A glance at last year’s figures confirms us in our belief that the topics we are focusing on are very much in tune with our customers’ needs: three of our five business areas saw significant economic growth in 2017. Our team structure was a major contributing factor here: the mixture of very experienced staff and young academics creates an exceptional dynamic that gives rise to future-oriented solutions – combining well-established, tried-and-tested principles with fresh and sometimes unconventional ideas. As such we believe we have a versatile team that will serve us excellently in the years to come.

In view of our research goal »Sensors and actuators for people and the environment«, I am especially pleased to note that one of our research teams has made it through to the finals of this year’s German Innovation Award for Climate and the Environment with its project to develop an environment-friendly cleaning gas for the semiconductor industry. But before I give away too much here, please read on for yourselves! I very much hope you enjoy our fascinating 2017 annual report.

Best regards,

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

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

We will remember 2017 as the year in which a far-reaching step was taken in terms of setting the future course in the field of microelectronics and nanoelectronics in Germany: the Federal Ministry of Education and Research confirmed funding of EUR 350 million for the new Research Fab Microelectronics Germany (German abbreviation: FMD) – a key strategic decision in favor of Germany as a technology base. From now on, eleven institutes within the Fraunhofer Group for Microelectronics and two Leibniz institutes will be pooling their expertise in the field of semiconductor-based micro-systems and nanosystems. The aim is to be able to offer our customers in large-scale industry as well as SMEs and universities the entire value creation chain for microelectronics and nanoelectronics from a single source. Fraunhofer EMFT will mainly be contributing its know-how in the areas of silicon technology, flexible electronics and circuit design, as well as participating in application areas for sensor technologies.

With the integration of the Oberpfaffenhofen training and application center and the new »Cell-Based Sensors« group at the Regensburg site early this year, we are already able to look back at a period of joint development with these new facilities: our new staff have given us fresh impetus and lots of fascinating new ideas that perfectly supplement our existing expertise. Since this has resulted in an expanded R&D portfolio, we have decided to somewhat adapt our strategic set-up. This is also reflected in our new public image as conveyed here in the annual report: in our »expertise triangle«, production-oriented microtechnologies form the centerpiece and basis for our other three areas of expertise, namely Innovative Sensor Solutions, Micro Dosing and Secure Electronics. We are very interested to hear your feedback and will be glad to receive any ideas and critique.

A glance at last year’s figures confirms us in our belief that the topics we are focusing on are very much in tune with our customers’ needs: three of our five business areas saw significant economic growth in 2017. Our team structure was a major contributing factor here: the mixture of very experienced staff and young academics creates an exceptional dynamic that gives rise to future-oriented solutions – combining well-established, tried-and-tested principles with fresh and sometimes unconventional ideas. As such we believe we have a versatile team that will serve us excellently in the years to come.

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# Table of Contents

## Fraunhofer EMFT
- Profile [10]
- Advisory Board [12]

## Areas of expertise
- Innovative Sensor Solutions [16]
- Micro Dosing [18]
- Safe and Secure Electronics [20]
- Manufacturing-oriented Microtechnologies [22]

## Examples of projects and applications
- Research Fab Microelectronics Germany (FMD) [52]
- High performance center: »Secure Connected Systems« [53]

## New cooperations
- Range of services and technologies [54]
- Center for Interconnection Technologies ZVE [60]

## Customers and cooperation partners
- An interview with Dr. Roman Pausch [66]
- Cooperation between Infineon and Fraunhofer EMFT [68]
- Universities [72]

## Special events
- Highlights [76]
- Events [78]

## Youth development
- Careers at Fraunhofer EMFT [82]
- Programs for school students [84]

## Press and media

## Scientific activities
- Academic publications and talks [94]
- Master theses [98]
- Doctorates [99]
- Patents [100]

## Contact [102]

## Publishing notes [105]
Fraunhofer EMFT buildings
Sensors already have a key role to play in our digitized world and will become increasingly important in the years to come as devices become interconnected («Internet of Things»). This involves rigorous requirements in terms of performance and robustness as well as the energy and cost efficiency of these miniature electronic aids. New solutions are in demand too — in the area of gas sensor and biosensor technology, for example.

In its R&D strategy, Fraunhofer EMFT addresses all these topics and is able to draw on a broad range of technological expertise — from semiconductor processes and MEMS technologies through to 3D integration and foil electronics. These production-oriented microtechnologies provide the basis for the other areas of expertise at Fraunhofer EMFT: Innovative Sensor Solutions, Secure Electronics and Micro Dosing. It is the interdisciplinary interplay between these areas of expertise in particular that gives rise to pioneering solutions. The overriding goal of the activities is to generate added value for society and the economy, which is why the focus is on orientation towards applications and customer needs. Numerous industry customers collaborate closely with scientists at the institution on joint projects, thereby making use of Fraunhofer EMFT’s outstanding technological infrastructure.

The Munich site provides an optimum setting for the institution’s research and development activities. Several global market leaders and SMEs in the field of sensors and systems are based here: they are able to benefit from Fraunhofer EMFT’s R&D activities as well as at 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 possesses a number of important patents in all its areas of expertise. Its innovations have been licensed by numerous partner enterprises, providing a key foundation in terms of funding. For example, the world’s smallest silicon membrane pump was developed at the institution, Fraunhofer EMFT’s 3D stacking technology is used in every mobile memory, and CC-TLP — a new international standard for ESD tests — likewise originates from the Fraunhofer EMFT labs.

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

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**Personnel development**

In 2017 Fraunhofer EMFT employed 119 staff. Of these, 96 worked in the scientific area and another 23 in the areas of administration, marketing, IT and technology. On average there were also 47 students and research assistants from a wide range of higher education institutions working on their diploma or master’s degree assignment at any given time and involved in the various research areas at Fraunhofer EMFT. Fraunhofer EMFT also employed two trainees.

**Total budget**

Fraunhofer EMFT once again performed successfully in fiscal 2017. The institution’s total budget amounted to EUR 14.2 million in 2017. Industry contracts generated a total volume of approx. EUR 4.2 million, accounting for 30.2 % of the total budget.

**Infrastructure**

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

- Class 10/100 cleanroom and gray room (866 m$^2$
- Class 1000 cleanroom and higher (121 m$^2$
- Laboratories: (1477 m$^2$
- Office areas and meeting rooms: (1852 m$^2$

In Regensburg, staff use the labs at the University of Regensburg. This ensures close professional dialog.

**Ongoing projects in 2017**

<table>
<thead>
<tr>
<th>2017</th>
<th>Industry</th>
<th>Public/EU</th>
<th>Other</th>
</tr>
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<td>60</td>
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**Development of earnings**

<table>
<thead>
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<th>2013</th>
<th>2014</th>
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<th>2016</th>
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<tr>
<td>0 Mio €</td>
<td>2 Mio €</td>
<td>4 Mio €</td>
<td>6 Mio €</td>
<td>8 Mio €</td>
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**Staff distribution**

- Research
- Administration, Marketing, IT
- Students and research assistants
- Trainees
The Fraunhofer EMFT Advisory Board is a consultative and supervisory body. It consists of a number of distinguished representatives from the areas of science and business. Members of the Advisory Board advise the Fraunhofer EMFT management and Fraunhofer board on issues relating to the specialist orientation and structural development of the institution.
AREAS OF EXPERTISE

- Innovative Sensor Solutions
- Manufacturing Oriented Microtechnologies
- Micro Dosing
- Safe and Secure Electronics
As the «sense organs of things» sensors have a key role to play in future applications in the area of the Internet of Things (IoT). However, this involves rigorous requirements in terms of performance and robustness as well as the energy and cost efficiency of these miniature electronic aids.

IoT sensor systems have to be able to run on very little energy or even be self-sufficient. Near-Field Communication (NFC) and low-power electronics are examples of technologies used for this purpose in IoT sensor nodes developed at Fraunhofer EMFT. BLE (Bluetooth Low Energy) technology can be used to interconnect these IoT sensor nodes, also enabling larger distances to be overcome. Meanwhile, sensor systems on flexible substrates enable an extremely low installation height, a high degree of flexibility, robustness and relatively low manufacturing costs, especially when produced in large quantities. The open form factor also allows integration in and on various surfaces. Fraunhofer EMFT has longstanding expertise and the necessary infrastructure to be able to produce such electronic systems efficiently and cost-effectively on foil using roll-to-roll methods.

There are already sophisticated solutions available to measure most physical parameters; however, markets can only be penetrated by means of novel concepts. One example is flow sensors for the dosage of minute amounts of liquids and gases within the nanoliter range. Various technological approaches are pursued in this area:

- one module for the dosage of tiny liquid volumes is based on capacitive sensorics (using the kind of chips which are also used in mobile phones). Fraunhofer EMFT researchers have developed a dosage module that is able to dispense tiny volumes of lubrication oil in a range of 2-30 nanoliters/minute on a closed loop basis in the bearings of machine tool spindles.

- One variant of this capacitive concept was developed in order to precisely measure and dispense very small volume packages (12 µl) of a highly effective cancer medication. This technology also has the potential to be used in future patch pumps.

- Another innovative dosage chip developed at Fraunhofer EMFT is based on the pressure difference principle. Samples of this dosage chip were produced at an industrial MEMS fab and used in different medical industrial projects. This dosage chip also has the potential to be deployed very cost-effectively in disposable medical products.

There is a need for somewhat more basic research in the field of chemical sensorics in general and the area of gas sensorics in particular. Gases and fluids can be analyzed very precisely by determining their physical properties, but the measuring systems used tend to be excessively large and expensive. What is more, the chemical sensors currently available often only provide stable and reliable measurements to a limited degree. Over time they lose their sensitivity and have to be re-calibrated, and they can also be subject to cross-sensitivities which distort measuring results. For this reason, Fraunhofer EMFT researchers are working on new optical, impedimetric and potentiometric sensors in order to achieve long-term stability and self-calibration in chemical parameters in gases and liquids. The institution has special measuring stations as well as the experience in measurement technology that is required here. What is more, individually tailored biochemical and chemical sensor materials and sensor concepts are developed at the institution for the purpose of analyte detection and the associated optical/electrical signaling.

Biosensorics poses an even greater challenge due to the complexity of the molecules. Innovative sensor materials are used at Fraunhofer EMFT to develop novel methods and techniques for detecting microorganisms, for example. Measurement systems based on such sensor materials can be constructed on an energy-efficient basis to ensure the technology is suitable for portable hand-held devices for use in such areas as medical technology and environmental analytics.

Meanwhile, cell-based sensorics makes use of micro-electronic systems to measure the response of living cells to various environmental factors and analytes. This kind of biotechnological hybrid can be used to measure and analyze the toxicity of chemicals, the effects of medication, environmental influences and even complex interactions with a high sample throughput. Potential applications extend to the most innovative branches of personalized, regenerative medicine. Foil-based lab-on-chip systems enable fast, low-cost point-of-care diagnosis of various illnesses.

One particular challenge lies in adapting chemical or biological sensors specifically to IoT applications. Fraunhofer EMFT has years of experience in the development of sensor system technologies which can especially be put to wide-ranging use in chemosensorics and biosensorics. One key component in terms of creating a stable and valid sensor system is the necessary system technology. Model-supported signal analysis, non-stationary measurement methods, multi-variant sensorics and modern methods of numerical signal processing provide the basis here.
Dosage of gases and liquids to the nearest nanoliter is a central and longstanding area of expertise at Fraunhofer EMFT, covering a broad range of applications – from medical technology through to industrial applications and consumer electronics.

Piezo-electrically powered micropumps are at the heart of micro dosing systems. The Fraunhofer EMFT team possesses extensive expertise and practical experience in the design of micropumps. On this basis, it is possible to adapt the technological requirements in terms of dosage precision, counter-pressure resistance, size, energy consumption, particle resistance, bubble tolerance and free-flow protection to the application in question.

Fraunhofer EMFT has designed a portfolio of silicon and stainless steel micropumps for the various areas of use. One main focus of R&D activities in the area of silicon micropumps is further miniaturization. The aim here is to significantly reduce production costs, thereby facilitating access to the mass markets. The smallest silicon membrane pump currently available in the world, sized 5 x 5 x 0.6 mm³, was developed at Fraunhofer EMFT. A key focus just now in the area of stainless steel micropumps is designing the micro dosing components. Here Fraunhofer EMFT cooperates closely with industry partners: the aim is for the latter to be able to manufacture the components themselves in high volumes subsequent to the respective technology transfer.

In addition to micropumps, Fraunhofer EMFT develops other micro dosing components that are indispensable for precise and reliable dosage.

• **Electronic activation systems for micropumps:** Electronic activation systems for micropumps are designed and developed for specific applications taking into account the various requirements. Factors such as the noise of the piezo actuator, piezo fatigue, piezo breakage and energy consumption can all be significant here.

• **Bubble separators:** This separating element is especially required for applications in medical technology, e.g. medical dosing systems, in order to reliably remove bubbles from the fluid path.

