people to work with. Excellent preparation and outstanding expertise – and flexible, too!”
"The talks were very effective. Thanks to the considerable experience of Fraunhofer EMFT staff we were quickly able identify the weak points in our processes. Solutions were proposed."
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 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 standard technologies, resulting in cost-effective solutions even for small and medium-sized companies.

**Bayerisches Demonstrationszentrum Polytronik (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.

**Center for Mikrosystemintegration Munich (CMM)**

Fraunhofer EMFT initiated the founding of the Center for Mikrosystemintegration 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.
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 UniBwM Faculty of Electrical Engineering and Information Technology and Fraunhofer EMFT, not least as a result of staffing connections. Prof. Maurer (Professorship for Integrated Circuits and Electronic Components) has been teaching at UniBwM since 2012, along with Prof. Kutter (Professorship for Polytronics). The cooperation originated under Prof. Eisele, who was appointed UniBwM’s first Emeritus of Excellence and today heads up the business area “Silicon Technologies and Devices” at Fraunhofer EMFT.

Dr. Sabine Trupp was accepted at Universität der Bundeswehr as a habilitation candidate and is working in the field of gas sensorics there.

Fraunhofer EMFT and Universität der Bundeswehr are well matched because of their complementary cleanroom facilities. Both institutions have set themselves the goal of intensifying their collaboration.

**Technische Universität München**

It was in 2011 that Fraunhofer EMFT laid the foundations for collaboration with the Chair for Technical Electrophysics held by Prof. Wachutka. Research there focuses on physically based modeling, numerical simulation and the characterization and diagnosis of production processes and 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. Other joint projects are currently in progress under Prof. Schmitt-Landsiedel, Prof. Lugli and Prof. Tornow.

**Universität Regensburg**

Ever since it was founded in 2009, the Fraunhofer EMFT business area Sensor Materials has worked closely with the Chair for Analytical Chemistry, Chemosensorics and Biosensorics at the University of Regensburg. Scientists at both institutions collaborate on developing fundamental opto-sensoric techniques and transferring these to applications in the areas of healthcare, life sciences and environmental analytics. The chair possesses considerable expertise in the field of biosensorics using physical transducers such as plasmon resonance (SPR) and impedimetry. Cooperation between the Sensor Materials group and the University of Regensburg is expanded continuously through the joint acquisition of funded projects, participation in university teaching and the supervision of students.

**Hochschule München**

Munich University of Applied Sciences is one of the biggest institutions of its kind in Germany. With some 17,500 students and being located in one of Europe’s leading economic hubs the university offers lots of opportunities and addresses a wide range of economic, technical and social issues.

Fraunhofer EMFT collaborated closely with Prof. Feiertag of the Electrical Engineering and IT Department in 2015, for example. Work was done on joint projects and there were also shared doctoral candidates.
Technische Universität Dresden

TU 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 future cooperation with Fraunhofer EMFT. In his courses at the Institute for Semiconductors and Microsystems (IHM), Prof. Kücher focuses on the connection between technological and economic challenges, since globalized competition is bringing about change such as specialization and resegmentation of the value creation chain which requires new strategies on the part of material, system and chip manufacturers. Current trends in micro/nanoelectronics – from “More Moore” to “More than Moore” – are thus always a key focus of the overall economic situation.

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

Polytechnische Universität Bukarest, (Universitateat Politehnica Bucuresti, UPB), Romania

Universitatea POLITEHNICA of Bucharest developed from a polytechnic school dating back to 1864 and is now the most important technical university in Romania. There are longstanding 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. The collaboration between the two institutions has resulted in joint conference presentations and publications.
BAVARIAN INNOVATION CLUSTERS

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 help companies become involved in joint product development, optimize internal processes and jointly penetrate markets. Fraunhofer EMFT is closely involved in the following clusters:

### Cluster Strategic Partnership Sensoric

The partnership organization Strategische Partnerschaft Sensorik e.V. in Regensburg is the platform for sensorics as part of the cluster offensive of the state of Bavaria. More than 60 companies and institutes now belong to this association. These are among Fraunhofer EMFT’s customers and cooperation partners.

Fraunhofer EMFT is a founding member of the cluster and its ZIM network “SensoIT”, which is involved with the use of sensor-supported IoT applications in all walks of life. An initial project sketch has already been submitted together with other network members.

In May 2015 Fraunhofer EMFT co-exhibited at the joint cluster stand presented at the “Sensor + Test” trade fair in Nuremberg. What is more, the Fraunhofer EMFT’s Sensor Materials group permanently represents the institution on site in Regensburg as a contact partner for cluster members. Staff members also frequently make use of the sensorics cluster’s excellent professional development program.

In 2015, the director of Fraunhofer EMFT – Prof. Kutter – was appointed one of the two spokespersons for the cluster.

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### Cluster Microsystems Technology

Fraunhofer EMFT has been very involved in the wide-ranging activities of the Cluster Microsystems Technology (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.

The Cluster Microsystems Technology has now undergone restructuring in terms of personnel and organization and Fraunhofer EMFT is pleased to be able to draw on the cross-sectoral communication and collaboration it offers, as well as supporting cluster partners in the future-oriented development of products and processes.

