Fraunhofer
EMFT

FRAUNHOFER RESEARCH INSTITUTION FOR MICROSYSYTEMS AND SOLID STATE TECHNOLOGIES EMFT

ANNUAL REPORT 2018

Fraunhofer EMFT

Annual Report 2018

FOREWORD

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

If I had to summarize last year in two words, I would say: “Diversity wins”.

Our very broad R&D portfolio has definitely gone down very well with our customers: five of our seven departments passed the EUR 500,000 mark in terms of revenue in 2018. These figures demonstrate that our topic areas are “catching on”, giving Fraunhofer EMFT fundamental stability.

Interdisciplinary collaboration and a wide-ranging partner network are key factors in terms of our strategy of gearing Fraunhofer EMFT more towards all-inclusive solutions than single technologies. The capacity to look beyond a narrow context and integrate a variety of perspectives has repeatedly enabled us to arrive at innovative yet practically feasible solutions.

This success is borne by a diverse international workforce. I strongly believe that it is precisely this social and cultural diversity that vastly enriches the research work carried out at Fraunhofer EMFT. In this connection I am particularly pleased that were able to attract more young scientists than usual last year, especially in the area of microdosing systems: we look forward to your ideas!

I very much hope you enjoy reading our fascinating annual report – and as always I look forward to receiving your feedback and input.

Best regards,

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

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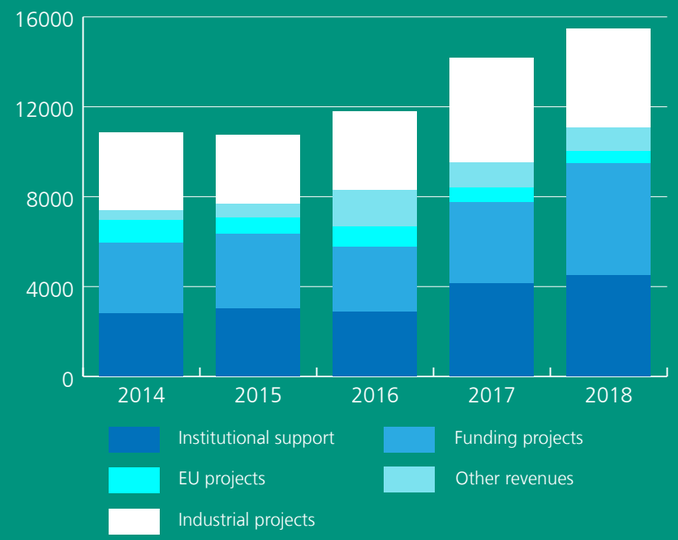
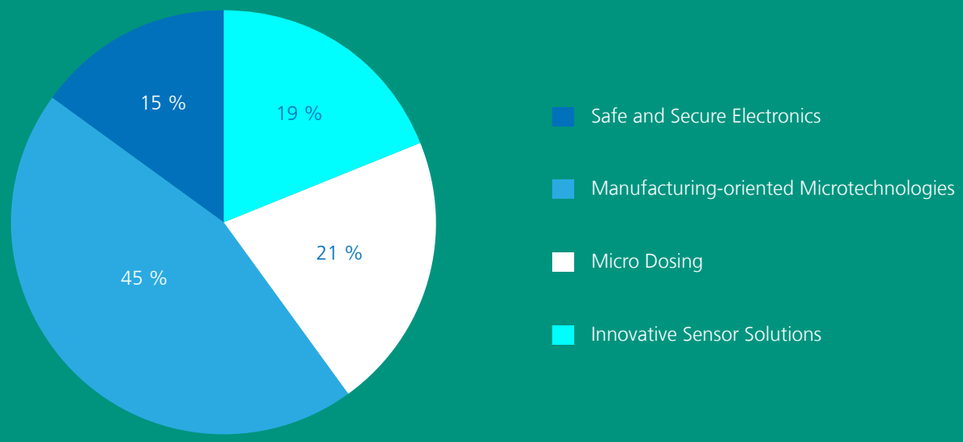
FRAUNHOFER EMFT

Fraunhofer EMFT building at Hansastrasse in Munich

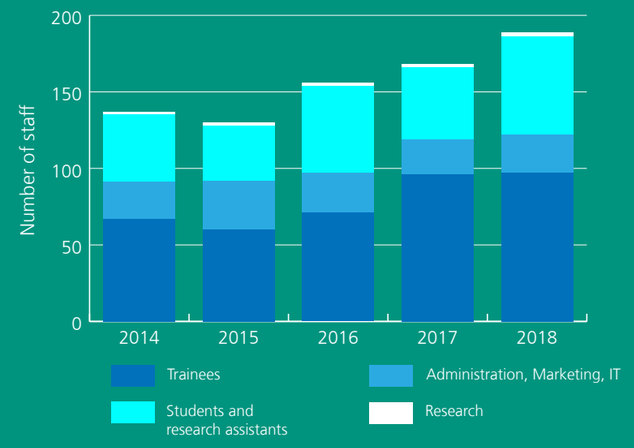
FACTS AND FIGURES

Fraunhofer EMFT's total budget amounted to EUR 15.5 million in 2018. Industry contracts generated a total volume of approx. EUR 4.5 million, accounting for 30.7 % of the total budget.



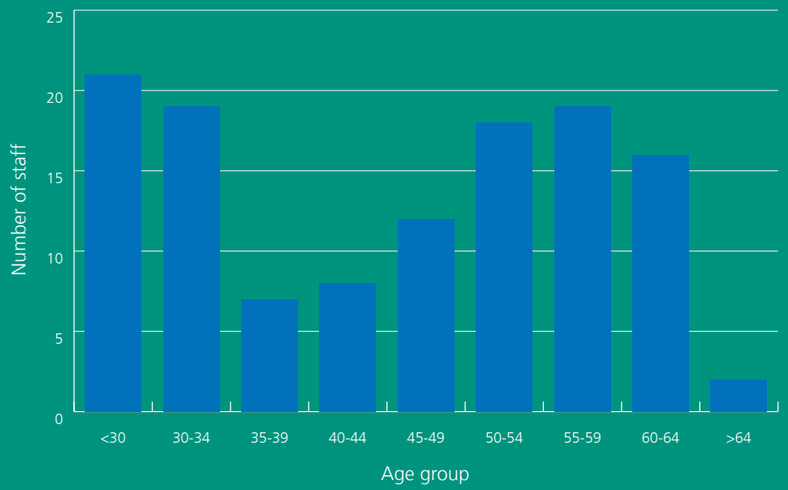


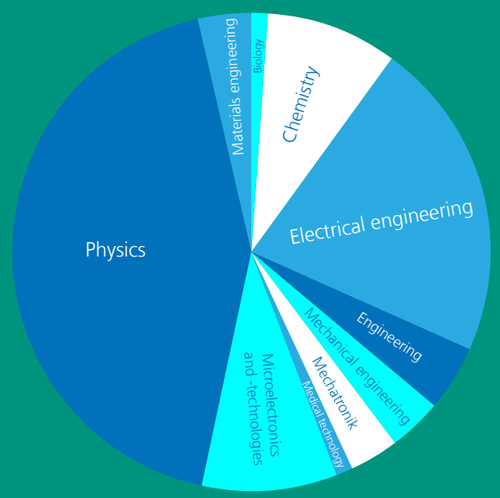
A total of 105 projects were implemented at Fraunhofer EMFT in 2018. The diagram shows how these projects were distributed among the Fraunhofer EMFT areas of expertise as percentages.



In 2018 Fraunhofer EMFT employed 122 staff. Of these, 97 worked in the scientific area and another 25 in the areas of administration, marketing, IT and technology. In addition, there were 64 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 three trainees.

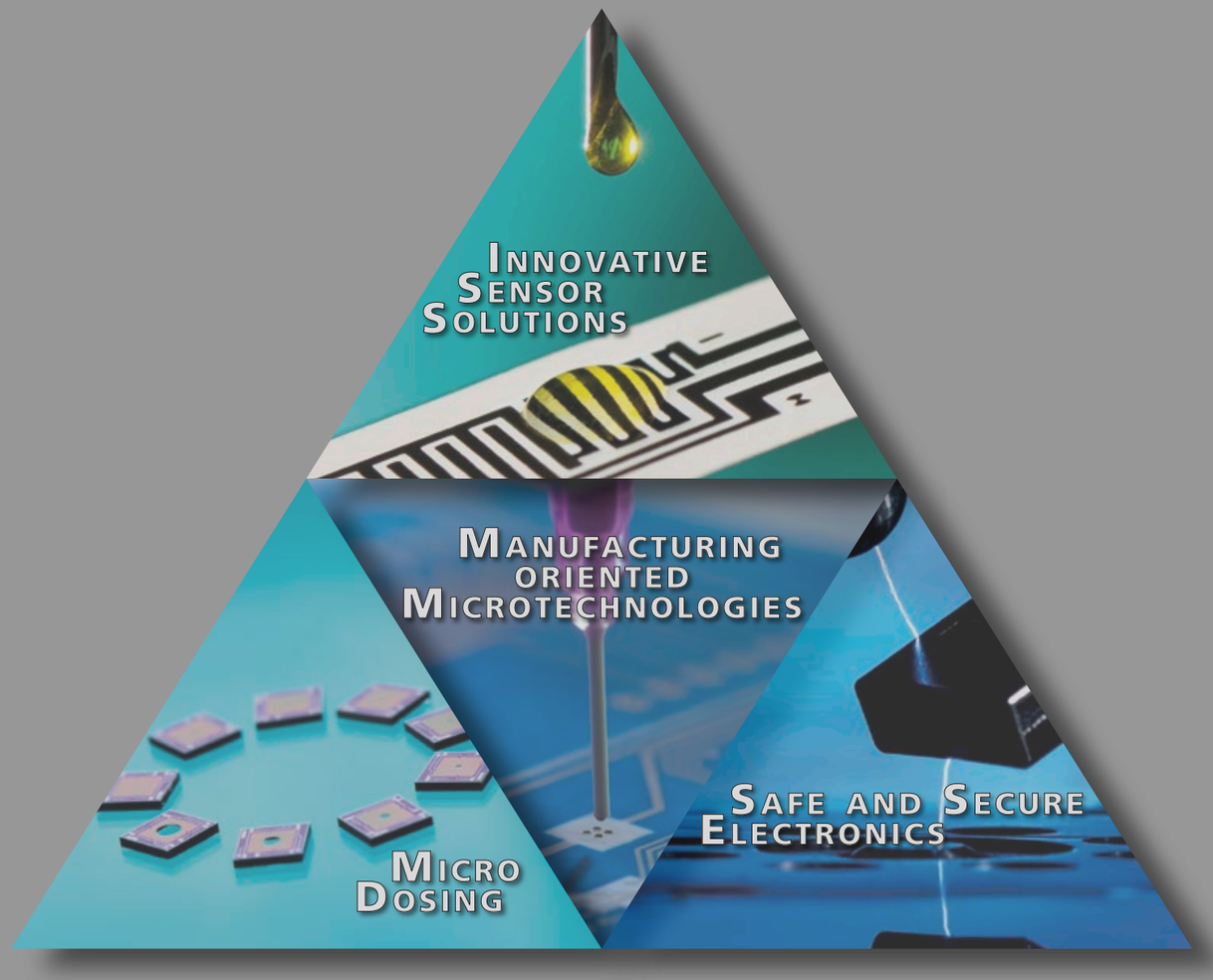
This diagram shows the age structure at Fraunhofer EMFT. The average age of all staff is 45.