• **Safety valve:** A safety valve is a passive component which is normally closed and self-blocking. It prevents so-called free-flow, as can occur in membrane pumps with passive one-way valves, for example.

• **Normally closed micro valve:** Self-blocking, active normally closed micro valve.

• **Integrated micropump driver:** Fully integrated circuit concepts allow highly efficient control of the micropump at minimum size. The control signals can be optimized for the selected micropump and the customer-specific application case in terms of voltage span, polarity and edge steepness.

In addition to its development expertise in the area of micro dosing components, the Fraunhofer EMFT team also has extensive system competence. Micro dosing as an interface technology requires a wide-ranging knowledge of such areas as fluid mechanics, elastomechanics, surface physics, chemistry and phase transformation. Understanding the causal relations between these various factors is essential in order to enable smooth interplay of all components in a micro dosing system.

In order to optimize the performance and reliability of their micro dosing systems even further, researchers work continually on new solutions – for example in the management of bubbles, particles and back pressure, dosage monitoring of very small quantities and also chemical resilience.

**Microfluidics on foil substrates**

In some areas of application such as medical technology and consumer electronics, disposable microfluidic systems open up attractive new market opportunities. Here, foil electronics offers interesting potential for the low-cost manufacture of disposable microfluidic systems in large quantities. At Fraunhofer EMFT, disposable dosage dispensers for aerosol and microjetting are printed on foil using the roll-to-roll method, for example (printed dispensers). These are suitable for applications such as fragrance and interior insecticide dosage.
IoT, Industry 4.0, Big Data – there is no question that digitalization has come to play a role in virtually all areas of our day-to-day lives. Secure electronic systems are required as the »infrastructure« of this interconnected world. The word »secure« has various facets here.

Firstly, electronic systems have to be 100% reliable in the sense of offering failure-free operation in sensitive areas such as medical technology, the automotive industry and aerospace technology. In its R&D activities, Fraunhofer EMFT pursues the goal of enabling so-called zero-defect systems.

- **Malfunction analysis and characterization:** The Fraunhofer EMFT measurement labs are able to carry out extensive multiparametric characterizations and reliability tests on electronic components and modules. Based on multiparametric characterization, it is possible to simulate physical input variables such as voltage, current, temperature, light, moisture and gases etc. under laboratory conditions, as well as determining the response of the component on its own and collectively and adjusting the simulation accordingly. The results serve as a basis for gathering evidence on measurement accuracy and reproducibility. Individual integrated circuits can be realized for further malfunction analyses and electrical tests in alternative housings and contact systems or contacted on the wafer sampler with contact probes. By applying suitable load tests to address the relevant error mechanisms, it is also possible to determine the anticipated reliability and service life of components and modules. Finally, services include systematic analysis of the causes of complex errors and reliability problems in electronic components and systems, reproduction of these under laboratory conditions, and identification of falsifications. The requirements range from simple industrial electronics through to complex qualifications for space flight.

- **ESD test and protection concepts:** The »Analysis & Tests« group has been involved with ESD protection for more than 25 years and supports industry customers from the most diverse sectors with risk analysis and the development of individual ESD protection structures for components and systems. So-called Capacitive Coupled Transmission Line Pulsing (CC-TLP) is a measuring technique developed and patented by researchers which exhibits a much higher level of precision and reproducibility than the conventional CDM (Charged Device Model) Test. This is especially important in highly miniaturized modules with a very low ESD tolerance. At system level, Fraunhofer EMFT experts are also specialized in tracing design-related disruptive effects and developing the appropriate protection concepts.

- **Functional reliability:** In application areas where safety is a key element such as autonomous driving, aerospace and also medical applications, absolute reliability of the electronic systems is crucial. Concepts are required in which the system as a whole continues to operate even in the event of malfunction, ensuring there is no risk to users. The Autokonf project currently in progress involves a switch developed by Fraunhofer EMFT being used to connect a multifunctional reserve control unit to a synchronous motor during operation within a limited period of time. The multifunctional control unit replaces the classic redundancy of several individual units in order to achieve a secure state for a limited period.

- **Special qualification processes:** Not all application cases of electronic modules, plugs and switches can be reliably validated by means of standardized tests. At Fraunhofer EMFT, test methods are developed for the purpose of durability validation prior to volume production which simulate potential loads in accelerated form. The environmental tests can be carried out with and without electric current load while characteristic variables are monitored at the same time. The effectiveness of measures applied to electronic modules to provide protection from climatic loads (condensation) is metrologically documented in the lab, after which potential improvements are discussed and verified with the customer.

- **Monitoring of electrical connections:** In the area of IoT, connectivity between the systems has a key role to play. The functional efficiency of the system as a whole depends on the electrical interfaces (fixed and moving contacts) working at all times. Integrated sensor systems enable continuous monitoring of the state of the connection, thereby helping to avoid system failure due to defective contacts.

The second aspect of »security« that is becoming increasingly important in the age of digitalization is the protection of electronic systems from manipulation and unwanted access. Only when data security is guaranteed will IoT applications become accepted on a wide scale. This is where concepts such as hardware security and manipulation protection come into play: after all, software-base solutions are often insufficient to protect sensitive data in electronic systems, e.g. in the field of banking and smart grid/smart metering, or when handling patient data and operating critical infrastructures.

- **Based on sensors and so-called Physical Unclonable Functions (PUF), Fraunhofer EMFT is developing hardware-based solutions to protect electronic systems from manipulation. One option is to derive cryptographic keys from the physically unique properties of a chip or assembly. Here, keys are generated based on physical properties. As soon as these properties are altered – as is necessarily in the event of a manipulation attempt – the key no longer works.**

- **Physical weaknesses and Hardware Trojans in highly integrated safety circuits – which can be inserted when such items are manufactured outside Europe – are to be identified in a protected lab at Fraunhofer EMFT. One aim, after the relevant retrograde preparation, is to detect deviations in physical realization from the design data.**

The third aspect of security refers to electronic systems being used to increase the safety of human beings, e.g. in occupational safety, medical applications or the area of Ambient Assisted Living. Fraunhofer EMFT solutions contribute to users' personal safety in the various application areas. In the field of medical technology, for example, the micro dosing components and systems developed at Fraunhofer EMFT ensure that components and systems developed at Fraunhofer EMFT ensure that solutions for medication dosage function reliably. In the area of occupational safety, Fraunhofer EMFT’s sensor solutions can be used to detect hazardous substances in the environment.
Fraunhofer EMFT is equipped with extensive cutting-edge technological facilities in the area of microelectronics and microtechnology which are maintained by experienced researchers and microtechnologists and used to develop customer-specific solutions. These Manufacturing-oriented Microtechnologies provide the basis for the other areas of expertise at Fraunhofer EMFT, ranging from technology and process analytics to the manufacture and testing of components and the realization of concrete sensor applications by means of system integration.

In the area of technology and process analytics, Fraunhofer EMFT offers an industry-compatible technology platform for testing new process media and optimizing selected process stages, thereby increasing performance and efficiency, for example. On request, it is also possible to realize small-series production – in cases where such small quantities are not available on the world market, for example. A CMOS line (200 mm, structural resolution up to 0.35 µm) is available for producing microtechnology components – all processes comply with the CMOS standard – and there is also a MEMS line (150 mm and 200 mm) for materials which are not CMOS-compatible. In addition to standardized silicon technology, the institution is also able to offer special processes such as silicon-germanium epitaxy as well as a wide range of integration technologies. The latter include 3D integration methods (W-TSV, SLID), anodic bonding at wafer level, the processing of glass substrates (TGV) and various metallization systems (aluminum, tungsten, copper and gold).

This broad range of technologies is complemented with modern in-line – i.e. destruction-free – measuring technology for the purpose of material and process characterization. Alternatively, there are various test structures available for the purpose of off-line process control. In addition, new analysis methods are developed according to customer-specific requirements that are suitable for production which are then integrated in existing production structures. Based on charge carrier lifetime measurements for example, effective methods have been developed to check contamination of high-impedance Float Zone material. Using the technologies available, it is possible to produce numerous components in the institution’s in-house cleanrooms. The focus here is on the development and optimization of electrical and optical components for modern sensor systems. In addition to component manufacture itself, it is also possible to create layouts and carry out extensive testing, e.g. reliability studies (HAST test).

The optical components developed at Fraunhofer EMFT include complex fluorescence modules, classic PIN photodiodes and sensitive silicon photomultipliers for individual photon detection. The latter are used in PET/MRI diagnostic imaging and were developed in close collaboration with an SME. In addition to a suitable sensor, individual photon detection also requires special electronics for signal analysis. In this context, Fraunhofer EMFT researchers develop highly sensitive, low-noise components to detect the very smallest signals. The development and manufacture of low-noise transis tors are Fraunhofer EMFT USPs. The institution possesses both the technological and metrological expertise required for JFETs, MOSFETs, varactor diodes and sensors, and this is put to intense use for industry contracts. A recently established low-frequency noise measurement system is now also being used by Keysight for demonstration purposes. Fraunhofer EMFT’s recently established low-noise transis tors are Fraunhofer EMFT USPs. The institution possesses both the technological and metrological expertise required for JFETs, MOSFETs, varactor diodes and sensors, and this is put to intense use for industry contracts. A recently established low-frequency noise measurement system is now also being used by Keysight for demonstration purposes. Fraunhofer EMFT’s recently established low-noise transis tors are Fraunhofer EMFT USPs. The institution possesses both the technological and metrological expertise required for JFETs, MOSFETs, varactor diodes and sensors, and this is put to intense use for industry contracts. A recently established low-frequency noise measurement system is now also being used by Keysight for demonstration purposes.

The optical and electrical components available are developed further on an ongoing basis for a range of sensor applications. Entire sensor systems including the appropriate interfaces are designed for demonstration purposes based on market relevance and at the request of customers. Fraunhofer EMFT has systems for pH measurement in liquids, spectroscopic analysis of gases and the monitoring of environmental parameters such as temperature and air humidity as well as the carbon dioxide and hydrogen content of ambient air. The current focus is on networking sensors by means of microsystem integration. Particular attention here is being paid to 3D integration – something that Fraunhofer EMFT has been involved in for many years as a central aspect in linking CMOS-compatible electronics with MEMS-based sensors. In addition, sensors are read out, controlled and networked via standardized interfaces. A collaborative industry venture was set up to create a multifunctional sensor platform for this purpose. This enables all sensors to be activated via USB or on a contactless basis via Bluetooth and NFC. Measurement parameters can then be read out conveniently using a commonly available smartphone, for example.

Foil electronics: Flexible, multifunctional electronics offers new possibilities for a range of smart, high-capacity products – in the context of the »Internet of Things« vision, for instance. In-house reel-to-reel production systems enable low-cost processing of foils and other flexible substrates to develop flexible, bendable, flat and large-area electronic systems. In this connection, foil processes developed at Fraunhofer EMFT are combined with techniques drawn from various conventional technological fields (e.g. silicon, MEMS or circuit board technologies). Here, heterointegration of silicon and foil technology has a key technological role to play: while silicon technology allows extremely miniaturized components to be realized, foil technology offers greater scope for design, enabling flexible, flat and biocompatible electronics. Examples of applications include sensors on curved surfaces, on-body sensors for health monitoring, multimodal sensors for robots which will interact with human beings in the future, smart textiles and a wide range of distributed and networked sensor modules for the intelligent control of machines and processes generally grouped under the catchword Industry 4.0. The combination of capabilities in the area of thin silicon and foil technology allows the realization of rewired ICs packaged in foil (chip-in-foil package) without having to dispense with the advantages of low installation height and flexibility.

Thin silicon: Extremely thin silicon chips are required for heterogeneous 3D integration and chip-in-foil packages. A fundamental requirement here is the technological expertise to produce thin wafers. The Munich site is excellently equipped for the complex processes required for thinning, so the devices produced at wafer level can be as thin as needed. Fraunhofer EMFT offers its patented »dicing by thinning« technology for the purpose of chip separation for very thin semiconductor wafers. These technologies can be used to create thin and flexible silicon chips with a thickness of 10 µm - 30 µm. Handling extremely thin silicon wafers of this kind poses considerable challenges. The technique for safe handling of thin silicon such as electrostatic carrier systems (e-carrier and e-foil) are likewise among Fraunhofer EMFT’s areas of expertise.