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Chemicals Cluster

Fraunhofer EMFT has been a member of the Chemicals Cluster since 2008. The Bavarian Chemicals Cluster brings together companies and research institutions operating in the chemical sector in Bavaria. Collaboration takes the form of cross-sectoral associations consisting of large and small industrial companies, universities and Fraunhofer institutes, while the cluster can also take on responsibility for obtaining external funding for joint projects as well as looking after project coordination.

Cluster activities focus on highly innovative topics, always in close collaboration with the regional Bavarian networks. Particular support is provided for recently founded companies and start-ups in the chemical sector by involving them more closely in cluster activities. In this way the Chemicals Cluster has led to the Bavarian chemical industry establishing a leading role for itself as Germany’s industrial efficiency driver.

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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 organized by the network. 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 medical technology suppliers. The focus is geared specifically towards promoting SMEs in Franconia, Bavaria and Thuringia by providing specialist expertise built up over many years. The aim of network cooperation is 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.

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Visitors to an event at Fraunhofer Haus
AWARDS
Fraunhofer EMFT scientist receives DeviceMed-Award
Prof. Mitsuma Koyanagi, Dr. Phil Garrou and Dr. Peter Ramm (left to right) during the award ceremony

Dr. Peter Ramm and Prof. Koyanagi win the 3DIC Pioneering Award

Dr. Peter Ramm of Fraunhofer EMFT and Professor Mitsumasa Koyanagi of Tohoku University received the 3DIC Pioneering Award at the 12th annual 3D ASIP (Architectures for Semiconductor Interconnect and Packaging) Conference in Redwood City CA.

Dr. Phil Garrou, Conference Chair, said: “Since we are now more than a decade into the concerted effort to commercialize 2.5 and 3DIC technology it seemed appropriate to look back and document who actually led the way in this technically challenging effort. After significant study, we are convinced that the research groups in Tohoku University and Fraunhofer – Munich were not only the first in the field, but also have continued their studies to this day to help commercialize this important leading edge technology.”

Profesor Koyanagi’s work started back with his seminal paper “Roadblocks in achieving 3-dimensional LSI” presented at the Symposium on Future Electronic Devices in 1989. His 1995 paper “Three dimensional Integration Technology Based on a Wafer Bonding Technique Using Micro Bumps” showed a process sequence similar to today’s TSV etch, thin and bond for an image sensor circuit.

Dr. Ramm began his work in the early 1990s in collaboration with Siemens under the German sponsored R&D program “Cubic Integration – VIC”. Their paper “Performance Improvement of the Memory Hierarchy of RISC-Systems by Application of 3-D Technology,” which appeared in IEEE Trans on Components, Packaging and Manufacturing Technology in 1996 woke up the larger community to the possibilities of using 3DIC. A key patent from that era was USP 5,563,084 “Method of Making a 3 Dimensional Integrated Circuits” which was issued in 1996.

Second place in the EARTO Innovation Award 2015

The “Markets for Tomorrow” project SkinHeal was runner-up in the category “Impact expected” in the contest for the 2015 EARTO Innovation Award of the European Association for Research and Technology Organizations in Brussels. The project was singled out among 17 competitors, including five in the field of healthcare, in recognition of its innovative approach to improving treatment of chronic wounds.

The project: SkinHeal

The project SkinHeal involved Fraunhofer EMFT working with partners to develop a technology for the cost-efficient production of microfluid actuators which perform one or more functions when integrated in a wound insert, such as sampling wound secretion, generating a vacuum for vacuum therapy or regulating the oxygen supply to the wound.

DeviceMed-Award for Fraunhofer EMFT researchers

Visitors to COMPAMED voted for Fraunhofer EMFT as the most innovative exhibitor in 2015, and colleagues on site received the DeviceMed Ad-Hoc Award.

Dr. Martin Richter and his team achieved this with a tiny piece of technological wizardry: the new micromembrane pump made of silicon which the scientists presented at COMPAMED 2015 measures just 5 x 5 x 0.6 mm³ – making it by far the smallest micropump in the world. The aim of this miniaturization is to significantly reduce industrial manufacturing costs after the industrial transfer of the technology to large-volume production.
VISITORS AND DELEGATIONS
A large number of visitors and delegations came to Fraunhofer EMFT once again in 2015 to meet the institution’s scientists and take a closer look at the Fraunhofer EMFT excellent technological infrastructure.

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**Visitors and delegations**

- **Students on the TUM mentoring program**, January 28, 2015
- **Delegation from Tokyo University, Japan**, February 16, 2015
- **Delegation from the Nagano Techno Foundation/ Nanotech International Center, Japan**, February 20, 2015
- **Deutsche Bank Advisory Board**, May 5, 2015
- **Delegation of nanoscientists from Thailand**, May 18, 2015
- **Center of Excellence for Micro- and Nanoelectronics, Egypt**, June 3, 2015
- **Delegation from Samsung Advanced Institute of Technology, Korea**, June 11, 2015
- **Electrical engineering students from Munich University of Applied Sciences**, June 25, 2015
- **Delegation from Tyndall National Institute & Government of Ireland**, July 20, 2015
- **Students from Høgskolen i Sør-Trøndelag – HiST, Trondheim, Norwegen**, September 14, 2015
- **Delegation from CEA, Frankreich**, September 29, 2015
- **Committee for the Coordination of Foreign Relations (AKA)**, October 8, 2015

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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 this event on March 26, 2015 was: “Colors and Frequencies” – to coincide with the UNESCO International Year of Light 2015.