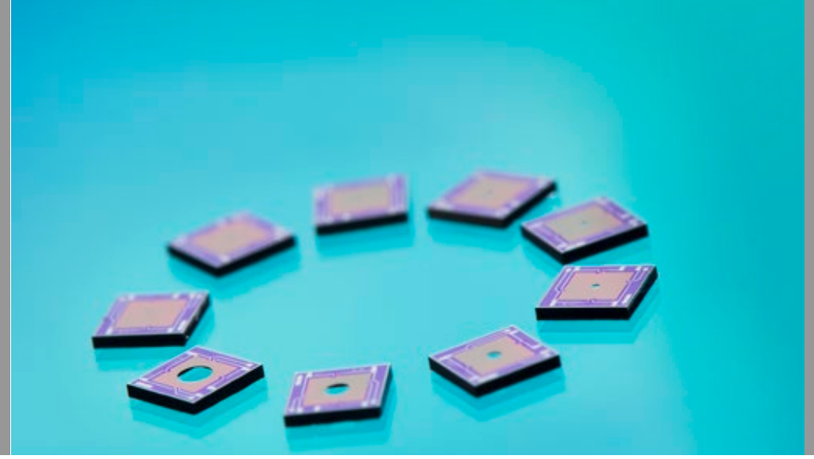


Distribution of subject areas at Fraunhofer EMFT: This diagram refers to the university degrees held by scientific staff (degrees in similar subject areas are grouped together). Physics and electrical engineering are the most common subject areas.

AREAS OF EXPERTISE



Sensor materials for combined in-line measurements



Silicon flow sensors

INNOVATIVE SENSOR SOLUTIONS

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). Yet while their potential uses are diverse, the demands made on these tiny electronic helpers in the various concrete applications are both highly complex and very specific. In many instances, standard solutions commonly available on the market are not able to meet this wide range of needs.

One research focus at Fraunhofer EMFT is innovative sensor solutions that can be individually tailored to our customers’ needs and requirements. With their broad technological expertise, Fraunhofer EMFT scientists develop novel, high-performance sensors, design robust, secure and fast sensor networks and create system solutions that enable the sensors to interact perfectly with their environment. In this area, in-house developments are sometimes combined with existing solutions.

R&D focus areas at Fraunhofer EMFT:

- Energy-efficient sensors
- Sensors on flexible substrates
- Flow sensorics
- Chemical sensorics/gas sensorics
- Biosensorics
- Cell-based sensorics
- Characterization and validation
- Combined sensor systems

For more detailed information, see our website:
https://www.emft.fraunhofer.de/en/competences/innovative-sensor-solutions.html

MICRO DOSING

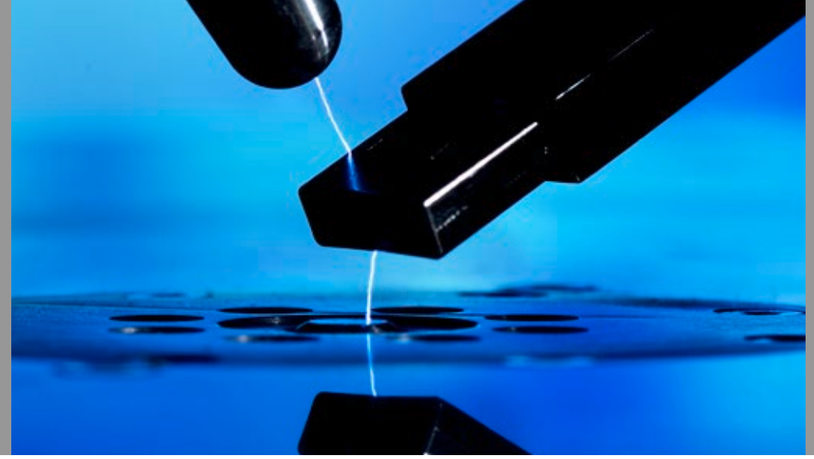
Precise dosage of gases and liquids to the nearest nanoliter is a central and longstanding area of expertise at Fraunhofer EMFT, covering a broad range of applications – from medical technology through to industrial applications and consumer electronics.

Piezo-electrically powered micropumps are at the heart of these 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 parameters in terms of dosage precision, counter-pressure resistance, size, energy consumption, particle resistance, bubble tolerance and free-flow protection to the requirements in question.

Fraunhofer EMFT has designed a portfolio of silicon and stainless steel/titanium 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 3.5 x 3.5 x 0.6 mm^3, was developed at Fraunhofer EMFT. A current key focus in the area of metal micropumps is designing the pumps and valves. 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 technology transfer.

In addition to the micropumps themselves, the Fraunhofer EMFT R&D portfolio also includes a very diverse range of micro dosing components in this research area, and the team possesses extensive system expertise, too. 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.

For more detailed information, see our website:
https://www.emft.fraunhofer.de/en/competences/micro-dosing.html



ESD system test with broadband measurement of the secondary discharge current

Detailed view of a foil system for temperature measurement during processing

SAFE AND SECURE ELECTRONICS

Internet of Things, 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. Safe and secure electronic systems are required as the "infrastructure" of this interconnected world. This area of expertise has various facets here.

Firstly, electronic systems have to be 100 % reliable in the sense of offering failsafe 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. Focus areas here include failure analyses and characterization of electronic modules and systems, development of novel ESD test and protection concepts and the monitoring of electrical connections using "intelligent" plugs.

The second aspect 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 Internet of Things applications become accepted by users on a wide scale. However, software-base solutions are often no longer sufficient 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. Fraunhofer EMFT collaborates with partners and customers on novel protection concepts at hardware level, e.g. based on so-called Physical Unclonable Functions (PUF).

The third aspect 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 microdosing 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.

For more detailed information, see our website:
https://www.emft.fraunhofer.de/en/competences/safe-secure-electronics.html

MANUFACTURING-ORIENTED MICROTECHNOLOGIES

Fraunhofer EMFT is equipped with extensive cutting-edge technological facilities in the area of microelectronics and microtechnology that 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. Expertise in this area include the following:

Technology and process analytics: 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.

Development of electrical and optical components: The optical and electrical components developed at Fraunhofer EMFT include complex fluorescence modules, conventional PIN photodiodes, sensitive silicon photomultipliers for individual photo detection and extremely low-noise transistors – something that is unique to Fraunhofer EMFT.

Foil electronics: Flexible electronics offers new possibilities for a wide range of "smart" high-performance products. In-house roll-to-roll production infrastructure enables low-cost processing of foils and other flexible substrates to develop flexible, flat and large-area electronic systems. Here, heterointegration of silicon and foil technology has a key technological role to play.

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 silicon, so the devices produced at wafer level can be as thin as needed.

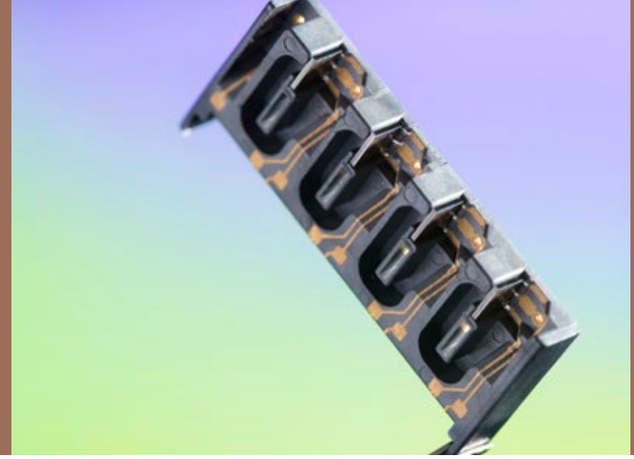
IC design: Very specific applications, the capacity to tap into new functions and areas of use, increased miniaturization, enhanced energy efficiency, low manufacturing costs and greater reliability often require new IC designs that are not available on the market in this form. Here, Fraunhofer EMFT supports its customers in designing complex analog and mixed-signal circuits, focused on novel sensoric concepts and mm-wave design.

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.

For more detailed information, see our website:
https://www.emft.fraunhofer.de/en/competences/manufacturing-oriented-microtechnologies.html

EXAMPLES OF PROJECTS AND APPLICATIONS

Tamper-protection foil wrapped around an electronics casing



Wireless intelligent circuit board connector for the continuous measurement of contact temperature and power load of an individual contact as basic data for preventive maintenance

Safe and Secure Electronics

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 takes its place. However, this solution is neither economically nor technically feasible since it would take up too much installation space inside the car.