IC design: Microchips are at the heart of countless products: they cluster numerous functions inside a minute space. However, very specific applications or the capacity to tap into new functions and areas of use, increased miniaturization, enhanced energy efficiency, low manufacturing costs and greater reliability often require new IC designs that are not available on the market in this form. Here, Fraunhofer EMFT supports its customers in designing complex analog and mixed-signal circuits, focused on novel sensoric concepts and millimeter design (SAR-ADC, Sigma-Delta ADC, PLL, micro wave structures).
**System integration:** By means of demonstrators, prototypes and systems, Fraunhofer EMFT scientists are able to illustrate potential application scenarios for the technologies and components developed at the institution. For customers, this development expertise is an essential part of the Fraunhofer EMFT service portfolio: SMEs in particular often require complete solutions rather than individual components. In particular, extensive expertise in system development provides an essential basis for translating innovative technologies and solutions (such as energy harvesting and ultra-low power consumption) quickly and successfully into applications to create future-oriented products. The development expertise of our experienced interdisciplinary team covers hardware and software, electronics, mechanics, optics and fluidics with micropumps and micro valves as well as the incorporation of innovative numerical signal processing concepts. Services in the area of system development range from drafting initial concepts through to feasibility demonstrators, prototypes and complete systems, depending on requirements.
Examples of projects and applications

RF and mm-wave Voltage Controlled Oscillators and transmission lines on a 3 x 3 mm² integrated circuit on the 22-FDSOI CMOS technology from GlobalFoundries
Fraunhofer EMFT is involved in various projects, collaborating with organizations in science and industry to conduct research and development regarding future-oriented solutions that aim to tackle some of the key challenges facing society today.

### 3D integration technologies for IoT applications

The trend towards the Internet of Things (IoT) makes heterogeneous 3D integration a key technology but also involves challenges in terms of relevant process technologies, such as wafer bonding: the enormous pressure of competition in the area of IoT applications means that the systems have to be increasingly smaller but at the same time more capable and robust. In order to meet these demands, Fraunhofer EMFT signed a license agreement with XPSR Corp. in September 2016 so as to be able to incorporate ZiBond® and DBI® (Direct Bond Interconnect) in its portfolio – two of the most cutting-edge 3D integration technologies.

Both processes can be carried out at relatively low temperatures of approx. 200 °C, which impacts positively on component reliability and durability. DBI® technology involves the components being both mechanically and electrically connected after special preparatory treatment of the copper and oxide surfaces used. Since this avoids the elaborate process of through-connecting chips, the systems can be produced more cost-effectively – a basic requirement for access to mass markets such as consumer electronics. Another advantage: the pitches (structural width and spacing) between the connections are at best reduced to just 2 µm. This enables very highly integrated systems-on-chips with enormous performance capacity – which is of particular interest in connection with high-performance applications such as processors. So-called Hybrid Memory Cubes are a trend in this area, where the memory and processor are integrated in a single 3D stack.

### Failsafe electronics for autonomous driving

Autonomous driving is an integral part of virtually all future mobility concepts. Since human intervention is not intended in the context of fully automated driving, the relevant sensors and electronic systems have to meet the very highest demands in terms of reliability: the system has to be able to respond to unforeseen events as well as remaining stable in the case of error or functional impairment – as caused by incorrect, delayed or missing information, if a component fails or if the energy supply is lost, for example.

Theoretically, all electronic components could be provided in duplicate: if one component were to fail, an identical one would be available to take its place. However, this solution is neither economically nor technically feasible since it would take up too much installation space inside the car.

Researchers at Fraunhofer EMFT have joined forces with several industry partners to develop a clever alternative with the project AutoKonf – a redundant, generic control unit. If the control device for the steering or brakes fails, the redundant generic control unit takes over the function in question and is able to control the car safely. In order to ensure the redundant control unit is able to perform the tasks of both steering and brake control, the project has focused on developing electronic systems which allow dynamic alteration of the signal distribution and power supply, for example.

The Fraunhofer EMFT team is looking into the integration of switching capability in plugs and interface modules. Among other things, classic switch matrices and novel techniques are investigated which work within a very small installation space, in particular with regard to reliability. For this purpose, a thermal design is being developed for the necessary assembly and interconnection technology.

By the end of the project, the aim is to develop the effectiveness of the concept in defined test and failure cases: an error is injected into the new system while the stability control is active. Using a vehicle test bench, the project partner and coordinator Intedis will then verify whether and to what extent vehicle stability is still maintained.

The project is being funded by the Federal Ministry of Education and Research (BMBF; allocation from the Business Plan of the Energy and Climate Fund (EKF), reference: 16EMO0187).

### Better chips for groundbreaking communication infrastructures

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

Characterization of ESD protection structures

On behalf of various industry customers, Fraunhofer EMFT researchers characterize ESD protection structures with high-current impulses on a transient and quasi-static basis in the automotive temperature range. The experts then use the analysis results to develop high-performance protection concepts for a variety of applications and requirements.

This work is carried out using a modern, fully equipped HP11301C TLP system in conjunction with a 300 mm Cascade PA300 or else the new HP1 ATS_8000A flying probe system in conjunction with the Agilent 62 GHz single shot oscilloscope DSOX96204Q.

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

Electrical connection technology as an intelligent diagnostic interface

Whether in automobiles – especially in the context of autonomous driving – or future industrial manufacturing: plugs and electrical connection technologies have a key role to play in digital networking. They are the main interface between machines, control units and data processing systems and so they provide the basis for the functionality, simple handling and reliability of automation technology.

Researchers at Fraunhofer EMFT in Oberpfaffenhofen are working on a completely new generation of active »intelligent« plugs, so-called Cyber Physical Connectors. The aim is to integrate miniaturized sensor systems in the plugs so as to be able to monitor the quality of the connection, for example. The idea goes further in that the built-sensors perform a kind of condition monitoring for the connected devices, also registering energy consumption, for instance.

For the sensors to be used efficiently, the data they generate has to be capable of being converted and analyzed directly in the plug. Here, R&D activities focus on the requirements involved in terms of the miniaturization and integration of sensors. For example, miniaturization must not result in any compromise in terms of quality or durability. What is more, the in some cases heterogeneous components have to be combined to form a reliably functioning overall system. In terms of both miniaturization and integration, researchers are pursuing innovative solutions from the wide-ranging Fraunhofer EMFT technology portfolio: this includes foil.

Biosensors detect plant viruses

Plant viruses cause economic losses of several billions of dollars every year. The often unspecific symptoms of a virus infection and the enormous variability of the genomes of plant viruses make it very challenging to come up with reliable diagnoses. In the event of an infection it is also vital to act quickly so as prevent spreading. However, the analyses required – such as single-stage simultaneous detection of various viruses in an infected plant – are difficult if not impossible to carry out using commonly available diagnosis kits.

The Fraunhofer project BioPat involves Fraunhofer EMFT researchers working alongside the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and the Fraunhofer Center for Systems Biotechnology CSB to develop highly specific and robust in-field sensor components for the detection of plant diseases. By creating novel biosensors, the team aims to enable fast, simple and simultaneous detection and differentiation of a wide range of viral genomes at an early stage of infection. The work being done on BioPat will focus on the analysis of viruses that are most relevant to the main crop plants in Chile and Germany, namely the grapevine and the potato.

As soon as the new generation of biosensors is established, it can quickly be adapted to meet other analytical requirements. This will open a wide spectrum of potential applications ranging from human pathogen detection to food analysis and marker-assisted breeding. The project is supported and funded by the Fraunhofer Executive Board.

EXAMPLES OF PROJECTS AND APPLICATIONS

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

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

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Examples of Projects and Applications

Electronic modules for future mobile phone generations

The aim of the joint European project REFERENCE under the coordination of SOITEC is to cluster European expertise in the area of microelectronics and initiate collaboration along the transnational value creation chain. Innovative production techniques are to be developed for new high-frequency (HF) technologies to be used in the electronic modules of future mobile phone generations such as 4G+ and 5G. For this purpose, the project partners aim to create HF substrates in the form of 200 mm and 300 mm wafers for the first time. Expansion of the improved HF substrates (200 mm and 300 mm) would allow HF modules with higher integration densities and bandwidths in future, thereby enabling higher data throughput rates at lower production costs.

The partners are seeking to pave the way for the internationally competitive mass production of complete HF modules of the next generation in Europe: the aim is to demonstrate the success of this new technology using HF modules for the new avionics bandwidth (4.2...4.4 GHz) as an example. This will enable wireless communication in aircraft in the future. Fraunhofer EMFT's focus here is developing the integrated circuits for the frequency synthesis, with the aim of creating circuits with optimized high-frequency properties due to the improved substrates.

The project is being funded by the EÇSEL initiative (Electronic Components and Systems for European Leadership), the central funding instrument for microelectronics and nanoelectronics under the European Framework Programme for Research and Innovation HORIZON 2020 (GA no.: 692477-2) and the BMBF initiative IKT2020 – Research for Innovation (reference: 16ESE0121).

Electrostatic carrier foils for thin wafers

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

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

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

The project «Electrostatic foil carrier for the processing of fragile and flexible substrates» is being funded under the internal Fraunhofer program MEF (Application 115.27/01).

Energy for smart objects

According to forecasts there will be as many as 24 billion networked objects by 2020 – more than a third of these being «smart» everyday objects that communicate and interact as part of the Internet of Things (IoT). A key issue here is energy supply: the smart objects have to be energy self-sufficient in order to be able to operate for as long a period as possible.

The EU project EnSO (Energy for Smart Objects) involves 39 partners from eight countries working on new solutions for an intelligent energy supply. The aim is to develop so-called AMES (Autonomous Micro Energy Sources). AMES combine various elements such as energy harvesting, energy management and micro-energy storage devices in order to ideally enable a lifelong operating period.

In this project, Fraunhofer EMFT researchers are developing concepts and technologies to integrate and embed electronic microchips in autonomous energy supply units. These compact packages will be well under one millimeter in height, and the aim is also to make them mechanically deformable so that they can be adapted to different environmental shapes. For
this purpose, the Munich experts are seeking to embed a very thin, bendable microchip in an ultra flat foil casing. Various technology concepts are currently being tested for the contacting: good results have been achieved with flip-chip contacting where the chip is set face-down on a wiring foil, contacted and embedded. The new packages proved to be robust in the first reliability tests. At the same time, a new concept has been developed in which the chip is set face-up on a foil and embedded with a casting compound. In an initial sample, the electrical contacting and the creation of the wiring level was achieved by means of laser opening of the via, stencil printing of contacts and fan-out wiring. In the next version, the connections will be realized using established thin-film lithography methods. This will then make it possible to create packages for chips with complex pad geometries.

The project is funded by the ECSEL initiative under the European Framework Programme for Research and Innovation HORIZON 2020 (GA no. 692482) and by the BMBF.

**Development and characterization of high-performance gas sensors**

The demand for sensitive, stable and long-lasting gas sensors is growing constantly – but the sensors currently available on the market do not generally meet all three of these requirements to an equal extent. Fraunhofer EMFT scientists are working on optimized solutions for chemical gas sensors, e.g. for CO₂. One goal is to gain a better understanding of sensor properties so as to be able to select the most suitable sensors for specific applications. In addition, the team is working to develop novel gas sensors that go beyond the current state of the art. The aim is to transfer the new insights to the market more quickly through close collaboration with two industry partners.

Researchers have a number of focus areas in their R&D activities: one approach is to synthesize novel materials – so-called hybrid organic-inorganic nano-materials – which exhibit high sensitivity towards specific gases such as CO₂. In order to be able to subject commercial and internally developed sensors to comprehensive testing, the team has also set up a gas measuring station at Fraunhofer EMFT. This set-up allows sensors to be characterized under the influence of various gases (CO, CO₂, H₂, acetone, ethanol, SO₂, NO₂). In the climate gas chamber it is possible to reproduce air humidity levels of between 5% and 95% and temperatures of 0°C to 100°C; furthermore, mixtures of up to three gases can be selected. The researchers use impedance spectroscopy to measure the electrical properties of the sensors in situ at various humidity levels.

Furthermore, the research team has developed a miniaturized evaluation kit as a useful addition to the gas measuring system. This approximately palm-sized device allows precise measurement of sensor response and recovery times. A conventional gas measuring system is not suited for this purpose since a complete gas exchange in the test chamber generally takes several minutes. The set-up consists of a PEEK cover which is screwed to a circuit board with a sealing ring. Three sensor sockets are positioned on the circuit board in order to achieve a gas exchange time and a measuring interval of approx. 350 ms.

**ESD characterization of remote keys**

The automated production of chipcard inlays on carrier foil is subject to a high risk of damage due to electrostatic discharge: this is because dual-band RFIDs (remote keys) with two antennas can form unconventional discharge paths. In collaboration with an industry partner, researchers at Fraunhofer EMFT investigated and modeled this type of discharge in inlays, replicating it by means of the appropriate stress methods such as CDM and VF-TLP. The aim was to achieve a better understanding of discharge characteristics. The results help enhance the robustness of the integrated circuit.

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

The aim of the internal Fraunhofer project low-Noise is to advance development of new, extremely low-noise FET transistors and adapt them to the specific requirements of potential customers. The advantage of the low-noise JFET is that it reaches a cut-off frequency of 1GHz – making it the »fastest« silicon-based JFET to date as compared to commercial products. In X-ray fluorescence applications, Fraunhofer EMFT’s low-noise JFETs take half the time to measure the same spectral resolution as transistors currently available on the market. What is more, the low-noise JFETs work at room temperature, so cooling is not necessary. This significantly simplifies assembly of the sensor as well as reducing both cost and power consumption.