Differing frequencies provide the basis for many technologies that enhance comfort and safety and indeed make our modern channels of communication possible in the first place. Sensors enable us to capture signals in diverse frequency ranges, including light.

At this event, Fraunhofer EMFT and its partners provided an overview of the role played by colors and frequencies in research activity at Fraunhofer EMFT.

**Medical Electronics Cooperation Forum**

Together with Bayern Innovativ, Fraunhofer EMFT organized the cooperation forum and exhibition “Medical Electronics” on April 29 in Munich. Numerous examples of innovations were exhibited from the field of electronics for medical devices and the latest developments and trends were presented in the areas of semiconductor technology, system integration and microsystems engineering. Participants benefited from an exchange of information and experience with experts from business and science as well as picking up ideas for future cooperations.

**TechSearch Workshop Panel Processing – Filling the Gap between Frontend and PCB**

The workshop “Panel Processing – Filling the Gap between Frontend and PCB” was organized on the Fraunhofer EMFT premises on November 9 in collaboration with TechSearch International Inc., USA. At this event, approx. 100 experts from industry and science discussed current trends in chip embedding and packaging technologies. The challenges and potential priorities for industry were debated and analyzed in a panel discussion.

**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 a lively exchange.

The event was held once again on November 17 and 18. In 2015 the event focused 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.
Trade Fairs in 2015

- **LOPE-C**
  Munich, April 3 - 5

- **Sensor + Test**
  Nuremberg, June 21 - 23

- **Semicon**
  Dresden, October 6 - 8

- **COMPAMED**
  Düsseldorf, November 16 - 19

Congresses attended in 2015

- **ECTC 2015**
  San Diego, USA, February 27

- **IMAPS International Conference on Device Packaging**
  Scottsdale, USA, March 17 - 19

- **SPIE Mictrotechnologies Smart Sensors, Actuators, and MEMS VII Conference**
  Barcelona, Spain, May 5

- **13th IEEE International NEW Circuits And Systems Conference**
  Grenoble, June 7 - 10

- **2015 Symposium on VLSI Technology & Circuits**
  Kyoto, Japan, June 16 - 19

- **IEEE 11th Conference on Ph.D. Research in Microelectronics and Electronics (PRIME) 2015**
  Glasgow, UK, June 29 - July 2

- **11th BBMEC International Biosensors and Bioanalytical Microtechniques in Environmental, Food & Clinical Analysis Conference**
  Regensburg, Germany, September 28 - 30

- **The 37th International Technical Forum on Electrical Overstress and Electrostatic Discharge**
  Reno, USA, September 27 - October 2

- **Semicon 2015**
  Dresden, Germany, October 6 - 8

- **2015 IEEE 21st international Symposium/or Design and Technology in Electronic Packaging (SiTME)**
  Brasov, Romania, October 22 - 25

- **MikroSystemTechnik Kongress 2015**
  Karlsruhe, Germany, October 26 - 28

- **ESD-Forum**
  Munich, Germany, November 5 - 6

- **Trillion Sensor Summit**
  Orlando, USA, December 8 - 10

- **3D ASIP**
  Redwood City, USA, December 15 - 17
YOUTH DEVELOPMENT
YOUTH DEVELOPMENT

FRAUNHOFER TALENT SCHOOL

CAREER ORIENTATION WEEKS

VISIT BY STUDENTS FROM A GIRLS’ INTERMEDIATE SECONDARY SCHOOL

TECH CACHING PARCOURS

CAREERS AT FRAUNHOFER EMFT

Fraunhofer EMFT scientist with school students in the lab
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 an active member of the initiative “National MINT Pact – a pact for bringing more women in STEM 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).

**Fraunhofer Talent School**

In 2015 once again, the Fraunhofer EMFT Talent School offered 10th - 13th grade school students unique insights into the world of research.

After three varied days, participants had gained a clear idea of how research is carried out into technical and scientific solutions. The young men and women also had the opportunity to support Fraunhofer EMFT researchers during the workshop. The latter provided the students with the necessary theoretical basis and discussed their research outcomes and experience with them.

Talks with Fraunhofer EMFT management team members provide insights into the everyday work of scientific researchers both nationally and internationally. The technophile school students also got to engage in intense discussion with others interest in MINT subjects (science, technology, engineering, math).

**Career orientation weeks**

Fraunhofer EMFT once again held career orientation weeks for school students in April 2015.

The institution offers a career orientation program for would-be scientists every year. Here the institution cooperates with various high schools, intermediate secondary schools and comprehensive schools in Munich and the surrounding area. The young participants are given a behind-the-scenes glimpse of the world of microsystems as well as finding out about the everyday working lives of scientists at Fraunhofer EMFT.

The following issues were examined during the one-week career orientation program:

- What do we need microelectronics for?
- From idea to reality – it all starts with a design
- How is a microchip produced and what is it made of?
- Working in a cleanroom – why cleanliness is so important
- What does plastic have to do with electronics?
- Flexible systems need thin chips
- Who checks to make sure everything works - and how?
- What is the lifetime of a microchip?
- Small, smaller, smallest – tiny pumps
“GO MINT – National Pact for Women in MINT Careers” is part of the German federal government’s qualification initiative and aims to counteract the looming shortage of specialists in scientific and technical professions, as well as tapping into the innovation potential of women in science and technology.