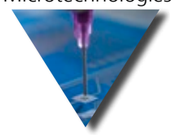
Researchers at Fraunhofer EMFT have joined forces with several industry partners to develop a clever alternative with the project *AutoKonf*: a redundant, generic control unit. If the control device for the steering or brakes fails, the redundant generic control unit takes over the function in question and is able to control the car safely. In order to ensure the redundant control unit can 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; subsidy from the Business Plan of the Energy and Climate Fund (EKF), funding reference no.: 16EMO0187).

Manufacturing-oriented Microtechnologies



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 (see picture above). 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 in-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 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, including foil technology that enables semiconductors to be embedded in extremely narrow gaps and allows small volumes. This efficiently supports the desired integration of sensor systems in interfaces such as plugs or press-fit contacts.

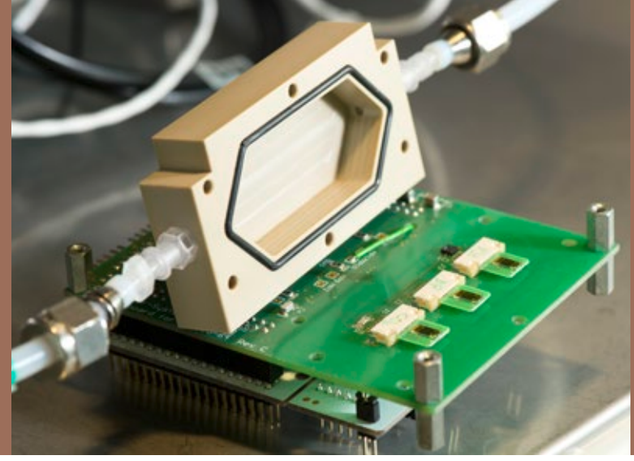
The project is funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy under funding reference no. 43-6622/532/4.

Innovative Sensor Solutions

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 to 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



Capacitance and resistance measurements with the Evaluation Kit

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.

Innovative Sensor Solutions

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 CO_2. 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 CO_2. 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, CO_2, H_2S, acetone, ethanol, SO_2, NO_x). In the climate gas chamber it is possible to reproduce air humidity levels of between 5% and 90% 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.

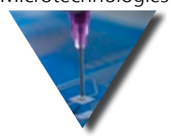
The research team has also developed a miniaturized evaluation kit as a useful addition to the gas measuring system (see picture, p. 23, top). This approximately palm-sized device allows precise measurement of sensor response and recovery times. A conventional gas measuring system is not suited for this 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.

Safe and Secure Electronics

Reliable detection of hardware trojans

In the BMBF-funded project *SyPASS* (funding reference no.: 16KIS0669), Infineon AG, Raith GmbH and Fraunhofer EMFT are collaborating to develop methods for the retrograde preparation of highly integrated safety circuits so as to recover layout information. Comparison with design data is to ensure reliable detection of hardware trojans. The particular challenges confronting this project are the structures and layer thicknesses of less than 10 nm in the preparation, the stability of the mapping using scanning electron microscopy and finally the synthesis and analysis of huge quantities of data.

Manufacturing-oriented Microtechnologies



High-performance modules for the Internet of Things

How can the vision of a highly connected society be realized with minimum impact on future energy resources? One possible answer is provided by the Fraunhofer lead project *Towards Zero Power Electronics*. This involves nine Fraunhofer institutes engaged in building a technology and methodology platform to realize highly integrated, extremely energy-efficient modules for the Internet of Things. The partners' ambitious goal is to minimize the energy and resource needs of electronic systems to an extreme degree. This is to be achieved by means of disruptive, internationally pioneering innovations at all levels of the value creation chain – from the components (e.g. radio transceivers, sensors and energy storage units) to system amalgamation (modularization, integration techniques) and the network technologies used.
Fraunhofer EMFT's contribution to this project is to create a gravimetric principle for particulate mass measurement which can be realized in a microsystem for use in a highly integrated CMOS sensor system with extremely low-noise analysis electronics. Needs-based media supply through microactuators will significantly reduce the response time and therefore the energy consumption of the particulate sensor. The sensor will support mobile and autonomous applications in the area of air quality monitoring. The partners involved are able to contribute a broad spectrum of interdisciplinary expertise ranging from semiconductor technologies, design methods and integration techniques to comprehensive systemic efficiency analysis.

The solutions developed as part of this project are also to be made directly accessible to industry partners via the technology platform.

Family of micropumps (silicon, metal and titanium)

Micro Dosing

Industrialization of stainless steel micropumps for medical technology

High flow rates or extreme miniaturization – with its extensive pump portfolio (see picture p. 25, top) 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 (RaPa) 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.

Micro Dosing

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.

Innovative Sensor Solutions

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 transfered 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 mineral oil 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 CaF_2 windows, 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.

Innovative Sensor Solutions

New sensor concept for FET transistors

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.

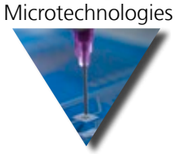
Conventional FET-based gas sensors measure the electrical contact potential difference between the substrate and a sensor layer mounted opposite. However, this set-up is prone to drift effects in gaseous mixtures with a high level of humidity and has a low level of sensitivity due to the finite air gap thickness.

Monitoring concealed solder connections (BGA, PGA, QFN)

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 CO_2 detection. The project was funded under the Fraunhofer Society's Discovery Program (funding reference no.: Discover 827100) and realized under a research contract for the industry partner LFoundry S.r.L.

Manufacturing-oriented Microtechnologies



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 practically oriented press-fit contact/copper sleeve combination featuring surface materials that are of interest from an industry point of view.

The research project is being funded by the AiF (German Federation of Industrial Research Associations) "Otto von Guericke" e.V. (IGF Application No.: N 09826/16, FVA no. 618 II "Accelerated Models II").

Securely 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 under the project MRE Test, funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy as part of the "Mikrosystemtechnik Bayern" program, funding reference no.: MST-1308-0001// BAY189/001) is to be transfered 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 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 Sensor Solutions

Aligned lamination of foil components on carrier substrate

Micro Dosing

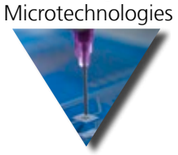
Smart catheter for cell-based heart attack therapy

About 10% of the population of the western world have to undergo angioplasty surgery at some time, due to cardiac arrhythmia or for a heart valve replacement. These minimally invasive procedures on the heart are supported by numerous intelligent imaging and sensor catheters acting as the surgeon's "eyes and ears". Despite the fact that these intelligent instruments are absolutely indispensable and indeed life-saving, there have been very few innovations in the recent years due to the frequently small production volumes. As a result, the level of demand among hospitals for instruments with improved functionality is very high. The project *Position-II* offers a unique solution to this problem. A consortium of 45 partners from 12 countries has introduced open technology platforms for miniaturization, in-tip AD conversion, wireless communication, MEMS converter technology and encapsulation. The platforms have the advantage that they are open to multiple users. This makes it possible to improve the performance of "smart" catheters at a low cost, thereby enabling the development of entirely new minimally invasive instruments.

As part of this project, Fraunhofer EMFT scientists are working on a catheter that transports stem cells to dead myocardial tissue. For this purpose, an appropriate dosing unit has to be found which pumps the cells through the catheter to the heart without the pressure in the heart and the additional fluidic counterpressure impairing the accuracy of the dosage.

The project is being funded by the ECSEL initiative (Electronic Components and Systems for European Leadership) under the reference number 783132.

Manufacturing-oriented Microtechnologies



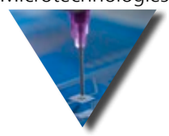
Electronic modules for future mobile phone generations

The aim of the joint European project REFERENCE under the coordination of SOITEC is to cluster Europe-wide 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 (4.24.4 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 ECSEL 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).

Manufacturing-oriented Microtechnologies

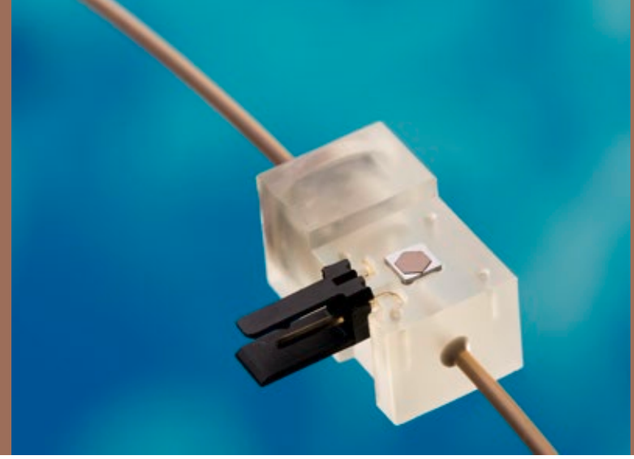


System integration technologies for multifunctional, foil-based electronic systems

Electronic systems in the age of Internet of Things have to be able to offer enhanced functionality as well as a high degree of connectivity capability, energy efficiency and reliability. For this reason, the usually heterogeneous components have to be integrated within an increasingly small space. In order to further increase the innovation dynamic in microelectronics by means of this multi-functionality, fundamental technologies have to be developed further for the purpose of system integration and harnessed for the industrial manufacture of future electronic systems.

Under the joint project *ADAMOS*, Fraunhofer EMFT researchers are collaborating with partners from science and industry to create new system integration technologies for multi-functional foil-based electronic systems (see picture above). For this purpose they are investigating and developing an adaptive laser structuring method for chip contacting and adapting roll-to-roll lithography to sensor strips that are several meters long. The success of the project is to be demonstrated by integrating sensor modules on foil strips for autonomous sensor nodes and flow measurements on wind turbines as well as functional chip-foil systems for fluidic applications in medical technology. Fraunhofer EMFT is making its roll-to-roll foil technology available to this joint project and is realizing chip integration for the three technology demonstrators by means of the new adaptive laser lithography.