Further optimization in the areas of robustness, limit frequency and noise will seek to reduce measuring time even further. In the medium term, this concept could potentially also be used in high-frequency oscillators and mixers. The project is being funded under the internal Fraunhofer program MEF.
Micropump driver ICs realized with 0.35 µm high voltage process

Industrialization of stainless steel micropumps for medical technology

High flow rates or extreme miniaturization – with its extensive pump portfolio, Fraunhofer EMFT is able to meet the most diverse requirements in the area of medical technology. For example, stainless steel, piezo-electric micromembrane pumps developed at the institution allow precise dosage rates of up to 200 ml/min with air and up to 80 ml/min with water. The wide spectrum of applications ranges from infusion and medication dosage systems to local suppression therapies for the treatment of chronic wounds.

In October 2017, Fraunhofer EMFT signed a long-term cooperation agreement with Rausch & Pausch GmbH for the industrialization and further technological advancement of the pumps. The world’s leading developer of hydraulic and pneumatic valve systems will contribute its automotive experience of large-scale production and quality standards and will take care of producing the pumps. For RaPa, the partnership is a major move into the new business area of medical technology.

Integrated high-voltage driver for micropumps

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

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

The project is being funded under the ECSEL initiative (Electronic Components and Systems for European Leadership), the central funding instrument for microelectronics and nanoelectronics in the European Framework Programme for Research and Innovation HORIZON 2020 (project reference: 661796).
Innovative Sensor Solutions

Safe and Secure Electronics

Manufacturing-oriented Microtechnologies

Micro Dosing

Compact and energy-efficient power semiconductors

Compact and energy-efficient power electronics is a key technology in being able to face up to the 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 pursued here: Firstly, the development of silicon technologies is being advanced based on cutting-edge 300 mm power semiconductor technologies. The second focus area is the development of new gallium nitride power semiconductor technologies suitable for mass production.

Fraunhofer EMFT is responsible for the detailed analysis of high-impedance 300 mm silicon substrates and partially processed components, looking at defects in the volume semiconductor and at the interfaces between the components. The aim is 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 under the European research program HORIZON 2020 (grant agreement no. 662133) and by the BMBF.

Correlation study between ESD test models

In September 2016, the Analysis & Test group received a grant worth $30,000 from the 2016 Educational Research Council of the American ESD Association Inc. promoting outstanding industry-related research in the area of electrostatic discharge. The award specifically supports a doctoral thesis looking into the correlation between the Capacitively Transmission Line Pulsing method (CC-TLP) developed at Fraunhofer EMFT and the Charged Device Model Test CDM, which involves a significant degree of measurement uncertainty. Cutting-edge integrated circuits with Gbit/s data rates are being tested. The sponsors are Cisco Corp, GlobalFoundries Corp. and the ESD Association.

Artificial sphincter system with microfluid actuators

Incontinence has become a widespread disease: there are some eight million sufferers in Germany alone. Together with DUALIS MedTech GmbH, Fraunhofer EMFT is working on a new artificial sphincter technology that allows a combination of diagnostics and therapy (theranostics). The sphincter function is realized in passive systems by opening and closing the urethra by means of a fluid-filled sleeve. However, the quantity of hydraulic fluid in the sleeve and therefore the closure function is not controlled manually, as in conventional solutions, but through the interaction of active microelectronic components: one micropump is responsible for emptying the sleeve, another is responsible for filling it. Both components are currently being developed at Fraunhofer EMFT. The actuators meet essential demands for the application such as high throughflow rates and a fast response, small size and low energy consumption. The newly developed articles have to be corrosion-proof and as well as being MRI-capable.

The integration of two pressure sensors also ensures that if threshold levels in the sleeve and/or the reservoir are exceeded – due to unforeseen occurrences such as coughing or laughing, for example – the pressure is automatically adjusted so that continence is ensured at all times. A remote control allows the treating physician to set tissue-preserving normal pressure at all times, without surgery: it is also simple for the patient to manually adjust the sleeve pressure (e.g. using preset modes such as sport and night mode).

The development work is being funded by the Bavarian Research Foundation.

Microwave spectroscopic analysis of liquids

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

In the project Glucosense, which was conducted as part of the BMBF-funded project NextGen, Fraunhofer EMFT researchers joined forces with the companies Infineon AG and easy-innovation GmbH to develop a measuring station that allows the temperature of liquids to be set precisely to ±0.01 K and subjected to very exact and reproducible analysis by means of microwave spectroscopy.

The automated measuring set-up was designed at Fraunhofer EMFT and realized in cooperation with Bundeswehr University Munich. The measurements carried out with a vector network analyzer (Keysight PNA N5247A) in the 110 GHz range on sample fluids showed the absolute necessity of temperature stabilization. In addition, it was possible to clearly detect foreign substances that had been introduced to the liquid such as sugar.
Miniaturized degassers for mobile applications

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

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

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

Mobile measuring device for gas detection

The EU project InForMed involves 42 European companies and research institutions coordinated by Philips GmbH who are seeking to establish a micro-production pilot line for new medical technology products. The partners intend to realize six types of demonstrators to indicate the feasibility of approx. 50% at flow rates of 50 - 200 µl/min. It has two standard luer connections for input and output as well as a connector for voltage control of the micropump, enabling the system to be integrated in most units without undue effort. The work was funded by a Fraunhofer-internal MEF project.

The researchers developed a special software to control the system as a whole and analyze the data. A graphic user interface allows users to enter the gas type, wavelength of the absorption band and the associated extinction coefficient in a database so as to determine gas concentrations quantitatively. The system has already been successfully tested with carbon dioxide.

Mobile detector for more than 60 environmentally harmful gases

Many gases that contribute to global air pollution can be detected by means of infrared absorption. But commercial IR spectrometers are usually cumbersome and expensive, so they can only be used as stationary equipment in a lab. A Fraunhofer EMFT research team is currently developing a portable IR multi-gas analyzer for mobile use. The compact system runs on batteries if necessary, and the measurements can be transferred directly for display on a tablet or laptop.

This enables analyses to be carried out directly on site so as to trace soil contamination or historical pollution such as solvents or petroleum-derived hydrocarbons.

The device operates in the wavelength ranges of 3.1 µm - 4.4 µm and 5.5 µm - 8.0 µm, covering the absorption of more than 60 harmful gas types relevant to the environment such as carbon dioxide, hydrogen sulphide and methane. By creating a 200 mm absorption path featuring gas-proof sealing by means of CaF₂ window, the development team was able to strike a sound compromise between size and sensitivity. Due to an internal reference gas generation function by means of filtering ambient air, the system does not require synthetic air for operation purposes. By means of automatically controlled membrane pumps, the reference and sample gas are successively put through the absorption path and subjected to spectral analysis.

Then the resulting absorption spectrum is calculated based on the two measurements.

The researchers developed a special software to control the system as a whole and analyze the data. A graphic user interface allows users to enter the gas type, wavelength of the absorption band and the associated extinction coefficient in a database so as to determine gas concentrations quantitatively. The system has already been successfully tested with carbon dioxide.

This project is being funded under the ECSEL initiative (Electronic Components and Systems for European Leadership), which is the central European funding instrument for microelectronics and nanoelectronics within the European Framework Programme for Research and Innovation «HORIZON 2020» (grant agreement no. 662155).
Field-effect transistors are used as chemical or biological sensors for a wide range of applications since they offer a number of key benefits: they are small, they can be manufactured at low cost and they consume very little energy. Researchers at Fraunhofer EMFT are working on a new FET sensor concept for carrying out measurements in both liquid and gaseous media. The novel set-up is to simplify packaging and allow more flexible measurements.

A research team at Fraunhofer EMFT collaborated with Asklepios Kliniken GmbH and the SME KETEK GmbH to develop a low-cost MRSA Rapid Test which is to be used for routine admission checks at hospitals or doctors’ surgeries. The early detection of an MRSA infection or colonization and application of the relevant treatment will significantly reduce the risk of transmission of the pathogens to other patients. The rapid test simply requires a nose smear to be taken from the patient. Whether or not MRSA is contained in the sample can be established quickly by using fluorescence indicators with a highly sensitive detection system.

Instead of this capacitive structure, researchers are using a miniaturized Faraday cup (600 x 100 μm², 450 μm deep) as the sensor element in their new concept: this has an embedded and entirely electrically insulated floating electrode. The electric potential of the cup is precisely defined. But the potential of the interior volume, or on the interior surface, can change due to environmental influences, for example due to the charge of a liquid or due to changes in charge in a gas-sensitive layer due to physical or chemical factors. These changes in charge can be detected by the floating electrode which is in turn connected to the gate of a read-out transistor.

Using components designed and produced at Fraunhofer EMFT, the development team has already been able to show that this module can be deployed both as a pH sensor in liquids and also as a gas sensor for the purpose of CO₂ detection. The project was funded under the Fraunhofer Society’s Discovery Program (reference: Discover 827100) and realized under a research contract for the industry partner LFoundry S.r.L.

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

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

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

Accelerated model for mechanically caused material damage

In the field of drive systems, press-fit technology presents an interesting alternative to other electrical contacting methods such as solder, screw or crimp connections. The benefits are minimal space requirements, repair capacity and a failure rate which is potentially between ten and hundred times lower. The press-fit procedure creates a touch zone between the press-fit contact and the copper sleeve in the circuit board. As a result of the pressure caused by the deformation of the press-fit contact when it is pressed in, this touch zone forms a gas-tight and corrosion-proof contact zone after about 24 hours. Inside this zone, the free electrons generate attraction forces that connect the two metal surfaces. In this way, a cold weld zone is formed within a few hours.

However, the process can also involve unintentional damage to the component. For example, microrelative movements between the press-fit contact and the copper sleeve in the circuit board, induced by vibrations, can result in fatigue damage or fatigue failure of the cold weld zone. The cold weld zone then disengages as a result of crack formation and crack growth. In collaboration with the Institute of Materials Technology and the Institute of Drive and Automotive Engineering, both at the University of Kassel, Fraunhofer EMFT researchers are working to develop an accelerated model so as to gain a better understanding of these undesired effects.

The Fraunhofer EMFT team is building a test bench to study the microrelative movements described above. The Munich experts also undertake precise electric characterizations of the contact resistance of the cold weld zone. Having conducted a detailed mechanical analysis and simulation, the team at the University of Kassel is involved in developing the accelerated model. The aim will then be to validate the model in the Fraunhofer EMFT labs using a practical example. The Munich experts also undertake precise electric characterizations of the contact resistance of the cold weld zone. The cold weld zone then disengages as a result of crack formation and crack growth. Having conducted a detailed mechanical analysis and simulation, the team at the University of Kassel is involved in developing the accelerated model. The aim will then be to validate the model in the Fraunhofer EMFT labs using a practical example.

Sensor nodes and their networking for digital production

Sensors have a key role to play in the Internet of Things, but they have to become more effective and cost-efficient in future in order to keep up with dynamic developments in this area. One critical point is the networking of the sensors: IoT applications in particular require the assembly of numerous cables and connectors. These components are sufficiently reliable but much too expensive for mass consumer markets. Wireless connectivity is not an option in many cases: the main obstacles are the energy supply to the sensor nodes and the often inadequate signal coverage in buildings (due to isolation by metal objects, for example).

In the project SensNet Fraunhofer EMFT researchers are therefore developing new concepts and experimentally verifying them so as to integrate sensors in a hierarchical information chain – from the detection of physical parameters through to data processing in a big data cloud environment. The sensors are to be networked effectively enough to be able to operate largely independently. The project is supported by the funding initiative Bayern Digital (reference: BD002/2001).

Securly networked sensors in the healthcare sector

The Internet of Things offers huge potential for the healthcare sector – ranging from diagnostics to patient safety and optimized logistical processes. A total of 21 European partners are involved in the project SERENE IoT, which aims to lay the foundations for IoT applications in healthcare. Within the scope of this project, the German consortium under the coordination of Fraunhofer EMFT is developing an IoT-capable mobile analysis device to detect multi-resistant Staphylococcus aureus (MRSA). The detection method (developed in the project MRE Test, funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology as part of the »Mikrosystemtechnik Bayern« program, reference: MST-1308-0001/BAY189/001) is to be transferred to an overall system with connectivity capability which can run on batteries. The basis is provided by new application-specific memory chips with a very low level of energy consumption. The research project is focusing on the development of a secure software architecture for IoT networking of medical devices and the secure transfer of confidential data. The concept of IoT-networked medical devices is being tested nationally using various demonstrators (mobile MRSA detector, device to detect postoperative infections, food pump, fall detector to identify and prevent falls) by the hospital of Ludwig Maximilian University, Munich.

The project SERENE IoT receives funding of EUR 5.1 million from the EUREKA cluster PENTA; 67% of this amount is provided through the Federal Ministry of Education and Research (BMBF).
Innovative tech area, the project will pursue a core development for chemical sensorics which is deliberately open in orientation so that it can be extended to include new applications or tasks while the joint work is being carried out.