Visit by students from a girls’ intermediate secondary school

17 school students from the intermediate secondary school Erzbischöfliche Mädchenrealschule Heilig Blut Erding took part in a Fraunhofer EMFT workshop day on March 24, 2015. The young participants were welcomed by a former student of the school who is currently completing her doctorate at Fraunhofer EMFT.

After a brief introduction to the institution’s topic areas, the students visited various stations so as to gain their own impression of what it’s like to work on microsystems: they much enjoyed using microscopes to look at microchips, getting in and out of cleanroom clothing and trying on shape memory materials and RFID technology. Their supervisors included five school students on a work experience program who were able to share their newly acquired expertise with the 6th grade students. The successful day’s outing was rounded off with a guided tour of the institution in small groups provided for the girls and their supervising teachers.

tech caching Parcours

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 (math, IT science and technology) 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.

This responds to the interest among intermediate secondary schools in offering MINT motivation programs for girls before they choose their school subject combinations at the end of 6th grade.

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
- Hightech topic areas covered: microsystems engineering, nanotechnologies, optical technologies
- Trained supervisors
- Group size: 12 - 16 school students
- Total duration approx. 2 - 2.5 hours
Many young people opt to begin professional life at Fraunhofer EMFT. The institution offers an excellent start to a career for trainees in research, science, technology and administration. Students in the field of physics, electrical engineering, process engineering, biochemistry and related areas have the opportunity to be 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.

“After completing my physics degree at TU München I applied to Fraunhofer EMFT in August this year – I was accepted right away. Since then I have been working in the ATIS working group, where I face the challenge of testing microchips and other electrical components in relation to electrostatic discharge (ESD). In addition to these practical applications, I also carry out research with my group into future testing methods as part of a doctoral program. This makes the work very varied, which is something I particularly appreciate. What I especially liked was the friendly reception I was given by my colleagues at Fraunhofer EMFT.” (Johannes Weber, doctoral student in the business area Circuits & Systems)

“I have been a student trainee in the Micro Dosing Systems department for over a year. I really enjoy my work and I find my colleagues very supportive. I’m working on a project in which we are developing a small, portable and efficient micro degasser system that can be used to remove bubbles and dissolved gases from a fluid. Here I am able to apply the theoretical knowledge from my master’s degree studies in physics (LMU) and electrical engineering (TU München), as well as gaining experience in applied research. What I find especially fascinating and motivating is that I’m involved in the entire process from research through to the product, and I can contribute my own ideas and knowledge.” (Simone Strohmair, student trainee in the business area Micro Dosing Systems)
“As part of my medical technology degree at the University of Ulm I am doing a mandatory practical semester in the Micro Dosing Systems department at Fraunhofer EMFT from September 2015 to February 2016. My colleagues got me fully involved in the lab work right from the start and they’ve been very supportive. I find it fascinating to be working at a research and development institution and constantly tackling new challenges. During my internship I realized that a finished product requires a lot of time, good ideas and a cleverly devised implementation strategy. And there are lots of test series to be carried out and analyzed, too. Alternative solutions can sometimes help you strike out on a new path. Working with other students has given me lots of insights into other disciplines. I very much appreciate the time I’ve spent here and I’m grateful to Fraunhofer EMFT for giving me this opportunity.” (Mareike Zimmermann, student trainee in the business area Micro Dosing Systems)

“I’ve been working as a trainee student in the Circuits & Systems department at Fraunhofer EMFT since October 2015. My colleagues gave me a very friendly welcome and made me feel at ease in the team right away. My group is looking at ESD protection in integrated circuits. This topic was new to me – in my master’s degree I specialized in high-frequency technology. But I was still able to contribute my knowledge, while at the same time learning a lot myself – especially in the field of integrated circuits. Since my colleagues encouraged me from the outset, I decided to do my master’s thesis here and I’m now just about to submit it. Having gained such positive impressions of Fraunhofer EMFT I’m now looking to embark on a career in research.” (Dennis Helmut, trainee student in the business area Circuits & Systems)
PRESS AND MEDIA RELATIONS
Fraunhofer EMFT engages in intensive press and media relations. It has been featured in print and online media in connection with various topics.

### PEOPLE

<table>
<thead>
<tr>
<th>Title</th>
<th>Source</th>
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<tbody>
<tr>
<td>Gleich drei Amtsübergaben bei der SPS</td>
<td>elektroniknet</td>
<td>25.02.2015</td>
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<td>Drei Amtsübergaben bei der SPS</td>
<td>Markt &amp; Technik</td>
<td>13.03.2015</td>
</tr>
<tr>
<td>AKADEMIEN, GESELLSCHAFTEN, INSTITUTIONEN</td>
<td>duz Magazin</td>
<td>21.08.2015</td>
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### INTERNET OF THINGS / INDUSTRY 4.0