The project is funded by the Federal Ministry of Education and Research (BMBF, funding reference no.: 16ES0727).



The smallest silicon micromembrane pump in the world, measuring 3.5 x 3.5 x 0.6 mm³

Innovative Sensor Solutions

Environmental analytics for all – co-creation with the maker scene

There is considerable public interest in the measurement of environmental parameters – whether water quality, food ingredients, nitrate and phosphate content in domestic gardens or air quality on people's doorstep. These kinds of measurements are generally elaborate and/or require sophisticated equipment that is only available in specialist labs. The measurement strips that are commonly available tend to be less precise and not easy to combine with web-based methods. In the project *CitizenSensor – Environmental analytics for all*, a Fraunhofer EMFT team is collaborating with citizen scientists to develop innovative and easy-to-use methods to measure environmental parameters. As an introduction to citizen science activities in this high-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.

Another fundamental project objective is examine the collaboration between citizen science and research organizations and create a new model of cooperation on this basis. The project is funded by the Federal Ministry of Education and Research (BMBF) under funding reference no.: 01BF1711B.

Safe and Secure Electronics

Condition monitoring of high-end production equipment

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 GmbH, 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.

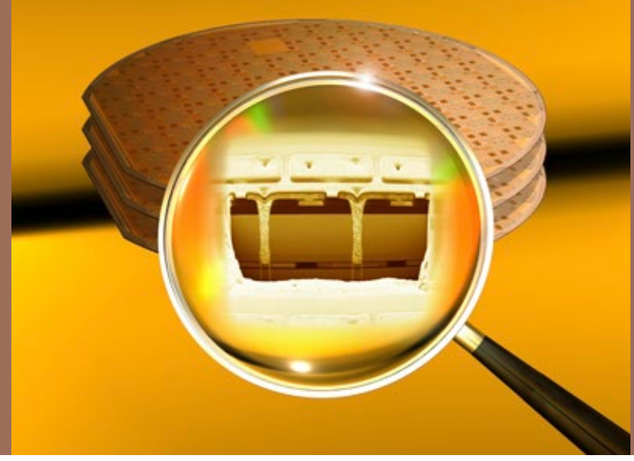
The fourth dimension: fragrances are introduced to virtual reality

Getting a bird's eye view of the world or traveling to the lowest point of the Earth – all this can be done very conveniently nowadays from the living room couch with the help of Virtual Reality (VR). VR technologies for hearing and seeing have been almost perfected, but one key sensory perception is still lacking – that of smell.

In the project *Scent – the Fourth Dimension for Virtual Reality*, Fraunhofer EMFT and Fraunhofer IVV scientists are developing an innovative fragrance dosage system to be positioned close to the nose that can produce new smells at every breath. This joint work is based on a design tool that defines not just the chemical properties of the odorants but also the pump-specific parameters and the dimensions of the fluidic components. With defined input parameters, the tool releases the required dosage volume for each individual odorant to be pumped out of the reservoir to the nose. The odor molecules are contained in the reservoir in a gas phase, with a separate unit being required for each odorant. One key requirement in being able to realize this complex dosage system is the extremely miniaturized pumps created by Fraunhofer EMFT, measuring just 3.5 x 3.5 mm² (see picture above).

In addition to the fluidic components already mentioned, researchers at Fraunhofer EMFT have also developed a new high-voltage driver for micropumps which can operate up to four micropumps via a single channel. In order to avoid unwanted aromas and ensure that the smells change at each breath, an internal Fraunhofer Discover project (funding reference no. 835196) developed a breathing cycle detector based on an environment sensor. This system is able to detect far enough in advance when the next inhalation will occur, allowing the required quantity of odor molecules to be emitted at each breath.

Micro Dosing



3D integration with TSV technology

Innovative
Sensor Solutions

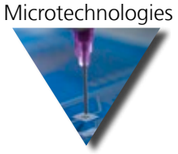
Fabric kit with integrated sensor system

When it comes to developing new pharmaceuticals and assessing biological, chemical or physical risks, 3D fabric models cultivated in the laboratory are becoming increasingly important as compared to the much less realistic 2D cell layers that have mostly been used up until now. In addition to biological fabric models, whose development is already well advanced, there is a demand for measurement and analysis methods to be able to measure the reaction of the cells to external stimuli as far as possible. Up to now it has generally been necessary to dismantle the fabric in order to access the cells embedded deep within it.

With the project *TissueSense*, Fraunhofer EMFT researchers are pursuing a fundamentally new concept: instead of installing sensor functions (electrodes, nano probes) in the model fabric subsequently or dismantling them after a predefined exposure period for the purpose of analysis, the 3D fabric model is made of individual layers based on a kind of modular principle. The cultivation of the individual fabric layers is initially carried out in 2D by means of cell monolayers on thin, porous polymer carriers with integrated signal converters. The fabric layers are then assembled in layers made up of these 2D constructs. Since the polymer carriers have a porous structure, the individual cell layers come into contact with each other after assembly to form a 3D construct and are able to exchange substances. By fitting the polymer carriers with signal converters, it is possible to obtain chemical or physical information from each individual cell layer of the 3D fabric model and transfer it in real time. When screening substance libraries on individually tailored organ models in particular, this opens up a whole new range of perspectives in terms of the quality of the biomedical information available as well as from the point of view of economy and testing capacity.

The project has been funded since 01.07.2018 under the internal Fraunhofer Discover Program, funding reference no. 027600628.

Manufacturing-oriented
Microtechnologies



3D integration technologies for IoT applications

The trend towards the Internet of Things (IoT) makes heterogeneous 3D integration (see picture p. 33, top) a key technology but this involves challenges in terms of the relevant process technologies, such as wafer bonding: the enormous pressure of competition in the area of IoT applications means that the systems have to be increasingly smaller but at the same time more capable and robust, too. In order to meet these demands, Fraunhofer EMFT signed a license agreement with XPERI 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.

Innovative
Sensor Solutions

A plaster that gets "under your skin"

"Intelligent plasters" can already do more than just cover up wounds: equipped with the necessary sensors, they are able to monitor body parameters such as temperature, moisture, pH, oxygen saturation and electrical potential. But what goes on beneath the surface of the skin is a closed book to most of the sensor plasters available nowadays.

In the EU project *ULIMPIA*, Fraunhofer EMFT is collaborating with 17 partners from six countries on a plaster that is also capable of detecting physical processes deep inside the body – such as measuring blood pressure or monitoring the bladder. For this purpose, the researchers combine state-of-the-art MEMS ultrasound technology with innovation in compliant patch technology. The aim is to create an open technology platform for diagnostic ultrasound patches.

As part of this project, Fraunhofer EMFT is developing a packaging technology to integrate several sensors and also ultrasound actuators on a foil and textile base. Among other things, the aim is to create a skin-friendly, flexible sensor plaster with the necessary microelectronics components for data logging and transfer. The platform will be accessible to various users and focus on the development of concrete applications. The project is funded under the PENTA program, funding reference no. 16ES0815.

Innovative
Sensor Solutions

Assistance system to detect black ice

Black ice and aquaplaning make streets dangerously slippery and can cause severe accidents. Assistance systems that are able to detect such road conditions and respond to them – for example by automatically reducing speed – would significantly enhance road safety. On behalf of Intel (funded as part of the center of excellence "Securely Networked Systems") Fraunhofer

Freshness monitoring of food products based on color change

EMFT scientists are working on a visual real-time system that is capable of detecting water on a road surface in its solid state.

The catch here is that within the visible spectrum, it is difficult to distinguish water from other materials, depending on quantities and light conditions. In order to avoid this problem, the development team is using the infrared spectral range for visual detection. Based on the mutual relationship between the water molecule vibrations, researchers are able to detect the solid state of water on various surfaces. The absorption of light reflects the emission of the molecules' natural vibration in different ways from one material to the next. This emission cannot be measured directly, however: it is calculated based on measurable variables (reflection or transmission).

In order to be able to offer the automotive industry an attractive solution, the researchers are testing to see whether low-cost CMOS image sensors as already used in smartphone cameras might also be suitable for detection. These sensors are mainly used for visible light but they are also sensitive to the near infrared range.

Innovative Sensor Solutions

Intelligent food packaging

Consumers can rarely assess the freshness of a food product with the naked eye. Yet easily perishable foods such as raw meat and fish products are highly susceptible to microbial decomposition processes.

Since it is very difficult to monitor the freshness of packaged products, Fraunhofer EMFT is collaborating with Fraunhofer IVV and industry partners on the project *FRESH* to develop a packaging foil which displays the degree of food freshness based on color (see picture, p. 35, top). Here, development involves integrating chemical sensor materials in food packaging so that it is possible to reliably determine the quality of the product at a single glance. The integrated sensors respond specifically to gases released when the products perish, triggering an obvious color reaction when a certain threshold is exceeded. In the future, the development of intelligent food packaging could have a very positive general impact: not only would it increase product safety, it would also reduce food waste at the end of the supply chain. The sensor packaging would reliably determine whether a product is still edible, no matter whether the best-before date had already expired or not.

Gefördert durch:
Bundesministerium für Ernährung und Landwirtschaft
aufgrund eines Beschlusses des Deutschen Bundestages
ptble

In collaboration with the partners EVONIK Resource Efficiency GmbH, Wipak Walsrode GmbH, Siegwerk Druckfarben AG & Co. KGaA, Albis Plastic GmbH and MuWe Fleischhandels GmbH and with funding provided by the Federal Ministry of Food and Agriculture (funding reference no. 281 A100116), the project is well on the way to increasing sustainability in the food industry.

Innovative exposure method for improved ESD protection

We are confronted with electrostatic discharge in day-to-day life more frequently than we would want – sometimes simply the harmless touch of a door handle is enough for us to feel an unpleasant sensation. Compared to electronic systems and technologies, however, human beings are relatively insensitive: even low voltage levels are sufficient to trigger anything from small-scale damage to serious disruption, especially in the case of high-speed technologies. This problem is further compounded by the ongoing miniaturization trend in microelectronics, which at the same time results in a reduction of the maximum permitted discharge voltage. Improved ESD protection is therefore crucial, especially in the environment of automated production. The aim is to create exposure models in order to test individual components for their ESD stability.