The project is funded by the Federal Ministry of Education and Research (BMBF, reference: 16EG0111B).

Environment-friendly cleaning gas for the semiconductor industry

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

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

The new cleaning process went into pilot use in mid-November, with the aim of securing approval for industrial production by the end of 2017. The project is funded partially under the BMBF’s »r+Impuls – Innovative technologies for resource efficiency – Impulses for industrial resource efficiency«, which in turn is embedded as part of the framework program »Research for Sustainability« (FONA).
Condition monitoring of high-end production equipment is a key aspect of Industry 4.0. As part of the Munich center of excellence »Secure Connected Systems«, Fraunhofer EMFT is working on the project PAMP (Predictive Advanced Maintenance for Pumps) in collaboration with Edwards, Fraunhofer ESK and Fraunhofer AISEC to develop improved characterization for the condition monitoring of vacuum pumps – specifically high-quality vacuum pumps used in conjunction with process facilities in semiconductor production.

One focus here is to investigate the connection between process and pump response. The implementation stages include creating a sensor set-up for selected pumps in the Fraunhofer EMFT cleanroom so as to be able to log data at various points on the pumps and also set up a linked sensor node network complete with a secure Internet of Things (IoT) infrastructure. Machine learning is to be deployed so as to detect irregularities in the sensor data. For this purpose, a data fusion of various sensor data is required in order to detect combinations and patterns, and software algorithms are needed to detect specific instability states.

Another aspect is encrypted wireless communication between the devices. A remote connection will make condition monitoring easier for operators in the factory. Information on the actual condition of a machine will be made available for retrieval. The Fraunhofer solution Industrial Data Space is to be used to prevent unauthorized access during data transmission – this is the new reference architecture for data storage in the area of networked industry automation (Industry 4.0). Sensor data from various units within the factory can be saved in a central database; access to this data is then limited by applying differing directives and access rights.
NEW COOPERATIONS

Multifunctional communication board (NFC, USB, BLE) for reading digitally networked sensor nodes (Cooperation Würth Elektronik eiSos/Fraunhofer EMFT)
The center is open to cooperations with other research institutions so as to further extend the partner network. Sponsorship and funding for the center comes from the Bavarian Ministry of Economic Affairs and Media, Energy and Technology, the Fraunhofer Society and various industry partners who are involved in joint projects.

The Internet of Things (IoT) will radically transform the environment in which we live and work. It is both a challenge and an opportunity for industry and research to support this transformation with innovative solutions. The high performance center »Secure Connected Systems« offers an application-oriented, interdisciplinary platform for cross-sectoral, generic and systematic research and collaboration focusing on the IoT-related areas of mobility, production technology and healthcare (smart health). Participating companies benefit from the network and technical expertise of TU Munich, Bundeswehr University Munich, the Fraunhofer institutes AISEC, EMFT and ESK and associated industry partners. The competence portfolio of the research platform covers the following:

- Conception, development and assembly of networked sensor nodes for data logging to serve customer-specific applications
- Networking of embedded systems such as sensor nodes and control units by means of wireless and wired communication systems
- Establishment of secure cloud-based data and control solutions
- Conception and establishment of real-time communication systems in an industrial setting
- Concept, evaluation and validation of new communication architectures and technologies for the real-time-capable, reliable and secure networking of vehicle and environment
- Testing conformity, performance and security in dedicated test environments and customer scenarios

The high performance center »Secure Connected Systems« has been in existence since July 2017, giving the capital of Bavaria a top-class interdisciplinary research platform for future IoT applications. It clusters the technical excellence of TU Munich, Bundeswehr University Munich and the Fraunhofer institutes AISEC, EMFT and ESK.

Fraunhofer EMFT is represented in three of these technology parks:

- **Silicon-Based Technologies:** The integration of new material systems for MEMS and NEMS sensors and actuators and their combination with CMOS processes is a key focus within this technology park. These technologies specifically enable the development and pilot production of intelligent sensor nodes, cyber-physical systems and hardware-oriented Industry 4.0 solutions. Here, Fraunhofer EMFT is able to contribute its technological expertise in the areas of CMOS 200 mm line, wafer thinning and MEMS technologies/systems.

- **Heterointegration:** In modern electronic products, components of differing technologies, structural sizes and materials have to be integrated in diverse packages. Focus areas of the new research infrastructures at Fraunhofer EMFT relate to the 3D integration and the further advancement of reel-to-reel integration technology on flexible foil substrates. Other challenges in this area are electrical and mechanical connections as well as protection from external influences.

- **Design, Test and Reliability:** The constantly growing complexity of microelectronic systems poses enormous challenges when it comes to design and production. New requirements have to be taken into account from the outset in terms of energy efficiency, performance capacity, installation size and in particular the reliability of the systems. In this technology park, Fraunhofer EMFT mainly contributes its expertise to the development of analog and digital ultra-low-power circuits in 22 nm and 28 nm FD-SOI, novel sensor concepts for environmental sensorics, analysis methods and protection concepts for enhanced ESD and EMV robustness as well as innovative approaches to secure electronics at chip level.

The aim of this nationwide cooperation is to be able to offer customers from large-scale industry as well as SMEs and universities the entire value creation chain for microelectronics and nanoelectronics from a single source. In addition, the closer dovetailing of key competences aims to help secure the future competitiveness of German microelectronics research as well as providing a platform on which to address exciting new research topics such as quantum technology and the handling of very large data quantities.

In order to advance future-related research topics efficiently and swiftly, the FMD is organized into four technology parks:

- **Silicon-Based Technologies**
- **Compound Semiconductors**
- **Silicon-Based Technologies**
- **Design, Test and Reliability**

Fraunhofer EMFT has a broad portfolio of technologies and expertise for the development of innovative sensor and actuator systems for the Internet of Things (IoT) and cyber-physical systems. The center is open to cooperations with other research institutions so as to further extend the partner network. Sponsorship and funding for the center comes from the Bavarian Ministry of Economic Affairs and Energy, the Fraunhofer Society and various industry partners who are involved in joint projects.

The cross-site cooperation Research Fab Microelectronics Germany (German abbreviation: FMD) initiated in 2017 networks the R&D infrastructure and technological expertise of eleven Fraunhofer institutes from the Group for Microelectronics, including Fraunhofer EMFT and the two Leibniz institutes FBH and IHP.
Cell and tissue samples grown in a 37 °C incubator.
Companies benefit from collaborating with Fraunhofer EMFT in that they are able to draw on the very latest research insights and innovations for their product development. Here, Fraunhofer EMFT supports its customers throughout the entire development process – from the idea through to implementation. Fraunhofer EMFT is able to offer its customers and partners the following services:

### Fraunhofer EMFT Range of Services

<table>
<thead>
<tr>
<th>Studies</th>
<th>Analysis &amp; Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology analyses</td>
<td>Risk and problem analysis</td>
</tr>
<tr>
<td>Feasibility studies</td>
<td>Development of test methods and equipment</td>
</tr>
<tr>
<td>Assessment in the case of damage claims</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modeling &amp; Simulation</th>
<th>Professional Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole process</td>
<td>Seminars and training programs</td>
</tr>
<tr>
<td>FEM simulation</td>
<td>Conferences</td>
</tr>
<tr>
<td>System response</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Customer-Specific Development</th>
<th>R&amp;D as part of publicly funded projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advance development</td>
<td>Joint projects with industry, funded publicly, e.g. by BMBF, German states, the EU</td>
</tr>
<tr>
<td>Single process modules and overall process</td>
<td>Coordination of industrial project consortia</td>
</tr>
<tr>
<td>Chip design</td>
<td>Consultancy for national and EU research applications</td>
</tr>
<tr>
<td>Components and systems</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prototypes and Small Series Production</th>
<th>Start-Ups &amp; Joint Ventures</th>
</tr>
</thead>
<tbody>
<tr>
<td>System design</td>
<td>Spin-offs for the commoditization of products and systems</td>
</tr>
<tr>
<td>Layout</td>
<td>Cooperation with industrial partners via joint ventures</td>
</tr>
<tr>
<td>Device design and construction</td>
<td></td>
</tr>
</tbody>
</table>

**FRAUNHOFER EMFT RANGE OF SERVICES**
An extensive infrastructure, a broad range of technologies and a well-developed network of partners in industry as well as among research institutes, universities and public-sector organizations make Fraunhofer EMFT an attractive partner in research and development, of interest to small and medium-sized companies as well as larger-scale industrial enterprises. Marketing the results of research is generally the responsibility of the corporate partner. Since 2007 Fraunhofer EMFT has also offered high-tech companies the opportunity to hire its high-quality facilities (such as cleanrooms, laboratories and equipment). Several companies have taken this opportunity and 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
- i-line stepper
- Nanoimprint
- Foil mounting and bonding technology
- Laser processing for cutting, marking and drilling various materials
- Plasma etching process for surface conditioning and reactive etching of polymers with nitrogen, oxygen and CF₆
- Foil mounting and bonding technology

### Microbiological laboratory
- Spectrofluorimetry for the qualitative and quantitative analysis of fluorescent samples, recording of excitation and fluorescence emission spectrums and implementation of kinetic measurements
- Electron absorption spectroscopy (UV/VIS spectroscopy) for qualitative and quantitative analysis, recording of absorption spectrums
- Transmitted light and phase-contrast microscopy with microscope camera
- Epifluorescence microscope for the analysis of fluorescent compounds
- Rotational vacuum concentrator for fast and low-impact drying of diverse, aqueous, acidic and solvent samples under rotation in a vacuum

### Analysis and testing
- Atomic force microscopy (AFM): measurement of surface roughness and step measurements up to max. 6 μm
- Scanning electron microscopy (REM) incl. energy-dispersive x-ray spectroscopy (EDX)
- In-line REM (Schottky emitter) and focused ion beam (Ga-FIB) with EDX and gas injection system (GIS)
- Spectral ellipsometer: measurement of thin layers and transparent materials
- Spectrometer: measurement of layer thickness of silicon (thick layers) and infrared permeable layers
- Target grinding device for sample preparation (grinding accuracy: ±2 μm)

### Application of large-area electronics and flexible substrates to foil sheets and using the reel-to-reel method
- Hot roll laminator for double-sided lamination
- In-line coating system for liquid coatings such as photoresist, dielectrics and passivation
- Sputter system for double-sided metalization of chrome and copper
- UV lithography with high resolution (5 - 15 μm structure width)
- Wet-chemical etching techniques for structuring metals
- Screen printing on foil sheets
- Screen printing using the reel-to-reel method
- Galvanic deposit of copper on premetallized foils

### FRAUNHOFER EMFT RANGE OF TECHNOLOGIES

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### X-ray diffractometry (XRD):
- Measurement of silicon-germanium content
- CVD epitaxy facility: quality control of high purity gases
- Plasma-supported etching and deposition systems to test gas compounds
- Wafer prober for electrical characterization

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At Fraunhofer EMFT’s ZVE (Zentrum für Verbindungstechnik in der Elektronik – Center for Interconnection Technologies) in Oberpfaffenhofen, experts have taught essential know-how relating to electrical connection technology for more than 30 years. The focus here is on professional development for QS coordinators, specialists and manual workers.

Even in times of Industry 4.0, good manual work is still very much in demand. Soldering and crimping are still an integral part of connection technology for electronic modules: both methods guarantee a high level of quality and reliability. With more than 30 years of experience, the ZVE in Oberpfaffenhofen has become established as an important training and professional development center within the region. The ZVE is accredited by both the European Space Agency ESA and the Association Connecting Electronics Industries IPC as a training and instruction center, and it runs courses offering subsequent certification.

The modern training concept used in Oberpfaffenhofen is based on the fact that it is virtually impossible to separate learning and work in the modern working environment. The «knowledge worker» has now been long established in classic production plants, too: continuous professional development is required in order to keep up with the state of the art. In order to integrate teaching in day-to-day work in an effective and practically oriented manner, the ZVE training concept supplements conventional seminars with flexible formats such as webinars as well as providing apps that make information accessible according to specific situations and needs. The study apps are also used for seminar preparation and follow-up. The spectrum of course topics ranges from production technologies and information on installation and production to repair and maintenance procedures. The expertise taught is not just dry theory: it is drawn directly from current R&D activities relating to electronic module production and electrical-mechanical connection technology.

In addition to courses and training programs, the ZVE also offers process qualification, process audits and damage analytics. The equipment available for this purpose includes a 2D and CT x-ray system, a scanning electron microscope, temperature change and climate test consoles and a metallography lab. Longstanding contacts with the aerospace industry have made the qualification of electronic modules under harsh environmental conditions one of the training center’s core areas of expertise.