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<tr>
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<tr>
<td>Maschinen stürmen die Märkte</td>
<td>Wirtschaftswoche</td>
<td>07.08.2015</td>
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<td>Smart Factory: Blaupause oder Blaues Wunder?</td>
<td>mpa</td>
<td>18.08.2015</td>
</tr>
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<td>Zukunftstechnologien 2020: Trends - Innovationen - Märkte</td>
<td>VDE Presse</td>
<td>18.08.2015</td>
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<td>Das Geschäft mit dem Megatrend</td>
<td>WiWo.de</td>
<td>18.08.2015</td>
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<tr>
<td>Test and Measurement: Keysight announces new business structure</td>
<td>RCR Wireless News (USA)</td>
<td>06.11.2015</td>
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<tr>
<td>Vor uns die Sensorflut</td>
<td>Elektronik.net</td>
<td>26/2015</td>
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## MEDICINE

<table>
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<td>Wie sich Elektronik im klinischen Umfeld einsetzen lässt</td>
<td>[ELEKTRONIK PRAXIS - 22.04.2015]</td>
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<td>Mikropumpe stabilisiert Druck im Auge</td>
<td>[Ärzte-Zeitung - 02.07.2015]</td>
</tr>
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<td>Mini-Pumpe regelt Augeninnendruck</td>
<td>[derstandart.at - 02.07.2015]</td>
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<td>Micro-pump in the eye could treat glaucoma</td>
<td>[Electronicsweekly.com - 06.07.2015]</td>
</tr>
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<td>Druckmessstrumpf als Wundschutz für Diabetes-Patienten</td>
<td>[ElektronikPraxis - 07.09.2015]</td>
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<td>A Bandage of a Different Color</td>
<td>[digitaltrends - 21.09.2015]</td>
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<tr>
<td>Miniaturpumpe regelt Augeninnendruck</td>
<td>[ELEKTRONIK PRAXIS - 09.2015]</td>
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<td>[Management &amp; Krankenhaus - 06.10.2015]</td>
<td>[Magdeburger Volksstimme - 17.10.2015]</td>
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<td>Miniaturpumpe fürs Auge</td>
<td>[fluid.de - 15.09.2015]</td>
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<td>Implantat benetzt Auge</td>
<td>[Südwest Presse - 26.10.2015]</td>
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<td>[Märkische Oderzeitung - 17.12.2015]</td>
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**FLEXIBLE ELECTRONIC**

Gedruckte Elektronik: Macht Verpackungen kommunikationsfähig
[Vatt KONTEXT - 02.2015]

Leuchtende Textilien mit vielen Möglichkeiten
[ELEKTRONIK PRAXIS - 04.03.2015]

Bend it like Silicon
Flexible Silicon and Plastic Circuits
[Electronic Engineering Journal - 02.07.2015]

Printed/Flexible/Stretchable Sensors: New Technologies Enable High Volume Applications
[CMM - 11.12.2015]

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**MICROPUMPS**

Die kleinste Pumpe der Welt
[Vogel Business Media - 10.02.2015]

Mikrodosiersystem
[COMPAMED - 09.11.2015]

Devicemed-Award für die kleinste Pumpe der Welt
[COMPAMED - 15.11.2015]
[LaborPraxis - 03.12.2015]

Nur die Besten gewinnen
[Devicemed - 16.12.2015]
SCIENTIFIC ACTIVITIES
"MIKROAUG" – eyepressure regulating system
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 2015. The following list provides a small selection of their academic publications and talks.

**Publications**

Peter Ramm
**Heterogeneous 3D Integration**
Resource Library Archives - 3D InCites, January 2015

Wolfgang A. Vitale, Montserrat Fernández-Bolaños, Reinhard Merkel, Amin Enayati, Ilja Ocket, Walter De Raedt, Josef Weber, Peter Ramm, Adrian M. Ionescu
**Fine Pitch 3D-TSV Based High Frequency Components for RF MEMS Applications**
Electronic Components and Technology Conference (ECTC), San Diego, USA, February 27, 2015

Julia Sporer
**Development of a Sensor Strip and Intelligent Protective Clothing for Carbon Monoxide**
9th Interdisciplinary Doctoral Student Seminar - Chemosensors and Biosensors in Process Analytics, Berlin, Germany, February 2015

Christian Götz
**PEDOT/PSS as transparent electrode material for impedimetric whole-cell biosensors**
9th Interdisciplinary Doctoral Student Seminar - Chemosensors and Biosensors in Process Analytics, Berlin, Germany, February 2015

Romy Freund
**Studies on the phototoxicity of bioanalytically relevant fluorophores with label-free whole-cell biosensors**
9th Interdisciplinary Doctoral Student Seminar - Chemosensors and Biosensors in Process Analytics, Berlin, Germany, February 2015

Peter Ramm, Armin Klumpp, Josef Weber, Alan Mathewson, Kafil M. Razeeb, Reinhard Pufall
**The European 3D Heterogeneous Integration Platform (e-BRAINS) – a Particular Focus on Reliability and Low-Temperature Processes for 3D Integrated Sensor Systems**
Proceedings IMAPS Device Packaging Conference, Scottsdale, USA, March 2015