However, conventional testing methods are already reaching their limits in terms of accuracy and reproducibility, so more precise methods of measurement are required. Fraunhofer EMFT has joined forces with Cisco to tackle this challenge by means of an industrial project in which the standardized method Charged Device Model (CDM) is compared to an innovative exposure method. So-called Capacitive Coupled Transmission Line Pulsing (CC-TLP) was developed at Fraunhofer EMFT, a method that enables more precise and reliable measurement. The great advantage of this measurement method is that unlike the CDM method, it does not produce uncontrollable air discharge that can hinder realistic measurement. As such, the CC-TLP model achieves a higher level of reproducibility and precision. Tests on various product circuits indicate a very good correlation with the CDM in terms of both the failure threshold and the error signature. One particularly useful feature is the possibility of testing circuits directly on a wafer so as to be able to detect ESD protection weaknesses at an early stage. The CC-TLP model is thus a valuable supplement to standardized measuring methods and may even offer an alternative in future.

The project was funded by the Silicon Valley Foundation.

Safe and Secure Electronics

Cell and tissue samples grown in a 37 °C-incubator

Micro Dosing

Autonomous implant for cancer treatment

When a cancer tumor starts to metastasize, the chances of the patient recovering get significantly worse. Metastasis is particularly dangerous in the case of malignant tumors: in spite of numerous attempts, no effective treatment has yet been found to stop the process. Fraunhofer EMFT pursued a new, innovative approach with its partner under the industrial project *µP Brain Test*. The aim of the project was to provide a silicon, bubble-tolerant MEMS micropump developed by Fraunhofer EMFT (TUDOS – Tumor Dosing) as the core element of an autonomous implant to combat meningeal metastasis. By means of metronomic dosing to the microliter, it is possible to maintain the therapeutic level as the basis for an entirely modernized and more patient-friendly cancer treatment. In addition to precise analysis of dosing stability in long-term testing of the pumped cytostatic, the interaction between the micropump and the active agent was investigated so as to prepare micropumps for medical examinations. This progress could be a key factor in future: after all, metastases are still the biggest stumbling block in the fight for survival against cancer.

Safe and Secure Electronics

Detecting degradation processes early on

Reliable, fail-safe electronics are crucial to the future vision of self-driving cars. Researchers at the Oberpfaffenhofen Training and Analysis Center are involved in a basic research project to develop a hitherto unique fail-operational approach for autonomous vehicles. Online diagnosis is to be used to detect incipient errors (degradation processes) in an electronic/electrical system early on (before the error actually occurs). In order to realize this novel anticipatory error detection method, the research team is working on a physical model of the cause and impact of errors in electronic systems. The specific focus is on energy wiring systems, i.e. supply lines and power distributors.

OptoMigration – an automated, high-precision wound healing assay *in vitro*

Innovative Sensor Solutions

Coordinated cell migration has a key role to play in physiological and also pathological processes. The most dangerous form of pathological migration is probably that of metastasizing tumor cells. As such, gaining a detailed understanding of the process is essential in order to be able to develop effective countermeasures to pathological cell migration in applied research.

Cell migration is mainly studied in a controlled laboratory environment (see picture above) on cultivated cell models (*in vitro*) using so-called wound healing assays, with the migration of a cell population being observed along its growth substrate, normally microscopically. For this purpose it is necessary to experimentally introduce a defined wound into a continuous cell layer into which the cells from the periphery of the wound can migrate. The existing, established assays are functional but can only be automated to a very limited extent and do not provide satisfying reproducibility or throughput. The project *OptoMigration* now adopts a new approach to the study of cell migration: the focus is on a composite, polymer-based material that is used for the high-precision optical wounding of cells cultivated on it. The core of the composite material is a light-sensitive layer which, when exposed to visible light, generates a toxic chemical species that locally kills cells growing on the surface of the substrate. The cells then grow from the periphery of the wound into the cleared space, which is documented microscopically. The contactless introduction of a defined wound to a cell layer provides the basis for a wound healing migration assay with a high degree of automation and parallelization. In particular, the anticipated precision of the introduced wound and its independence from the influence of the experimenter will significantly improve the reproducibility of this assay and make automation possible in the first place.

The project is being run jointly with ibidi GmbH (Martinsried) and funded by the Federal Ministry of Education and Research (BMBF) under the funding initiative KMUinnovativ, funding reference no. 13XP5074B.

RANGE OF SERVICES AND TECHNOLOGIES

Regulated system consisting of a micropump and flow sensor for the high-precision dosing of infusion solutions and medication

Innovative micro flow sensor combined with a micropump for distributed gas sensorics in the field of Industry 4.0

FRAUNHOFER EMFT RANGE OF SERVICES

Studies

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

Modeling & Simulation

- Whole process
- FEM simulation
- System response

Customer-Specific Development

- Advance development
- Single process modules and overall process
- ASIC design
- Components and systems

Prototypes and Small Series Production

- System design
- Layout
- Device design and construction

Analysis & Test

- Risk and problem analysis
- Development of test methods and equipment

Professional Development

- Seminars and training programs
- Conferences

R&D as part of publicly funded projects

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

Start-Ups & Joint Ventures

- Spin-offs for the commoditization of products and systems
- Participation of industrial partners via joint ventures

Reliability testing of thin chip foil packages

FRAUNHOFER EMFT RANGE OF TECHNOLOGIES

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 SiO_2 and $Si3N_4$, PECVD of SiO_2 and Si_3N_4)
- Highly conductive layers (Al/Si, Ti, W, doped poly-Si)
- Plasma etching processes (Si, SiO_2, Si_3N_4, Al, W)
- Electroplating (Cu, Sn)

200mm lithography cluster

- Proximity exposure
- Double-sided exposure
- Contact exposure
- Electron ray exposure
- Ion beam writing with FIB
- i-line stepper
- Nanoimprint

Si-MEMS technology

- Cleanroom technology for 150mm wafers (silicon, ceramics, glass)
- Metal coating (Cu, Ti, TiW, Pt, Au, Ni)
- Dielectric layers (Si, SiO_2, Si_3N_4, SiC, polyimide)
- Wafer bonding, bonding techniques by means of adhesion
- Structuring with mask aligner 2 µm

Substrate processing

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

Analytics and material characterization

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

Microbiological laboratory

- Spectral fluorimetry for the qualitative and quantitative analysis of fluorescent samples, kinetic measurements
- Absorption spectroscopy (UV/VIS) for qualitative and quantitative analysis
- Transmitted light and phase-contrast microscope with microscope camera
- Epifluorescence microscope with microscope camera
- Rotational vacuum concentrator for fast and low-impact drying of aqueous, acidic and solvent samples

Application of large-area electronics and flexible substrates to foil sheets and using the roll-to-roll method

- Hot roll laminator for double-sided lamination
- In-line coating system for liquid coatings such as photoresist, dielectrics and passivation
- Sputter system for double-sided metallization of chrome and copper
- UV lithography with high resolution (5 – 15 µm structure width)
- Wet-chemical etching techniques for structuring metals
- Screen printing on foil sheets
- Screen printing using the roll-to-roll method
- Galvanic deposit of copper on premetallized foils
- Laser processing for cutting, marking and drilling various materials
- Plasma process for surface conditioning and reactive etching of polymers with nitrogen, oxygen and CF_4
- Foil mounting and bonding technology

Analysis and testing

- Semi-automatic wafer prober up to 300 mm using thermo chuck (-55 °C-+300 °C) and laser
- Semiconductor parameter analyzers
- Network analyzers in the megahertz range up to 110 gigahertz and Simulator Agilent ADS
- Generation and measurement of high-current pulses in the picosecond and nanosecond range
- 62 gigahertz real-time oscilloscope
- Electrostatic discharge characterization and exposure (automatic 2-pin tester, CDM, HBM, TLP, VF-TLP, CC-TLP)
- Robustness measuring station for EOS/ESD
- Electrochemical impedance spectroscopy
- Environmental test chamber 100 cc – moisture and gases
- Oscilloscope
- Permanent bending tester for flexible and rigid-flex structures
- Physical analysis of integrated circuit boards
- 2D X-ray analytics for circuit boards
- ESA – Accepted Qualification Lab
- Environment simulation laboratory
- Contaminometer to detect ionic contamination
- Friction corrosion tests on soluble compounds
- Zwick universal testing machine with heating and cooling facility