The ZVE’s R&D activities are very much geared towards the Internet of Things (IoT): this is because in networked environments, connectivity and the reliability of the electronic interfaces are an absolute must for the system as a whole to function smoothly – especially in safety-sensitive areas such as autonomous driving. In this context, researchers are working to develop so-called Cyber Physical Connectors, for example: these are plug connectors fitted with sensors and enable continuous monitoring of the connection state. This allows avoidance of system failure due to defective contacts.
CUSTOMERS AND COOPERATION PARTNERS

Fretting corrosion / micrometer test bench with modifiable fretting exposure
Dr. Roman Pausch, Managing Director of Rausch & Pausch GmbH (RAPA), talked to us about success strategies for SMEs, the role of Fraunhofer as a development partner and cooperation with Fraunhofer EMFT.

You opted for a strategic partnership with Fraunhofer EMFT to allow RAPA to tap into the new business area of medical technology. How did you find out about Fraunhofer EMFT?

Dr. Pausch: The key insight for us from the last financial crisis was that we needed to develop a diversification strategy. Currently we only supply the automotive industry, but this hasn’t always been the case: decades ago, RAPA GmbH had a well-established source of revenue in medical technology which we’d now like to revitalize. However, our own activities in this area date back so far that we no longer have any close familiarity with the market. For this reason, we hired a kind of trend scout consultant who happened to have a fairly good knowledge of the Fraunhofer scene. So essentially, our contact with Fraunhofer EMFT came about more by chance, but it was a great fit right from the start. As far as Fraunhofer in general is concerned we have already had a number of successful collaborative ventures – with Fraunhofer IPA in Stuttgart, for example.

Fraunhofer Society and its institutes regard innovative SMEs as their most important target group. Taking a more broader perspective than the specific cooperation with Fraunhofer EMFT: how can Fraunhofer effectively support R&D companies such as RAPA?

Dr. Pausch: Like all other companies nowadays, SMEs have to operate in a globalized world. In a country such as Germany, the most promising strategy as I see it is to be able set yourself apart from the masses – preferably with high-tech applications or products aimed at niche markets. In terms of application development, SMEs here in Germany are generally in a fairly solid position. However, resources in the area of basic development are typically more limited as compared to corporations and large-scale industry. But it is precisely at this early stage that key preliminary work has to be done for later product development, and as I see it, this is the particular attraction of cooperation with Fraunhofer. With their application-oriented perspective, the Fraunhofer institutes can perform a kind of mediator function, filtering out of the ideas with the greatest practical relevance from the many exciting new approaches and solutions that emerge from the institutes and universities.

In our case, we’re focusing on high-tech niche products with practical relevance in our cooperation with Fraunhofer EMFT. In doing so we’re now benefiting hugely from the extensive expertise that Martin Richter has built up in his group over the past 12 years. We wouldn’t have been able to invest in this kind of preparatory work ourselves to tap into the medtech market.

Fraunhofer EMFT and its German partner company Rausch & Pausch GmbH (RAPA) are specialized in the development of stainless steel micropumps, such as μP303 (Ø 20 mm) and μP304 (Ø 29 mm). Their successful cooperation clearly demonstrates the model of Fraunhofer’s ‘strategic outsourcing’ concept.

Finally, a look ahead to the future: what would you definitely have like to have achieved in five years’ time in terms of your cooperation with Fraunhofer EMFT?

Dr. Pausch: We already accomplished our first milestone in 2017 – the partnership agreement; the next step will be to establish our own medical technology company, which will be in 2018. We’re currently assembling a team to take care of the industrialization of metal micropumps. And we’re busy planning our own plant for these new activities at the moment, too. In five years’ time, we hope we’ll be generating revenue from serial production of our first application. Specific plans include an application in the area of wound healing and a condition monitoring system for air. All in all we’re considering bringing out an entire product family for various applications, of course. I’d particularly like to emphasize the fact that collaboration with the Fraunhofer EMFT team is highly professional and partnership-based. This goes very well with our own corporate culture, which is always geared towards a partner-ship approach – with customers, suppliers and employees. Our team is certainly incredibly motivated to get involved in setting up this new area and we look forward very much to our ongoing collaboration with Fraunhofer EMFT.

Dr. Roman Pausch, Managing Director of Rausch & Pausch GmbH (RAPA), talked to us about success strategies for SMEs, the role of Fraunhofer as a development partner and cooperation with Fraunhofer EMFT.

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Fraunhofer EMFT and Infineon are able to look back over many years of collaboration in the areas of heterogeneous integration. Dr. Reinhard Pufall (Infineon) and Dr. Peter Ramm (Fraunhofer EMFT) explain why longstanding cooperation of this kind is such an invaluable asset nowadays in particular, and they provide insights into visionary ideas such as a proposal for the flagship initiative Health EU.

You are currently working together to prepare for the planned EU flagship project «HEALTH EU – Human avatars to prevent and cure diseases». What is the idea behind this project?

Dr. Ramm: Flagship projects are strategic EU research initiatives with a budget of approx. EUR 1 billion that are designed to run over a period of 10 years and pursue a visionary goal. Under the leadership of EPFL Lausanne and ETH Zurich, we have developed a proposal for such an initiative called «Health EU».

The idea is to create a digital twin for every EU citizen – a so-called medical avatar. The avatar is developed on an ongoing basis by feeding in data from its human counterpart – such as vital signs recorded by sensors on the body. The aim is to use the avatar to prevent and heal illnesses, but always geared towards the specific individual in question. The constellation of the individual, the avatar and the doctor will help develop the best possible therapy for the person concerned. Let me give an example to illustrate how this might work: an EU citizen suddenly feels unwell while hiking in Austria and suffers an irregular heart rhythm. Normally he would go to the nearest hospital and they would probably keep him there to carry out further tests, just to be on the safe side. It would then probably turn out in the end that he wouldn't really have needed to stay in hospital. But meanwhile, the man’s vacation is over – and costs have been incurred running into several thousands of euros. According to our idea, the avatar would draw on historical and current analysis data so as to automatically establish that the irregular heart rhythm does not pose a health hazard; the recommendation to the patient would then be to continue his vacation and go to the doctor after returning home.

A key point here of course is to ensure there is no unauthorized access to the personal data – this will be a major aspect of the work we are doing.

Dr. Pufall: Up until now, treatment has tended to be geared very much towards statistics. Our solution would be the first method for finding out exactly what is wrong with the person based on in-situ measurements. The doctor can then develop a much more effectively targeted therapy – a significant health benefit for the chronically ill in particular. I can also imagine that this personalized approach would help reduce the use of medication to some extent.

What is your role in this project?

Dr. Ramm: Natural sensor systems are required in order to be able to generate as much data as possible so as to gather information on a person’s state of health – and »sensor system« here usually means sensor integration by means of a communication IC. This already brings us to heterogeneous system integration – a key technology that merges various devices such as processors and sensors to form a single system in miniaturized form so that it can be worn conveniently on the body. In addition, power management has to be optimized so as to enable as long a service life as possible.

We’ve been cooperating closely with Infineon for many years in the area of 3D integration, in particular the 3D integration of MEMS – typically sensors and ICs. The reliability of these heterogeneous systems has a key role to play here, especially in application areas such as healthcare and automotive. Our partners at Infineon are specialists in designing products that meet the very highest demands in terms of reliability.

Dr. Pufall: It’s always rather difficult to define the concept of »reliability« clearly and precisely. It’s really the expectation that a system will function smoothly over a defined period of time in every way. And how do you achieve that? A lot of people think we select particularly reliable products out of a pool of products, but that’s not the case. In fact reliability is integrated in product design. Based on a knowledge of the so-called physics of failure, you effectively pre-select potential solutions by selecting the right materials and applying simulation methods that tell you whether a car component really will work for 15 years in the way it is supposed to. You then only use the most promising options to build a prototype and test it under rigorous conditions.

Heterogeneous 3D integration confronts us reliability experts with a particular challenge in this context since there is an incredibly wide range of material factors to understand and take into account. Only then can we use this innovative technology to create products to the high level of quality required.

What exactly is the focus of your collaboration?

Dr. Ramm: The idea is to produce novel sensors, though the focus of our collaborative work with Infineon is research and development in the area of optimized system integration technologies for heterogeneous sensor systems. In our collaborative work, we are looking to establish a joint platform in the medium term which we can use to make application demonstrators. Another focus area is testing the reliability of sensor systems. In this area we are also able to look back over a long, well-established partnership with Infineon in the course of which we have created a broad base of shared knowledge. At the same time a kind of academic link has formed between Infineon and Fraunhofer EMFT: we jointly supervise master’s degree students and doctoral candidates who are pursuing new approaches and innovative ideas.

From the point of view of Infineon, what is the greatest benefit of collaborating with Fraunhofer EMFT?

Dr. Pufall: As far as we are concerned, the quality of the products we produce and sell is a crucial market factor. And it is often the underlying knowledge in the background that makes all the difference when it comes to quality. There are lots of high-performance sensors in existence, but in many cases it is not easy to miniaturize them or cluster them to create multi-sensors without causing mutual disruption, for instance. With its experience of heterogeneous system integration, Fraunhofer EMFT has precisely the expertise required – and that is of enormous interest to us. One key benefit of such a longstanding partnership is that each partner understands what the other needs. Nowadays, I don’t believe you can simply go out and award an external development contract – it simply doesn’t work any more. The technologies we are working with are much too complex.

Dr. Ramm: Our mission is applied research, and I find it hugely motivating to find my research work has been used in a product that is successful on the market.

What are your goals for the years to come in terms of your collaboration?

Dr. Pufall: I believe it’s important to go on developing our expertise in the areas of 3D integration, measuring technology and simulation processes so as to arrive at increasingly effective and substantiated conclusions in relation to component reliability. If we manage to achieve that I will already be very satisfied.
The second thing I am interested in is knowledge management. If you can work in a field for so many years as intensively as Peter Ramm in 3D integration, this is a huge benefit. In our company, it is often not easy to preserve existing knowledge since there is high rate of staff fluctuation. I believe that in industry in particular, much more should be done to promote preservation of the knowledge that has been built up.

**Dr. Ramm:** I hope we can not just continue our collaboration but actually intensify it, e.g. in the area of in-situ measurement for heterogeneous system integration – this involves testing the reliability of heterogeneous systems in particularly tough conditions. For this purpose, we have made a strategic investment in a piece of large-scale equipment that allows heterogeneous systems to be exposed to temperature, humidity, moisture, steam and pressure according to defined standards. What is fascinating here is that we are currently developing a measurement method in which sensor elements are studied during testing. This means you can see exactly when the component actually fails. By contrast, the method currently established in industry today involves checking at defined intervals whether or not the system is still working – so ultimately you do not know precisely when the failure occurred.

One very practical advantage of our approach is that you save measuring time – you can discontinue the operation as soon as the component fails. But what we are really interested in from a scientific point of view is: what happens to the system just before failure occurs? Insights here could move us ahead significantly in reliability research.

**Dr. Pufall:** I have to sell products that are zero-error – not just at the beginning but even after 15 years of use in the field. This is the expectation our customers have of quality products. Ongoing collaboration on these issues is absolutely crucial to our success.
Through the Chair for Technical Electrophysics there is also close collaboration with Dr. Gabriele Schrag and Prof. Gerhard Wachutka. Research there focuses on physically based modeling, numerical simulation and the characterization and diagnosis of production processes and the operating response of microstructured components. Collaborative research aims to further strengthen Fraunhofer EMFT expertise in this area. There are plans for joint doctoral dissertations on various preliminary research topics.

**University of Regensburg**

Fraunhofer EMFT has a longstanding collaboration with the Institute for Analytical Chemistry, Chemo- and Biosensors at the University of Regensburg. Since January 1, 2017, Prof. Joachim Wegener has been in charge of the Fraunhofer EMFT group Cell-Based Sensors (ZBS) in Regensburg. Joachim Wegener is Professor of Bioanalytics and Biosensors, and the work he does with his group mainly focuses on developing physical sensors that allow living cells to be examined on a non-invasive, label-free basis. The aim of this new initiative is to harness Fraunhofer EMFT expertise in the areas of microelectronics and polymer electronics for cell-based sensors, thereby penetrating new areas of application in bioanalytics and biotechnology.

**Technical University of Dresden**

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

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

**Bundeswehr University Munich**

There is a close link between the Faculty of Electrical Engineering and Information Technology at Bundeswehr University Munich and Fraunhofer EMFT, not least as a result of staffing connections: Prof. Linus Maurer (Professorship for Integrated Circuits and Electronic Components) has taught at the university since 2012, along with Prof. Christoph Kutter (Professorship for Polytronics). The cooperation originated under Prof. Ignaz Eisele, who was appointed the university’s first Emeritus of Excellence and today heads up the business area Silicon Technologies and Devices at Fraunhofer EMFT. Dr. Sabine Trupp, Head of the Sensor Materials group at Fraunhofer EMFT, was accepted as a habilitation candidate in the area of gas sensorics at Bundeswehr University in 2015. Dr. Ronnie Bose, Head of the Polytronic Technologies group at Fraunhofer EMFT, has been doing his habilitation at the Institute of Physics, Bundeswehr University Munich, since 2016. His area of research is flexible hybrid integration and microsystem technologies.