Wolfgang A. Vitale, Montserrat Fernandez-Bolanos, Reinhard Merkel, Amin Enayati, Ilja Ocket, Walter De Raedt, Josef Weber, Peter Ramm, Adrian M. Ionescu
**Fine pitch 3D-TSV based high frequency components for RF MEMS applications**
Electronic Components and Technology Conference (ECTC), 2015 IEEE 65th, vol., no., pp.585,590, May 26.- 29, 2015, DOI: 10.1109/ECTC.2015.7159650

Wolfgang A. Vitale, Montserrat Fernandez-Bolaños, Robert Wieland, Josef Weber, Peter Ramm, Adrian M. Ionescu
**Ultra fine-pitch TSV technology for ultra-dense high-Q RF inductors**
2015 Symposium on VLSI Technology & Circuits, Kyoto, Japan, June 2015
Electrostatic discharge sensitivity investigation on organic field-effect thin film transistors

13th IEEE International NEW Circuits and Systems Conference, Grenoble, France, June 7 - 10, 2015

Vincenzo Fiore, Placido Battiato, Sahel Abdinia, Stephanie Jacobs, Isabelle Chartier, Romain Coppard, Gerhard Klink, Eugenio Cantatore, Egidio Ragonese, Giuseppe Palmisano

An Integrated 13.56-MHz RFID Tag in a Printed Organic Complementary TFT Technology on Flexible Substrate


Low-cost high-grade steel micropump for sample feeding of a miniaturized gas sensor system for early detection of fires

MikroSystemTechnik Kongress 2015, Karlsruhe, Deutschland, October 26 - 28, 2015


Limits of dosing accuracy of a regulated nanoliter per second microdosing system for lubricant dosing with a capacitive time-of-flight flow sensor

MikroSystemTechnik Kongress 2015, Karlsruhe, Deutschland, October 26 - 28, 2015

SBN 978-3-8007-4100-7, pp. 50-53

Simulation and characterization of a bi-directional three-chamber micropump made of high-grade steel

MikroSystemTechnik Kongress 2015, Karlsruhe, Deutschland, October 26 - 28, 2015

ISBN 978-3-8007-4100-7, pp. 467-470

Particle tolerance of micromembrane pumps with low chamber height and passive flap valves

MikroSystemTechnik Kongress 2015, Karlsruhe, Deutschland, October 26 - 28, 2015

ISBN 978-3-8007-4100-7, pp. 489-492

Assessment of CDM resistance using CC-TLP

ESD-Forum, Munich, Germany, November 5 - 6, 2015

In-Situ Measurements of Stress Currents During System Level ESD Tests

ESD-Forum, Munich, Germany, November 5 - 6, 2015

Generic Electrostatic Discharges Protection Solutions for RF and Millimeter-Wave Applications


Current and Future 3D Activities at Fraunhofer

IEEE Xplore, Proc. 3DIC, Sendai, Japan, December 2015
Talks

Peter Ramm, Armin Klumpp, Alan Mathewson, Kafil M. Razzeeb, Reinhard Pufall
The European 3D Heterogeneous Integration Platform (e-BRAINS) – a Particular Focus on Reliability and Low-Temperature Processes for 3D Integrated Sensor Systems
IMAPS Device Packaging Conference, Scottsdale, Arizona, USA, March 17 - 19, 2015

Christoph Kutter
Sensors as the key enablers for the Internet of Things – the Trillion Sensor Initiative
AMA Science Advisory Board, Reutlingen, Germany, March 25, 2015

Sabine Trupp
Sensor materials - from nanosensors to surface sensorics
Specialist seminar on nanotechnology in paper manufacture, Papiertechnische Stiftung, Munich, Germany, April 28 - 29, 2015

Robert Wieland
Wafer edge protection kit for MEMS and TSV Si-etching
SPIE Microtechnologies Smart Sensors, Actuators, and MEMS VII Conference, Barcelona, Spain, May 5, 2015

Christoph Kutter
Sensors for the Internet of Things
Tsinghua-ROHM International Forum of Industry-Academia, Beijing, China, May 8, 2015

Nagarajan Palavasam, Christof Landesberger, Karlheinz Bock
Integration of ultra-thin silicon chips in foil substrates and mechanical reliability analysis
EU Project CONTEST Summer School, Lille, France, May 18 - 22, 2015

Peter Ramm, Wolfgang A. Vitale, Montserrat Fernández-Bolaños, Reinhard Merkel, Amin Enayati, Ilja Ocket, Walter De Raedt, Josef Weber, Adrian M. Ionescu
Fine Pitch 3D-TSV Based High Frequency Components for RF MEMS Applications
ECTC 2015, San Diego, USA, May 26 - 28, 2015

Nagarajan Palavasam, Christof Landesberger, Christoph Kutter
Finite Element Analysis of uniaxial bending of ultra-thin Silicon dies embedded in flexible foil substrates

Andy Heinig, Muhammad Waqas Chaudhary, Peter Schneider, Josef Weber, Peter Ramm
Current and Future 3D Activities at Fraunhofer
3DIC 2015 / IEEE, Sendai, Japan, August 31 - September 2, 2015

Christoph Kutter
Sensors for the Internet of Things
11th BBMEC International Biosensor Conference Regensburg, Germany, September 28 - 30, 2015

Heinrich Wolf, Horst Gieser
Secondary Discharge - A Potential Risk During System Level HBM ESD Testing
The 37th International Technical Forum on Electrical Overstress and Electrostatic Discharge, Reno, USA, October 27 - November 2, 2015
Johann Bourgeat, Boris Heintz, Jean Jimenez, Philippe Galy, Tekfouy Lim