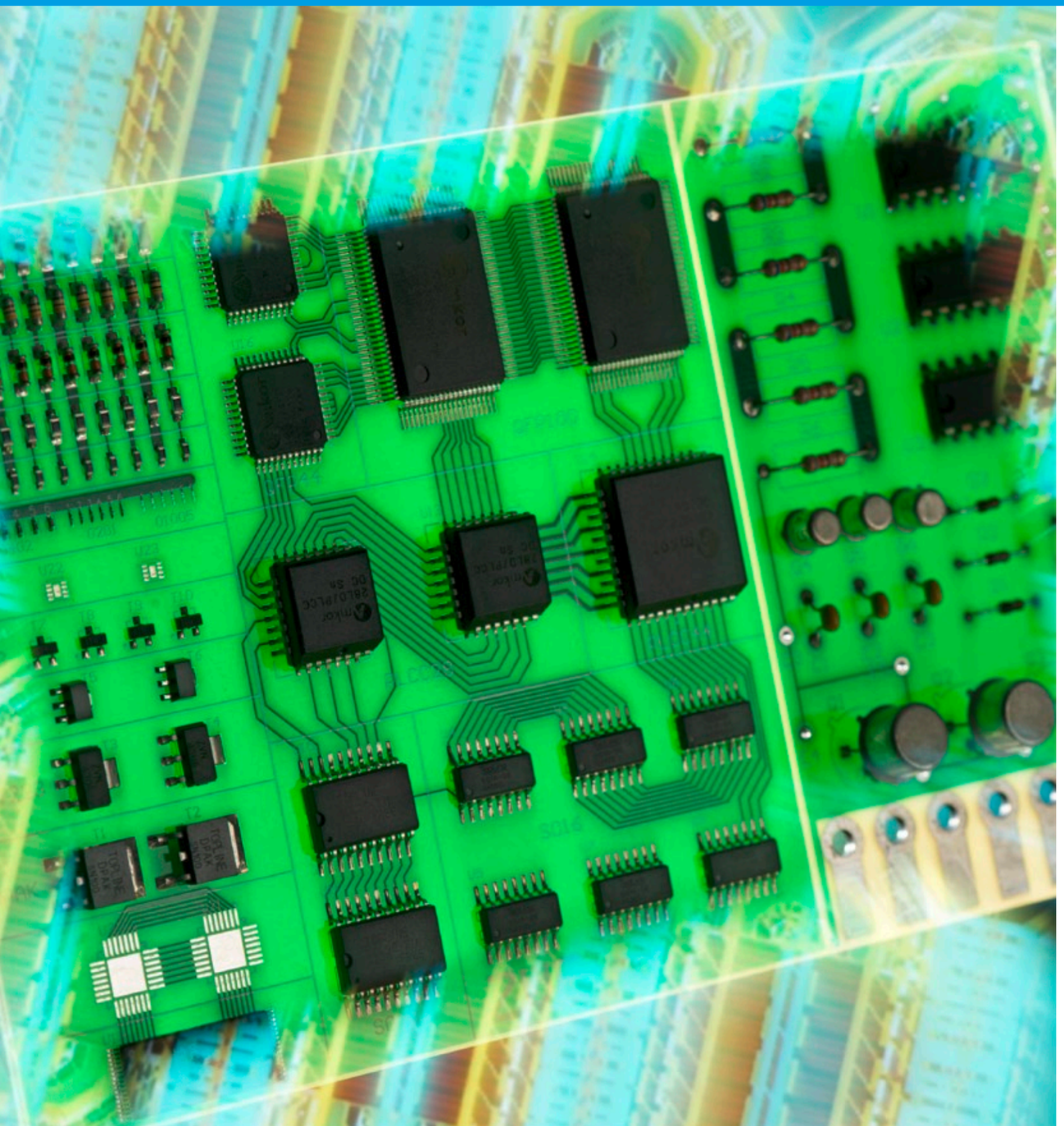
Studios for advanced training

- Crimping learning lab
- Wiring harness learning lab
- Lab for night work and module repair
- Soldering training center with 20 fully fitted workstations
- ESA STR-258 Skills Training School

CENTER FOR INTERCONNECTION TECHNOLOGIES ZVE

STCrimp course: Demonstration of a Go-NoGo test on a 4-jaw 8-pin crimp

ZVE training board for the IPC courses
IPC J-STD 001 and IPC-7711/21



CENTER FOR INTERCONNECTION TECHNOLOGIES ZVE

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 an initial 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

Device for measuring blood clotting

Prof. Christoph Kutter
Director of the Fraunhofer EMFT

RESEARCH FAB MICROELECTRONICS GERMANY (FMD)

Nationwide coordinated technology expertise from a single source

Fraunhofer is one of 13 members of the FMD (Forschungsfabrik Elektronik Deutschland – Research Fab Microelectronics Germany): with more than 2,000 scientists, it is the biggest cross-site R+D alliance for microelectronics and nanoelectronics in Europe. Under this novel collaborative venture, the advantages of two outstanding, decentralized research organizations – Fraunhofer Society and Leibniz Association – are linked via a central organization to the world's most high-performance provider for applied research, development and innovation in the field of microelectronics and nanoelectronics. Due to its close dovetailing and coherent presence, the FMD is able to offer more comprehensive and straightforward access to the next generation of technologies – serving not just large-scale industry customers but in particular for SMEs and start-ups.

The Federal Ministry of Education and Research (BMBF) provides funding for establishing the FMD amounting to a total of EUR 350 million, mainly covering the modernization of the institutes' research facilities. In providing this funding, the BMBF is seeking to strengthen the innovation capacity of the semiconductor and electronics industry in Europe against the background of global competition, supporting this endeavor with the largest-scale investment to be made in research equipment since German reunification.

One and a half years after the start of the project on April 6, 2017, a wide range of equipment purchased to modernize lab facilities at FMD sites all over Germany has been put into operation. The festive inauguration of an initial integration line took place on September 28, 2018 on the occasion of the 1st FMD Innovation Day at the Fraunhofer Institute for Reliability and Microintegration IZM in Berlin.

At approximately the half-way point of the project term, 45 percent of the planned FMD investments have been successfully made.

The establishment of the FMD is coordinated from a central office in Berlin, with additional sites having been set up in Dresden and Munich in line with the idea of creating a virtual organization. The FMD office is the central point of contact for potential and existing customers so it is a key driving force behind business development in the area of microelectronics and nanoelectronics.

In order to be able to offer nationwide coordinated technology and system developments from a single source, the technological expertise areas of the institutes have been grouped into six general sections during the initial set-up phase and developed on this basis: these are the so-called technology platforms "Microwave and Terahertz"/"Power Electronics"/"Extended CMOS"/"Optoelectronic Systems"/"Sensor Systems"/"MEMS Actuators". On these technology platforms the FMD offers technological developments along the entire supply chain – from system design to testing and reliability.

In addition to these technologically oriented services, the FMD also provides cross-institute application solutions from a single source. This enables customers to realize combined and optimized system solutions with the FMD and their institutes. Here the research fab collaborates synergetically with the business units of the institutes. In this way the FMD is able to offer customers a much broader range of application solutions.

Last year, several successful project participations were established and order contracts concluded in collaboration with the FMD. In 2018 projects worth a total of EUR 41.1 million were in progress based on FMD investments – a considerable achievement in this early phase. The industry share of this project volume was 30 percent, thereby underscoring the importance of this unique cooperation in German microelectronics research from the industrial perspective.

In 2019 the FMD will move onto its next phase: after the establishment and structuring of the organization, Europe's biggest cross-site R+D alliance for microelectronics and nanoelectronics will prove its excellence on the market in partnership with its institutes.

HIGH PERFORMANCE CENTER: “SECURE CONNECTED SYSTEMS”

The high performance center “Secure Connected Systems” (LZ SVS) clusters the technical prowess of TU Munich, Bundeswehr University Munich and the Fraunhofer institutes AISEC, EMFT and ESK. Since July 2017, the center has provided an application-oriented and interdisciplinary platform for cross-sectoral and cross-thematic, systematic research and collaboration based in Munich with a focus on the Internet of Things (IoT)-related areas of Networked Mobility, Industry 4.0 and Health. However, the aspects of hardware security, operational reliability and data security are highly relevant to many other sectors, which is why the center intends to successively expand into other fields of application in the future as well.

The aim of the center’s partners is to offer their customers comprehensive yet user-friendly solutions in the area of cyber security. There is a considerable demand here, especially among SMEs. Many smaller companies do not have the capacity to handle this complex matter on their own. Yet given the sheer speed of technology development, they are forced to open up to the areas of digitalization, Industry 4.0 and IoT in order to be able to keep abreast of international competition. Here the center not only offers professional support: thanks to the enormous breadth of its expertise, it is also able to address customers’ individual needs. This is especially attractive to SMEs in the region, thereby strengthening Bavaria as an industrial base.

The center is also engaged in important activities at national and international level: here its application projects cover areas such as industry and automation and the automotive sector, where German companies are global leaders. These areas are in urgent need of digitalization, however. The LZ SVS makes a vital contribution here, strengthening Munich as an industrial base – in the automotive sector, for example – by bringing digital technologies to conventional industries.

Dr. Sabine Trupp is responsible for coordinating the work within the scope of the high performance centre. Sponsorship and funding for the center comes from the Bavarian Ministry of Economic Affairs, Regional Development and Energy, the Fraunhofer Society and various industry partners who are involved in joint projects.

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 vehicle environment networking
- Testing conformity, performance and security in dedicated test environments and customer scenarios

Prof. Peter Kücher,
Head of Business Development

"ARTIFICIAL INTELLIGENCE BEGINS AT THE SENSOR LEVEL"

Artificial Intelligence (AI), Big Data and Internet of Things (IoT) are the latest buzzwords – all of them very much geared towards software. Is the golden age of microelectronics over?

Prof. Kücher: No, I really don't think so – after all, AI, Big Data and IoT all start at the sensor level: without sensors to pick up the data to be processed, there is no intelligence. Udo Martin Gomez put it in a nutshell in his keynote speech at the 2017 MST Congress: sensors are already the hidden champions of the IoT.

What challenges does this involve and what is Fraunhofer EMFT's response?

Prof. Kücher: Sensors for IoT have to be as invisible as possible on the one hand but they also have to offer as many benefits as possible for the application: highly intelligent, compact sensors are needed that don't just record data but preferably process it, too. What is more, a real basis technology for sensors no longer exists, what we are seeing is increasingly specific and fragmented technologies – due to the enormous range of customer applications and needs. We have to be able to respond flexibly and swiftly to this application-specific demand. In addition to high production volumes of standard sensors, we need more and more intelligent production – or "sensors on demand", if you like. A key development issue for me is sensor data fusion: by linking the output data from different sensors it is possible to collect better-quality information, thereby enormously increasing the relevance of the data generated.

As I see it, there is great potential for Fraunhofer EMFT in doing more to combine our silicon and foil technologies: this will enable us to develop highly innovative solutions to meet individual customer needs in the future – serving the most diverse areas of application, too. We have a good network with the leading sensor manufacturers, and working on joint development projects enables us to find the most suitable sensor for our customers. Here we have to strike a good balance between in-house production and developing license agreements with other companies. Fundamentally, however, we have to realize that a single Fraunhofer institute will rarely be able to find the answers to the complex requests coming from industry on its own in future. Many of Fraunhofer's current activities are based on this underlying idea.