Fraunhofer EMFT and Bundeswehr University Munich complement each other ideally due to the nature of their respective cleanroom facilities. The close connection between the university and Fraunhofer EMFT is also reflected in their collaboration on the integration of new, innovative functionalities and components in existing silicon standard technologies. Here, Fraunhofer EMFT contributes its expertise in the area of add-on technologies and their combination with standard technologies. The goal of the project is to collaborate with industry partners so as to advance new developments – from high-risk research through to product maturity and implementation. The two institutions aim to intensify their collaboration in the future.
PECVD cleaning plasma with environmental-friendly and PFC-free Fluorine-chemistry «Solvaclean™»
As a collaborative venture between Solvay Fluor GmbH, Texas Instruments Deutschland GmbH, Fraunhofer EMFT and Muegge GmbH, the project ecoFluor involved the development of a method for cleaning coating chambers in semiconductor production that dispenses with climate-damaging gases and also reduces the amount of energy required. The innovative method created by the project consortium was nominated for the 2017 German Innovation Award for Climate and the Environment, progressing to the final round of the 15 best applications.

Microchips for mobile phones or calculators are produced on facilities in the semiconductor industry that have to undergo thorough cleaning after each work stage. Currently this is carried out using perfluorinated compounds and nitrogen trifluoride (NF₃) gases, which are up to 17,000 times as damaging to the environment as the greenhouse gas carbon dioxide. This is because the gases are highly stable and remain in the atmosphere for a long time.

The team working on the ecoFluor project uses an alternative gas mixture that makes do with significantly less fluorine. This would make its greenhouse potential comparable to that of carbon dioxide. In addition, the new gas is to shorten machine cleaning time, thereby cutting costs.

A Fraunhofer EMFT team has already spent several years collaborating with partners from the chemicals company Solvay to investigate various fluorine gas mixtures in terms of their environmental compatibility. They have come to the conclusion that these alternatives are essentially suitable for cleaning purposes. They also clean highly efficiently. The project is now focusing on subjecting the most successful gas mixture from the lab to practical testing in an industrial setting.

Dieter Hemmetzberger, research associate at Fraunhofer EMFT, received the Fraunhofer Society award as Trainer of the Year. The Fraunhofer Trainer Award was introduced in 2013 to honor outstanding work in the field of training. The award goes to committed trainers, training coordinators and training teams. The 2017 award was presented on May 10, 2017 at the Training Forum in Berlin: the recipient of this coveted award was Johann-Dieter Hemmetzberger, Fraunhofer EMFT research associate in the field of flexible electronics.

Mr. Hemmetzberger has worked as a trainer and training coordinator at Fraunhofer EMFT since 2002 and has devoted his expertise and support to helping many trainees successfully complete their course. Dieter Hemmetzberger consistently manages to build teams of trainees in which there is a great sense of mutual trust and respect. This has an enormous impact on the trainees’ motivation and interest. In addition to their technical training, it is important to him to ensure they develop social skills and acquire a methodical approach. “Young people have to develop a personality of their own in the course of their vocational training.” This is something he attaches particular importance to as a trainer.

Thanks to Dieter Hemmetzberger’s expert supervision, Ms. Sonia Marin was able to successfully develop her personality and her professional skills: she scored the top grade in Bavaria on completing her training course as a microtechnologist in 2016.
Executive Round Table

The Executive Round Table on the Future of Maintenance and Repair was held at Fraunhofer EMFT on 16 February 2017. At this event organized by TÜV Süd Akademie and Deutsche Medienakademie, experts from industry and research discussed concrete methods and use cases with the roundtable participants.

Topics included the development of machine-specific sensor databases and live online aids for use on site at the machines by means of AR-guided hands-free wearables such as head-up displays. Other interesting ideas include preventive maintenance and repair activities based on anticipatory sensorics for the consumer sector. For example, it would be conceivable for providers of more complex products such as high-performance computers to extend their range to include online maintenance services via IoT.

Fraunhofer EMFT Director Prof. Kutter gave a talk on the subject of sensorics in the area of smart maintenance technologies.

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 15, 2017 was »Physical states«.

The interaction between physical conditions and the materials in our environment is a never-ending source of interest to application-oriented research. How can gaseous substances in the ambient air be made visible and measurable in solid or liquid materials? How can we develop gas sensors that function reliably and independently of temperature and pressure? How is it possible to extract liquids from harmful gases using a simple, low-cost method? Fraunhofer EMFT researchers focus on these and many other fascinating issues in the course of the their day-to-day work. The talks centered on the question of how semiconductor technology and microelectronics can make use of physical states.

At the subsequent get-together, Fraunhofer EMFT experts invited the approx. 90 participants to engage in further discussion.

Joint workshop with Yole: the promising future of sensors in IoT

As the »sense of organs of objects«, sensors will pave the way for the success of networked devices in IoT applications – but what are the opportunities and challenges involved for Europe industry and research? This was the subject of the second joint MEMS seminar organized by Yole Développement and Fraunhofer EMFT in Munich on July 3 and 4.

Experts from well-known companies such as Audi, Bosch and Infineon shed light on challenges and trends in the key IoT growth markets Industry 4.0, building + automation and the automotive sector from the industry perspective. In addition, the approx. 100 participants discussed the latest developments in the area of sensor applications on the way towards the »next big thing«.

Forum MedTechPharma

Forum MedTechPharma e.V. held an information event on the Fraunhofer EMFT premises on July 12 on the subject of »Funding programs for medical technology«. Interested companies in the medtech sector as well as representatives of higher education institutions and non-university research institutions were able to gain an overview of the diverse funding opportunities at state, federal and EU level, as well as obtaining individual consultation on their project ideas from the speakers if they wished.

MikroSystemTechnik Kongress 2017

Germany is regarded as one of the most successful and innovative countries in the field of microsystems technology today. This was reflected at MikroSystemTechnik Kongress 2017: the VDE (Association for Electrical, Electronic & Information Technologies), which organizes the congress every two years, reported some 800 enthusiastic audience members, more than 100 talks and an exhibition featuring 40 companies working in areas such as biosensorics, chemical sensorics and micronano integration.

In 2017, Fraunhofer EMFT presented a lab-on-chip system for on-site DNA diagnosis, a complete foil system for temperatures measurement and display and a microdosing system for medication dosage including a silicon micropump and a Sensirion flow sensor. Another real »micro eyecatcher« was the silicon micropump to support gas sensorics in mobile end devices.

Forum be-flexible

From November 15 - 16, Fraunhofer EMFT once again invited participants to its well-established workshop »be-flexible« on the subject of materials, production, new technologies and applications in the field of flexible hybrid electronics (FHE) and printed electronics (PE).

2017 saw a new development here: for the first time, the event was held not at the premises of the Munich institution but at Messe München as part of SEMICON Europa and productronica – Europe’s biggest semiconductor production trade show. Bringing these events together at a single place and time could possibly pave the way for establishing a new European platform for flexible electronics, production technologies and application scenarios.
Pupils in the laboratory
tyouth development
Many young people opt to start their working life at Fraunhofer EMFT. The institution offers an excellent start to a career for trainees in research, science, technology and administration. Students of physics, electrical engineering, process engineering, biochemistry and related areas have the opportunity to get involved in applied research at a practical level. They can take an internship, work as a research assistant, write their diploma/bachelor’s/master’s assignment or undertake doctoral studies.

I've been working at Fraunhofer EMFT since 01.03.2017 in the Silicon Technologies & Devices sector. My areas of responsibility are very exciting: the main focus of my work is process control using machine learning algorithms. I’m also involved in embedded software development for NFC readers, NFC tags and Bluetooth modules. This gives me the opportunity to explore many scientific areas ranging from embedded systems to neural networks. I have met many different people here who are experts in this field. My work at Fraunhofer EMFT has helped me a lot to bring the theoretical content of my studies to life. I studied different concepts at the university but they were not clear until I joined Fraunhofer EMFT. In short: my work here is really interesting and fascinating. My career goal for the future is to do my PhD in System on Chip Technologies.

Manoj Rohit Vemparala

I've been working as a placement student at Fraunhofer EMFT since September 2017 in the Microdosage Systems department. During this time I've been involved in a wide range of different areas, all of which are really interesting: creating measuring boards and circuits, PCB design, pump assembly and characterization and evaluating measurement data. The working atmosphere in our young, motivated team is really great. My next step will be to take my master's degree – in the long-term I’m also considering doing a doctorate.

Fabian Lickert

I've worked in the Microdosage Systems department since October 1, 2016 as a doctoral student and R&D process engineer. My main focus is dealing with the front and back-end production systems for our microdosage systems. What I like about the work is that my entire day is filled with diverse and challenging tasks. I’m particularly pleased to have been able to work with international industry partners on some projects. My main goal for the foreseeable future is to get my doctorate, of course.

Henry Leistner

I've been working as a placement student at Fraunhofer EMFT since 2017 in the Lap-on-Chip Technologies group. My area of work includes dynamic DNA fluorescence measurements in foil-based microfluidics using melting curve analysis and multi-channel silicon photomultipliers, isothcophoresis and filter integration in foil-based microfluidics for the purpose of on-chip sample preparation for lab-on-chip applications such as nucleic acid tests. What I really like about my work here is that our internal projects are efficiently planned and then directly implemented. My colleagues are incredibly productive and fast, too – but they’re also very patient and always helpful if I have any questions. My next goal in the future is to complete my master’s thesis. After that I’d like to get some work experience abroad.

Andrej Seb

I am doing an internship in the Analysis & Test group. Since my introduction to the whole area of ESD, I’ve gained a lot of experience supporting the team with measuring work and test evaluations. My colleagues are highly skilled, especially in the area of ESD, and they’re all very patient and helpful. This has made it very easy for me to settle into my internship. My goals for the future: I’d like to complete by Bachelor of Science and then take a master’s degree. During my degree course I’d definitely like to stay on at Fraunhofer EMFT as a placement student.

Ellen Jinutkova
For 20 years now, Fraunhofer EMFT has been involved in supporting young people in science and technology, giving them insights into the training and degree options available to them in the technical field.

Career orientation weeks

Fraunhofer EMFT 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, and they also find out about the everyday working lives of scientists at Fraunhofer EMFT. The following topics were the subject of the one-week career orientation program in July 2017:

- What do we need microelectronics for?
- How is a microchip made?
- Working in the cleanroom – why cleanliness is crucial
- What does plastic have to do with electronics?
- Flexible systems need thin chips
- Who checks to make sure everything works and what is the service life of a microchip?
- Small, smaller, smallest – tiny pumps
- Chemistry and microelectronics – how do they go together?

Fraunhofer Talent School

The Fraunhofer Talent School enables young people from age 16 to spend three days getting a close-up experience of applied research: in workshops they collaborate with Fraunhofer scientists to work on current scientific problems.

Fraunhofer EMFT organized its own Talent School from October 27 - 29, 2017 on the subject of “Flexible sensors for the electronics of the future”. The program included various workshops on subjects such as photolithography, screen printing and scanning electronic microscopy (SEM). Working in small groups, the participants had the opportunity to independently carry out experiments and practical tasks in the Fraunhofer EMFT labs and cleanrooms.

The seven male and five female students were highly motivated and involved throughout the entire program – the lithography and screen prints went down especially well.

GO MINT – National Pact for Women in MINT Careers

“GO MINT – National Pact for Women in MINT Careers” is a nationwide initiative in Germany which aims to counteract the shortage of specialists in scientific and technical professions, while at the same time tapping into the innovation potential of women in science and technology. Fraunhofer EMFT has been a partner to the National MINT Pact since 2009.

Girls’ Day on April 27, 2017

Five school girls from grades 8 and 9 had the opportunity to get a taste of the atmosphere in a real laboratory at this year’s Girls’ Day at Fraunhofer EMFT on April 27. The program included name tags with QR code and visits to the cleanroom and chemistry lab – complete with a rather different kind of fashion show: the girls were instantly transformed into “real” researchers when they put on cleanroom clothing. In addition to gaining fascinating insights into day-to-day working life at a research institution, the girls had lots of fun too, of course!

I learned interesting things (school grade)

“Everything was cool – but especially getting to see a cleanroom!”

“It was a lot of fun – I found the cleanrooms really interesting!”

“My favorite things were the laser lab and using the microscopes!”

It was a fun day (school grade)
PRESS AND MEDIA
Anwendungen zur vereinfachten Patienten-Compliance.


Bei der häufigsten Form des grünen Stars, der Glaukom, wird ein winziger Stent ins Auge gesetzt, um die erhöhten Augeninnendruck-Werte abzuleiten. Der Eingriff führt zu einer langfristigen Senkung des Augendrucks, die dazu beitragen soll, die Schädigung der Netzhaut zu verlangsamen oder zu verhindern.


Erb sah die Entwicklung als Erfolg an, der den Patienten helfen muss, das Versagen des Glaukos zu erkennen. Die innovative Methode des mikroelektronischen Druckablaufs bei grünem Star ist eine besondere Einteilung des Glaukoms mit einer Viertelstunde. Die Operation beträgt zwischen 1.000 und 1.200 Euro, die Erfolgsquote liegt bei über 80%.