**Self-ESD-Protected Transmission Line Broadband in CMOS28nm UTBB-FDSOI**
The 37th International Technical Forum on Electrical Overstress and Electostatic Discharge, Reno, USA, October 27 - November 2, 2015

Christof Landesberger

**New processing scheme for embedding and inter-connection of ultra-thin IC devices in flexible chip foil packages**
Semicon 2015, Dresden, Germany, October 6 - 8, 2015

Martin Richter

**Cost efficient miniaturised silicon micropumps for medical applications**
Semicon 2015, Dresden, Germany, October 6 - 8, 2015

Robert Wieland

**Innovative and environmental friendly Fluorine F2 based cleaning process to replace C2F6, CF4 and NF3 as cleaning gas**
Semicon 2015, Dresden, Germany, October 6 - 8, 2015

Nagarajan Palavesam, Detlef Bonfert, Waltraud Hell, Christof Landesberger, Horst Gieser, Christoph Kutter, Karlheinz Bock

**Electrical Behaviour of Flip-Chip Bonded Thin Silicon Chip-on-Foil Assembly during Bending**
2015 IEEE 21st international Symposium for Design and Technology in Electronic Packaging (SIITME), Bravos, Romania, October 22 - 25, 2015

Dennis Helmut

**Simulation and Characterization of Setups for CDM and CC-TLP**
ESD-Forum, Munich, Germany, November 5 - 6, 2015

Tekfouy Lim

**System Level Investigation of a Multi-Modal, Modular Artificial Skin**
ESD-Forum, Munich, Germany, November 5 - 6, 2015

Heinrich Wolf

**In-Situ Measurements of Stress Currents During System Level ESD Tests**
ESD-Forum, Munich, Germany, November 5 - 6, 2015

Christof Landesberger

**Embedding Die in Flexible Substrates**

Christoph Kutter

**Sensoren für das Internet der Dinge**
Erfurt Technology Dialog, at the Thuringian State Parliament, Erfurt, Germany, November 9, 2015

Christoph Kutter

**Printing processes and roll-to-roll assembly processes for extreme high volume sensor applications**
Trillion Sensor Summit, Orlando, USA, December 8 - 10, 2015

Peter Ramm

**Our Early and Ongoing Work in 3D Integration**
3D ASIP, Redwood City, CA, USA, December 15 - 17, 2015
Bernadette Kinzel
**Design of an integrated high-voltage driver for piezoelectric microfluidic elements**
TU München
Supervisor: Dr. Erkan Isa

Jan Jansen
**Evaluation of the use of a micropump for cell biological and medical purposes**
TU München
Supervisor: Dr. Martin Richter

Simone Kager
**Bonding technique for the hermetic encapsulation of a fluidic eye implant**
TU München
Supervisor: Dr. Martin Richter

Melanie Bähtz
**Development of a foil-based Biofluoro Chip as sensitivity test for bacteria**
University of Regensburg
Supervisor: Dr. Jennifer Schmidt

Maria Zinkl
**Impedance-based analysis of adherent cells using interdigitated electrodes of subcellular dimensions**
University of Regensburg
Supervisor: Christian Götz

Jawad Esmatullah
**EBS-Jawad-Construction and characterization of an experimental setup for the investigation of up-converting dyes**
TU München
Supervisor: Leonhard Meixner
Sensor element for carbon monoxide detection
Sabine Trupp, Matthias Stich, Julia Sporer
DE 102013218997

Method for the detection of resistant pathogens and method for the execution of the same
Jennifer Schmidt, Ignaz Eisele, Sabine Trupp, Karl Haberger, Wolfgang Sittel
DE 10 2013 225 037

Fluid sensor and method for investigating a fluid
Ignaz Eisele
DE 10 2015 104 419 A1

A process for etching and chamber cleaning and a gas therefore
Robert Wieland, Michael Pittroff, Jamila Boudaden
WO 2015/173003 A1
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.

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<tr>
<th>Organisation</th>
<th>Scientist</th>
<th>Position</th>
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<tr>
<td>Cluster-Offensive Bayern</td>
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<td>Chemistry</td>
<td>Sabine Trupp</td>
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<td>Erwin Yacoub</td>
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<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>Christoph Kutter</td>
<td>Spokesperson</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>dib, deutscher ingenieurinnenbund e.v.</td>
<td>Sabine Scherbaum</td>
<td>Member</td>
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<tr>
<td>German Physical Society</td>
<td>Christoph Kutter</td>
<td>Members</td>
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<td>Hanns-Erik Endres</td>
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<td>Axel Wille</td>
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<td>ECS, Electrochemical Society</td>
<td>Peter Ramm</td>
<td>Symposium organisator</td>
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<td>Peter Ramm</td>
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<td>Eduard Rhein Stiftung</td>
<td>Christoph Kutter</td>
<td>Member of the Board of Curators</td>
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<td>EOS/ESD Association, USA EOS/ESD Association, USA</td>
<td>Horst A. Gieser</td>
<td>Members</td>
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<td>Heinrich Wolf</td>
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<tr>
<td>EOS/ESD Symposium, USA</td>
<td>Heinrich Wolf</td>
<td>Member of the Technical Program Committee</td>
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<td>ESD Association</td>
<td>Horst Gieser</td>
<td>Members, standardization, experts</td>
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<td></td>
<td>Heinrich Wolf</td>
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### Organisations and Scientists