Can you give us a few examples?

Prof. Kücher: First of all you have our 17 high performance centers all over Germany. Here, several institutes collaborate on projects and combine their expertise. Here in Munich we have the high performance center: "Secure Connected Systems". We at Fraunhofer EMFT contribute our sensorics expertise, while the institutes ESK and AISEC focus on the areas of communication technology and security. A lot of customers quickly see the huge benefits of this alliance, so it doesn't take long to convince partners that the concept of the transfer platform is the right option. Then there's our collaboration as part of the FMD (Research Fab Microelectronics Germany) – another example of efficient cooperation between Fraunhofer institutes with the addition of two Leibniz Association institutes. We are also networked via clusters such as Sensorik Bayern – a strategic partnership through which promising business relationships are cultivated at the regional level. Industry cooperations such as those on the subject of micropumps can give rise to whole new approaches for the advancement of sensor systems in the future.

The interview was conducted by Sophia Drimmel.

UNIVERSITIES


Prof. Marc Tornow

Technical University of Munich (TUM)

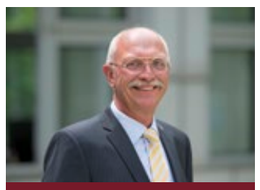
In the spring of 2016 it was possible to gain the services of Prof. Marc Tornow to head up the Silicon Technologies and Devices department together with Prof. Ignaz Eisele. Marc Tornow holds the Professorship in Molecular Electronics at Technical University of Munich and is involved in research into nanoscale components in molecular electronics and biosensorics.

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. Joint doctoral dissertations on various preliminary research topics further enrich collaboration.


Prof. Joachim Wegener

University of Regensburg

Fraunhofer EMFT has engaged in 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.


Prof. Dr. Peter Kücher

Technical University of Dresden

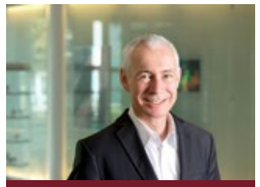
Technical University of Dresden has been one of Germany's eleven Universities of Excellence since 2013. The honorary professorship of Prof. Peter Kücher at the Faculty of Electrical Engineering forms the basis for cooperation with Fraunhofer EMFT.

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 has led to changes such as specialization and resegmentation of the supply chain. This requires manufacturers of materials, production facilities and chips to adopt new strategic approaches. For this reason, current trends in microelectronics/nanoelectronics – from "More Moore" to "More than Moore" – need to be viewed from the perspective of the overall economic context. Fraunhofer EMFT also cooperates closely with the Electronics Packaging Laboratory (IAVT) on scientific topics.

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.


Prof. Christoph Kutter


Prof. Ignaz Eisele

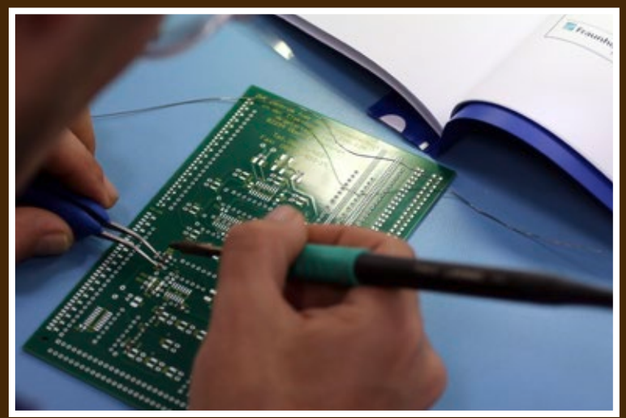

Prof. Linus Maurer


Dr. Sabine Trupp


Dr. Indranil Ronnie Bose

SPECIAL EVENTS

Ultra-thin chip-foil packages



HIGHLIGHTS

20 years of hand soldering courses at the disabled workshop

A very special training course given by the ZVE (Zentrum für Verbindungstechnik – Center for Interconnection Technologies) celebrated its 20th anniversary this summer: it was in 1998 that ZVE trainer Günter Paul gave the very first course entitled "Introduction to THT hand soldering technique" at the HPCA workshop for the disabled.

Ever since then, the experienced trainer has provided employees of the workshop's circuit board assembly department instruction in the art of hand soldering once a year – a job that requires a steady hand, maximum concentration and absolute precision.
"For people with a physical or mental disability, the challenge is even greater than for an entirely healthy individual," says Paul. At the very first training session he realized after just a few minutes that he would have to alter his training concept somewhat:
"I need much more time to explain to individual participants how to hold the soldering iron correctly, for example, and how to get both hands at the soldering point at the same time," says Paul.

Patience and dedication have paid off over the years: gradually, Paul was able to offer increasingly demanding and comprehensive instruction. In 2010 the ZVE developed its own circuit board for practical courses and the HPCA workshops took over production of them. Today, some of Paul's longstanding protégés are able to create soldering joints independently – and even politely point out to their trainer when he makes a mistake himself.

"The cooperation with HPCA is particularly important to Fraunhofer EMFT and I'm very keen to be able to carry on our fine tradition of giving courses in the future," says Prof. Christoph Kutter, Director of Fraunhofer EMFT. This year the research institution covered the full costs of the course by way of an "anniversary gift". The program included hand soldering of electronic modules in a range of different technologies. At the end of the day, participants were able to take a smiley home with them which they had soldered themselves.

Bernadette Kinzel wins the Best Presenter Award

IEEE APEC is the world's leading event in the area of applied power electronics. In 2018 the conference and exhibition took place in San Antonio, Texas, USA, attracting visitors from all over the world. APEC focuses on the practical application-related aspects of power electronics. For this reason, it is not simply a designer conference but is aimed at a broad public.

Fraunhofer EMFT is therefore particularly proud that one of its scientists won the Best Presenter Award at this conference. In the session "T40: Industrial Applications", Bernadette Kinzel received the Best Presenter Award for her talk entitled "A Non-Isolated Asynchronous Low Power High Voltage Boost Converter for Discontinuous Conduction Mode and Portable Applications". Fraunhofer EMFT offers its cordial congratulations on this superb accomplishment.

The paper for the talk was submitted by Frank Vanselow.

EVENTS

Panasonic ME Tech Days

The Panasonic ME Tech Days took place on the Fraunhofer EMFT premises on two occasions in 2018. On April 4 and 5 and on September 26 and 27, Panasonic customers were able to participate in various one-day workshops and Panasonic labs offered at the institution. In addition to presentations of cutting-edge technologies and Panasonic products, Fraunhofer EMFT also provided fascinating insights into its own research.

Fraunhofer EMFT Annual Event

Once a year, Fraunhofer EMFT invites all those interested to an annual event on its own premises in order to provide insights into its research work.

This year the motto was: "Cell meets chip". Although the areas of microelectronics and biology would initially appear to be two parallel scientific universes, they do have one fundamental aspect in common: both microelectronic and biological systems use electrical impulses to process information. This gave rise to the establishment of fascinating disciplinary research areas last year.

Visitors obtained insights into the center's current projects as well as the activities it is planning for the future. In addition, various demonstrators were presented from a number of different fields of application so as to inspire potential joint project ideas. The subsequent get-together provided an opportunity for technical discussions and networking.

"A secure path from sensor to cloud"

On 19 June, 2018, the high performance center "Secure Connected Systems" and event partner ZD.B (Zentrum Digitalisierung.Bayern) organized a customer event at Fraunhofer EMFT. The motto of the program was "A secure path from sensor to cloud" and included numerous interesting talks on this subject. The day also featured a tour of the Fraunhofer EMFT cleanroom basement for guests.

FUTURAS IN RES

On June 28 and 29, 2018, the Fraunhofer Society invited guests to the international conference FUTURAS IN RES in Berlin. The motto of the event was "Biological transformation in production". The idea here is to incorporate the processes and principles of living nature in technical systems. Numerous international representatives from the areas of science, business and politics attended the forum to find out about this fascinating future topic and talk about potential solutions.

The conference is unique in that it brings together an extremely diverse range of experts from the most varied disciplines and sectors who are able to develop entirely new innovative ideas based on interdisciplinary perspectives and discussions. In this way, future production projects can be optimized in terms of sustainability, innovative strength and competitiveness.

The Fraunhofer EMFT was represented with an exhibit from the field of cell-based sensor technology. The research follows the concept of growing living cells directly on the surface of physical transducers and to follow the cells' response to chemicals, drugs or microorganisms non-invasively, without use of chemical indicators (label-free). Key parameters of cell physiology, like cell viability, proliferation or migration rates, are accessible in real time. Such cell-based sensors help to reduce animal experiments in fundamental biomedicine, drug development and toxicity screening.

FMD Innovation Day 2018 – Smart Microsystems

The FMD (Research Fab Microelectronics Germany) – Europe's largest-scale research alliance in the field of microelectronics – organized the 1st FMD Innovation Day 2018 with the motto "Smart Microsystems" in Berlin on September 27 and 28 2018. The FMD is made up of the Fraunhofer Microelectronics Group and the Leibniz institutes FBH and IHP. Participants were offered a congress consisting of talks and an accompanying exhibition. The program was divided into a total of three distinct sessions with numerous talks on the subjects: "Autonomous microsystems", "Environmental sensorics with LiDAR" and "Smart sensorics in industry". Visitors were able to engage with technology experts and users on site at the individual talk sessions and exhibitions as well as finding out about the FMD's enormous potential. In the accompanying exhibition Fraunhofer EMFT was represented with a foil system for temperature measurement from the field of flexible electronics.

MedTech Pharma Forum conference

On October 11, 2018 Fraunhofer EMFT was the venue for a conference put on by the MedTech Pharma Forum on the subject of "Artificial Intelligence in medical technology". Artificial Intelligence is a constantly present topic that is frequently discussed – not least due to both the worries and the positive expectations it involves. Artificial Intelligence is already a phenomenon we encounter in our day-to-day lives, with the personal assistant "Siri" in our smartphones, Amazon's "Alexa" and self-driving cars. AI is becoming increasingly influential in medtech as well, and is mainly having a positive impact on very wide range of different application fields. The conference offered numerous talks as well as accompanying exhibitions that provided visitors with information about current developments and potential benefits as well as the risks and challenges involved. Companies thus had the opportunity to identify individual market prospects and network with possible cooperation partners.