Der Eingriff erfolgt unter dem Einblick eines Operationsmikroskops. Der Schnitt in die Hornhaut ist so klein, dass er nicht genäht wird. Der Abfluss von Kammerwasser wird beschleunigt, was sich bis hinter das Glaskörper auswirkt, wo sich die Netzhaut mit Nährstoffen versorgt. Es wird in der Regel die Kosten der Krankenkassen übernommen. Wenn man Kontaktlinsen trägt, kann der Eingriff in der Regel die Kosten übernehmen.
Quartz resonator to analyze cytomechanics
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 2017. The following list provides a small selection of their academic publications and talks.

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**Publications**

Akrum El Hasr, Stefan Pirmann, Anett Kolander, Erwin Vycoub-George, Martin König, Christof Landesberger, Anja Voigt, Gabi Grützner, Uwe Schnakenberg
Six-layer lamination of a new dry film negative-tone photosresist for fabricating complex 3D microfluidic devices
Microfluid Nanofluid, DOI 10.1007/s10404-017-1877-8, Springer-Verlag Berlin Heidelberg, February 13, 2017

Josel Weber, Peter Ramm
Super-Brains for the IoT Age
Fraunhofer VμE Microelectronics News, February 2017, p. 3

Jamila Boudaden
SMART HVAC SENSORS FOR SMART ENERGY
Smart Systems Integration Proceedings, Cork, Ireland, 2017

Michael Henfling, Ursula Gossner, Christoph Kutter, Walter Hansch, Sabine Trupp
Simultaneous optical and electrical CO₂ detection in one sensitive film

Christoph Jenke, Jaume Pallejà Rubio, Sebastian Kibler, Johannes Häfner, Martin Richter, Christoph Kutter

Stephan Altmanroshofer, Jamila Boudaden, Robert Wieland, Ignaz Eisele, Christoph Kutter
Microwave plasma assisted process for cleaning and deposition in future semiconductor technology
2017 Global Conference on Polymer and Composite Materials (PCM 2017), Guangzhou, China, May 23 - 25, 2017

Peter Ramm, Gilles Poupin, Pascal Courdierc, Markus Leitgeb, Maake M. Visser Taklo
The Advancement of Device Packaging - A Resume on IMAPS DPC 2017
Journal »Advancing Microelectronics«, Vol. 44 No. 3, May/June 2017

3D TSV based high frequency components for RF IC and RF MEMS applications
IEEE Xplore, July 2017


Marin Peterlik, Josef Kögöl, Leonhard Sturm
Phase Noise Evaluation of a Novel Low-Noise Field Effect Transistor
Applied Research Conference (ARC), Munich, July 7, 2017

Onsyla Lang, Laszlo Köhlíai, Joachim Wegener
Label-free profiling of cell dynamics: A sequence of impedance-based assays to estimate tumor cell invasive- ness in vitro
Experimental Cell Research, July 2017

Ignaz Eisele
Impedimetric CO₂ sensor

Correlation study of different CDM testers and CC-TLP

Johannes Weber, Wolfgang Reinprecht, Horst Gieser, Heinrich Wolf, Linus Maurer
Correlation Limits between Capacitively Coupled Transmission Line Pulsing (CC-TLP) and CDM for a Large Chip-on-Flex Assembly

Indraumma Banerjee, Tagrid Salih, Anna Ohlander, Aman Russom
Three dimensional Slipdisc aimed at viral load detection
HIV and Hepatitis Nordic Conference, Stockholm, September 27 - 29, 2017

Peter Ramm, Josef Weber, Rolf Aschenbrenner, Michael Töpper, Johannes Häfner, Martin Richter, Christoph Kutter
Miniaturisierung von Mikromembranpumpen für die Integration in Mobilfunkgeräte (Miniaturization of micromembrane pumps for integration in mobile phones)
MicroSystemTechnik Kongress 2017, Munich, October 22 - 26, 2017

Anna Ohlander, And read Seb, Indranil Bose, Thomas Ganka, Florian Wiest, Christoph Kutter
Dynamic fluorescence measurements on DNA microarrays in foil-based microfluidics using multichannel silicon photomultipliers
MicroSystemTechnik Kongress 2017, Munich, October 22 - 26, 2017

Johannes Hämmer, Anna Bauer, Yining Tian, Sebastian Kibler, Martin Richter, Christoph Kutter
Miniaturisierung von Mikromembranpumpen für die Integration in Mobilfunkgeräte (Miniaturization of micromembrane pumps for integration in mobile phones)
MicroSystemTechnik Kongress 2017, Munich, October 22 - 26, 2017

MikroSystemTechnik Kongress 2017, Munich, October 22 - 26, 2017

Dekkou Lim, Ekta Sharma, David Borggreve, Emmanouil Piston, Sylvain Bourdel, Eran Nezvat Iba, Frank Vanselow, Philippe Ferrari, Linus Maurer
Slow-wave coplanar strip line based low-power 80 GHz voltage control oscillator on 22-nm FDSOI technology
IEEE Asia-Pacific Microwave Conference, Kuala Lumper, Malaysia, November 13 - 16, 2017

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**Academic Publications and Talks**

EDX analysis at the SEM
ACADEMIC PUBLICATIONS AND TALKS

Pragoti Pran Bora, David Borggreve, Frank Varselkov, Erkan Isa, Linus Maurer
Low-Voltage Low-Distortion Sampling Switch Design in 22 nm FD-SOI CMOS Technology
ICECS2017, IEEE, Batumi, Georgia, December 5 - 8, 2017

Stephan Altmanhofer, Jamila Boudaden, Robert Wieland, Ignaz Eisele, Christoph Kutter
Microwave plasma assisted process for cleaning and deposition in future semiconductor technology

Christian R. Engst, Matthias Rommel, Christian Bscheid, Ignaz Eisele and Christoph Kutter
Bulk lifetime characterization of corona charged silicon wafers with high resistivity by means of microwave detected photocconductivity
https://doi.org/10.1063/1.4993127

**Talks**

Joachim Wegener
Profilierung der Pharmakologie von GPCRs mit einem ganzzelligen Biosensor
Batsheva de Rothschild Seminar on New Concepts in Biosensing 2017, Dead Sea (Israel), February 13, 2017

Indranil Ronnie Bose, Patrick Gest, Christof Landesberger, Christoph Kutter
Roll-to-Roll processed foil inlay as an electrostatic chuck for flexible thin semiconductor wafer handling
Smart Systems Integration, International Conference and Exhibition on Integration Issues of Miniaturized Systems, Zurich, Switzerland, March 8 - 9, 2017

Axel Wille
Mikroentgaser – Gasförmiges dem Flüssigen entziehen (Micro degassers – extracting gaseous substances from liquids)
Fraunhofer EMFT Annual Event, Munich, March 15, 2017

Joachim Wegener
Monitoring Living Cells with Physical Transducers
Fraunhofer IGB, Stuttgart, April 24, 2017

Jamila Boudaden
Invited Talk: An approach to reduce greenhouse gases in the semiconductor industry using F2 for CVD chamber cleaning
1st International Materials Science and Engineering for Green Energy Conference, Iran, Morocco, May 10 - 12, 2017

Christof Landesberger
Hybrid integration of thin silicon devices on and in flexible film substrates
Printed Electronics Europe, Berlin, May 10 - 11, 2017

Joachim Wegener
Profilierung der Pharmakologie von GPCRs mit Impedimetrischen Monitoring vonzellbasierten Assays
Affinity 2017, Paris, France, June 26, 2017

Axel Wille
The Role of Micro Diaphragm Pumps in Medical Technologies
IHK Lübeck, July 4, 2017

Jamila Boudaden
Impediment CO2 sensor
1st International Materials Science and Engineering for Green Energy Conference, Ifran, Morocco, May 10 - 12, 2017

Stephan Altmannshofer, Jamila Boudaden, Robert Wieland, Ignaz Eisele, Christoph Kutter
Microwave plasma assisted process for cleaning and deposition in future semiconductor technology

Christian R. Engst, Matthias Rommel, Christian Bscheid, Ignaz Eisele and Christoph Kutter
Bulk lifetime characterization of corona charged silicon wafers with high resistivity by means of microwave detected photocconductivity
https://doi.org/10.1063/1.4993127

**Talks**

Peter Ramm
Invited Talk: Low-Temperature 3D Integration Processes for Reliable Heterogeneous Systems
International Conference on Functional Integrated nanoSystems nanoFIS, Graz, November 22 - 24, 2017
Christian Götz
Expanding the scope of impedance spectroscopy for the analysis of adherent cells: electrode material, electrode design and data analysis
Doctoral dissertation in natural sciences (Dr. rer. nat.) at the Faculty of Chemistry and Pharmacy, University of Regensburg
The doctoral dissertation was completed from January 2013 to October 2017 at Fraunhofer EMFT in Regensburg and at the Institute of Analytical Chemistry, Chemo- and Biosensors, University of Regensburg. The dissertation was submitted to the Faculty of Chemistry and Pharmacy at the University of Regensburg on October 13, 2017 and successfully defended on December 5, 2017 (»magna cum laude«).
The dissertation was supervised by Prof. Dr. Joachim Wegener.

Sebastian Kibler
Two-phase flow sensor for controlled microdosing of mineral oil in an autonomous dosage system
Doctoral dissertation (Dr.-Ing.) at the Faculty of Electrical Engineering and IT, Bundeswehr University Munich.
The doctoral dissertation was completed from 2011 to 2016 at Fraunhofer EMFT in Munich. The dissertation was submitted to the Faculty of Electrical Engineering and IT, Bundeswehr University Munich on November 4, 2016 and successfully defended on March 16, 2017 (»magna cum laude«).
The dissertation was supervised by Prof. Dr. Christoph Kutter.

Anna Ohlander:
Foil-based lab-on-chip technologies for advanced point-of-care molecular diagnostics
Doctoral dissertation (Tekn. Dr.) at KTH Royal Institute of Technology, School of bioteknologi (BIO), Stockholm, Sweden.
The doctoral dissertation was completed from 2010 to 2017 at Fraunhofer EMFT in Munich. The dissertation was submitted to KTH Royal Institute of Technology, School of bioteknologi (BIO), Proteomics och nanobiotechnology (Clinical Microfluidics and Nanobiotechnology), Stockholm, Sweden on April 26, 2017 and successfully defended on May 19, 2017.
The dissertation was supervised by Associate Professor Aman Russom.

Lorenz Grünerbel
Construction and characterization of electric contacting between foil components
Master thesis, Munich University of Applied Sciences
Supervisor: Johann Dieter Hemmetzberger

Patrick Schweimer
Establishment and characterization of electric contacting between foil components
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Bassem Badawi
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Master Thesis, Technical University Munich
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Christian Götz
Expanding the scope of impedance spectroscopy for the analysis of adherent cells: electrode material, electrode design and data analysis
Doctoral dissertation in natural sciences (Dr. rer. nat.) at the Faculty of Chemistry and Pharmacy, University of Regensburg
The doctoral dissertation was completed from January 2013 to October 2017 at Fraunhofer EMFT in Regensburg and at the Institute of Analytical Chemistry, Chemo- and Biosensors, University of Regensburg. The dissertation was submitted to the Faculty of Chemistry and Pharmacy at the University of Regensburg on October 13, 2017 and successfully defended on December 5, 2017 (»magna cum laude«).
The dissertation was supervised by Prof. Dr. Joachim Wegener.

Anna Ohlander:
Foil-based lab-on-chip technologies for advanced point-of-care molecular diagnostics
Doctoral dissertation (Tekn. Dr.) at KTH Royal Institute of Technology, School of bioteknologi (BIO), Stockholm, Sweden.
The doctoral dissertation was completed from 2010 to 2017 at Fraunhofer EMFT in Munich. The dissertation was submitted to KTH Royal Institute of Technology, School of bioteknologi (BIO), Proteomics och nanobiotechnology (Clinical Microfluidics and Nanobiotechnology), Stockholm, Sweden on April 26, 2017 and successfully defended on May 19, 2017.
The dissertation was supervised by Associate Professor Aman Russom.
Interdigitated electrodes for impedance-based monitoring of animal cells

Anna Ohlander, Gerhard Klink, Karlheinz Bock, Aman Russom
DE 50 2013 006 824

System to carry out a contactless measurement on a sample and sample carrier
Anna Ohlander, Gerhard Klink, Karlheinz Bock, Aman Russom
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Sensor arrangement for a vacuum therapy system, vacuum therapy system with sensor functions and analysis method
Gerhard Mohr, Anna Hezinger, Sabine Trupp, Jennifer Schmidt, Matthias Stich
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Christof Landesberger, Dieter Bolmann, Waltraud Hell, Gerhard Klink
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Jamila Boudaden, Benjamin Gruber
WO 2017 134 247

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Martin Richter, Martin Wackerle, Christian Wald
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Open jet dosing system for the eye
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