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<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 ESD-FORUM e.V.</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>
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<tr>
<td>Landshut University, Microsystems Technology Cluster</td>
<td>Robert Faul</td>
<td>Technical consultant</td>
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<tr>
<td>IEEE, Institute of Electrical and Electronics Engineers, USA</td>
<td>Peter Kücher, Christoph Kutter, Linus Maurer, Peter Ramm</td>
<td>Members</td>
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<td></td>
<td>Detlef Bonfert</td>
<td>Senior member</td>
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<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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<td>IEEE (EDS), Electron Devices Society, USA</td>
<td>Detlef Bonfert, Peter Ramm</td>
<td>Members</td>
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<td>IEEE (ComSoc), Communication Society, USA</td>
<td>Detlef Bonfert</td>
<td>Member</td>
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<td>IEEE (IITC), International Interconnect Technology Conference, USA</td>
<td>Peter Ramm</td>
<td>Member of the Technical Program Committee</td>
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<tr>
<td>IEEE (ISCDG), International Semiconductor Conference Dresden - Grenoble</td>
<td>Christoph Kutter</td>
<td>Head of the Technical Program Committee</td>
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<td>IEEE (MTT), Microwave Theory and Techniques Society, USA</td>
<td>Detlef Bonfert, Linus Maurer</td>
<td>Members</td>
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<tr>
<td>IEEE (3DIC), International 3D System Integration Conference</td>
<td>Peter Ramm</td>
<td>Head of the Organizing Committee Europe and Founding member</td>
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<td>IEEE Sensor Council</td>
<td>Peter Kücher</td>
<td>Member</td>
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MEMBERSHIPS

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<tr>
<td>IEW, International Electrostatic Workshop, USA</td>
<td>Heinrich Wolf</td>
<td>Member of the Technical Program Committee</td>
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<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, International Microelectronics Assembly and Packaging Society, USA</td>
<td>Peter Ramm</td>
<td>“Fellow of Society” and member of the Awards Committee</td>
</tr>
<tr>
<td>iMAPS DPC, iMAPS Device Packaging Conference, USA</td>
<td>Peter Ramm</td>
<td>General Chair Elect</td>
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<tr>
<td>Industry Council on ESD-Target Levels</td>
<td>Horst A. Gieser</td>
<td>Member</td>
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<tr>
<td>Innovationspreis der deutschen Wirtschaft</td>
<td>Christoph Kutter</td>
<td>Member of the Board of Trustees</td>
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<tr>
<td>ISSE; International Spring Seminar in Electronics</td>
<td>Detlef Bonfert</td>
<td>Member of the Steering Committee</td>
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<tr>
<td>IWLPC, International Wafer-Level Packaging Conference</td>
<td>Peter Ramm</td>
<td>Chairman of the Subcommittee on 3D Integration</td>
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<tr>
<td>mst</td>
<td>femNetmeets meets Nano and Optics in the National Pact for Women in MINT Careers</td>
<td>Sabine Scherbaum</td>
</tr>
<tr>
<td>MST Congress</td>
<td>Martin Richter</td>
<td>Member of the Program 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 North America</td>
<td>Peter Ramm</td>
<td>Member of the „Standards 3DS-IC“ Committee and the Technical Program Committee</td>
</tr>
<tr>
<td>SIITME, International Symposium for Design and Technology in Electronic Packaging</td>
<td>Detlef Bonfert</td>
<td>Member of the Steering Committee</td>
</tr>
<tr>
<td></td>
<td>Detlef Bonfert</td>
<td>Member of the Scientific Committee and chairman of the Technical Program Committee</td>
</tr>
</tbody>
</table>
### SCIENTIFIC ACTIVITIES

**Integrated micropump driver**

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Scientist</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMTA, Surface Mount Technology Association</td>
<td>Peter Ramm</td>
<td>Member of the Technical Program Committee IWLPC</td>
</tr>
<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-Association for Microelectronics, Micro and Precision Engineering, GMM</td>
<td>Christoph Kutter</td>
<td>Deputy Chair</td>
</tr>
<tr>
<td></td>
<td>Horst A. Gieser, Christoph Jenke, Sebastian Kibler, Linus Maurer, Martin Richter</td>
<td>Members</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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<td>VDI VDE IT GmbH</td>
<td>Christoph Kutter</td>
<td>Member of the Supervisory Board</td>
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<tr>
<td></td>
<td>Robert Wieland</td>
<td>Member</td>
</tr>
<tr>
<td>ZAK-Zentrum für angewandte Kompetenz und Mentoring der Frauenakademie München</td>
<td>Sabine Scherbaum</td>
<td>Mentor</td>
</tr>
</tbody>
</table>
CONTACT
Silicon chip set up for characterization with the Advanced Low Frequency Noise Analyzer
PUBLISHING NOTES

FRAUNHOFER EMFT JAHRESVERANSTALTUNG

Farben und Frequenzen

26. März 2015, Seminarsaal 2. OG