Forum be-flexible

From November 13 to 14, 2018, SEMI Europe and Fraunhofer EMFT 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). As in 2017, the event was not held on Fraunhofer EMFT's own premises but at Munich Trade Fair Center – this time as part of the trade shows SEMICON Europe and electronica. 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.

PROMOTING YOUNG TALENTS

CAREERS AT FRAUNHOFER EMFT

I've been working as a doctoral student and development engineer in the area of design and simulation in the Microdosing Systems Department since 2017. My main area of interest is finite elements simulation in fluid mechanics and structural mechanics for microdosing system components. Another focus of my work is R&D projects in medical technology. What I particularly like about working at Fraunhofer EMFT is the interdisciplinary aspect as well as the fact that you have a lot of scope for independent work. The working atmosphere is very pleasant – we have a young team and colleagues are very open and supportive. The next thing I want to do is get my doctorate.

Claudia Durasiewicz

I've been a placement student in the Marketing, Communication and Strategy Group since April 2018. The team has a very broad area of work so I've been able to gain a lot of different impressions – everything from helping design the website and doing press liaison work through to experiencing my first trade show visit from the exhibitor's point of view. Before joining Fraunhofer EMFT I tended to have more to do with conventional B2C and B2B companies. This is why it's so interesting for me to get experience of the strategic approach pursued by a research institution. The most important thing about my job? Apart from the work itself, it's definitely the team. As I see it, teamwork is the basis for a successful and fulfilling professional life. Having tried it out thoroughly, I've come to the conclusion that I've hit the jackpot :) My immediate goal is to complete my master's thesis of course. Afterwards I see myself going into brand strategy, as I believe this provides the perfect combination of analytical and creative work. I'll probably be going into the agency sector first so as to be able to get experience of lots of different projects in a relatively short period of time.

Johanna Markl

I've been a research associate in the area of Interconnected Systems since 01.12.2017. My main focus is on materials science processes in electrical contacts. My area of work also includes supporting the development of intelligent plugs and creating an e-learning platform on the subject of automation technology. I'm also part of a development project to create a diagnostic system (Predictive Maintenance). The thing I especially like about working at Fraunhofer EMFT is that there is lots of space for creativity and taking on independent responsibility. This gives you a lot of freedom – in terms of both what you work on and how you use your time. I also very much appreciate working with so many dedicated and highly skilled colleagues. There are lots of opportunities to learn more, and every day I can look forward to varied assignments. I also have an excellent work-life balance here, which is something I really appreciate. My future goal is to obtain my doctorate. I would like to do my dissertation at Fraunhofer EMFT.

Ixchen Édua Elías Ilosvay

Since 01.07.2017 I've been working as an assistant with subsequent master's thesis in the Microdosing Systems Department at Fraunhofer EMFT. I mainly work on the development and design of analog circuits, testing electrical pump parameters and analyzing measurements. I'm also involved in soldering circuit boards and take care of small-scale programming tasks, as well as creating simulations. What I really like about the work here is the friendly environment and collaborating with highly qualified colleagues. I also get a close-up view of research and constantly have to do with fascinating topics. I particularly welcome the fact that independent work is promoted at Fraunhofer EMFT and that I'm responsible for what I do. My next goal is to get a doctorate.

Jakob Eppinger

Since 01.11.2018 I've been working as an intern in the Marketing, Communication and Strategy Department at Fraunhofer EMFT. I took my school-leaving certificate in the summer of 2018 and the idea of my internship is to get some work experience before starting a university degree course. I support my colleagues in the areas of press liaison work, event management and producing a wide range of different print media. I also help organize various events and occasionally accompany my colleagues to these so as to provide on-site assistance. My area of work also includes various research assignments for scientific assistants as well as market research, cultivating contacts and managing the databases. My involvement in such a wide range of different areas has enabled me to learn an amazing amount in this very short time and I've gained lots of practical experience, too. I especially like the positive work atmosphere. Everyone is very supportive and friendly, which made it very easy for me to settle in at Fraunhofer EMFT – the internship has already been extremely enriching. My work here also gives me some insight into fascinating research projects, another aspect I really enjoy. My next goal in the future is to start my degree course.

Sophia Drimmel

I've been employed as a placement student in the Microdosing Systems Department at Fraunhofer EMFT since 01.07.2018. My focus is mainly on software development using MATLAB. My area of work also includes characterizing micropumps by means of flow and stroke measurements and analyzing the measurement results with Origin. I also adapt measuring stations and develop pump casings using Inventor. The work at Fraunhofer EMFT is very varied and there's a huge amount you can learn. The work climate is great, too – everyone's very friendly and supportive, and I feel very much at home here at Fraunhofer EMFT. My next career goal for the future is to complete my bachelor's degree – I'm currently writing my final thesis at Fraunhofer EMFT.

Oliver Zett

I've been working as a development engineer in the Microdosing Systems Department at Fraunhofer EMFT – or to be more precise in the Metal Components Group – since September 2018. My work mainly focuses on project handling and project management. As a materials scientist I am involved in investigating the piezo ceramics required for powering pumps, for example. My doctoral thesis is on pumps for complex media (protein solutions, body fluids, pharmaceuticals, etc.) in order to gain fundamental insights into the use of micropumps in medical technology. The work is very varied and as a research associate you have lots of scope to contribute your own ideas. We are in close contact with customers so the main focus is always on practical application: this means we're always involved in research areas that are currently in demand and never far removed from industrial application. In our department, doctoral students are able to take over project management functions so you get a good insights into project management methods and task planning. At the same time you have the opportunity to establish contacts in science and take part in various conferences through publications. What is more, there is always lots of support – within your own group, in the department and indeed throughout the institute as a whole. Then there are are good advanced training opportunities, too. My next career goal is to complete my doctoral dissertation.

Agnes Bußmann

I've been employed as a placement student at Fraunhofer EMFT since 01.03.2018 in the sector of Sensor and Microsystem Integration (SiD SMI). Additionally, I'm currently working on my master's degree thesis. My work mainly focuses on sensor network integration: I'm developing a software stack for multiple sensor integration. This includes firmware development for NFC readers, tags and Bluetooth modules and a Java application to visualize and monitor real time sensor data. Currently, I'm working on process control and optimization using machine learning algorithms. Being involved in multiple projects has given me freedom to explore a broad range of topics from embedded systems to developing machine learning algorithms. I also got the chance to collaborate with very friendly people who have deep expertise in their fields. My career goal is to be part of a passionate and enthusiastic team working on neural processing units to deliver AI solutions.

Kiran Krishna

Girls' Day 2018 participants

PROGRAMS FOR SCHOOL STUDENTS

Career orientation weeks

Fraunhofer EMFT holds career orientation weeks for school students at least once a year. The aim of the cooperation with various upper secondary schools, lower secondary schools and comprehensive schools is to give young participants an insight into the world of microsystems and show them something of the day-to-day working life of scientists at Fraunhofer EMFT. Once again this year, school students were exposed to fascinating topics and issues in the course of the career orientation weeks:

- What do we need microelectronics for?
- It all starts with design
- Working in the cleanroom – why cleanliness is crucial
- What does plastic have to do with electronics?
- Flexible systems need thin layers
- Who checks to make sure everything works and what is the service life of a microchip?
- Small, smaller, smallest – tiny pumps for microdosing
- Crimping and soldering – how are electronic systems connected to one another?

Girls' Day on April 26, 2018

"Working in the lab – what does a scientist do?" – this was the motto of the 20018 Girls' Day at Fraunhofer EMFT. Five girls from Gymnasium Oberhaching got their first taste of lab work. The participants enjoyed a day full of new impressions. There were interesting workshops in the cleanroom and chemistry lab to give them some initial insights into everyday working life at a research institution: all in all it was a fascinating day during which they learned a lot of new things about the world of science. Nonetheless, the fun factor was important too. One aspect here was a rather different kind of fashion show: the girls were instantly transformed into 'real' researchers when they put on cleanroom clothing.

Fraunhofer Talent School

One especially popular Fraunhofer program to support youngsters is the Fraunhofer Talent School. This gives young people from the age of approx. 15 the opportunity to gain interesting insights into the world of research.

Fraunhofer EMFT offers this program on a regular basis too, and this year two students visited the institution's facilities from October 25 to 28, 2018. Their experience included fascinating workshops giving them a first-hand experience of "Flexible Electronics for the Electronics of the Future". Working with experienced Fraunhofer EMFT scientists, the youngsters were able to get involved in engaging research projects. And they weren't just there to stand by and watch: all of them got to work independently on the equipment. The youngsters gained in-depth insights into screen printing, lithography, electrical measuring technology and scanning electron microscopy, learning how to measure layers of just a few micrometers, for example, and finding out how these layers are used in sensors. The electronics involved was an important aspect too, of course: a microcomputer was used to show how measurements are digitalized, enabling the electrical signals emitted by the sensors to be converted into measurement data.

Displaying an obvious interest in technology, the students were fully engaged and highly motivated. Proactive involvement and questioning on the individual topics enabled them to satisfy their curiosity and take away fresh impressions from the world of research.

SCIENTIFIC ACTIVITIES

Universal micropump driver

Laboratory for characterizing gas sensorics procedure and gas sensors

ACADEMIC PUBLICATIONS AND TALKS

Publications

Stephan Altmannshofer, Bastian Miller, Alexander W. Holleitner, Jamila Boudaden, Ignaz Eisele, Christoph Kutter
Deposition of micro crystalline silicon films using micro-wave plasma enhanced chemical vapor deposition
Thin Solid Films, Volume 645, January 1, 2018, pages 180 - 186; https://doi.org/10.1016/j.tsf.2017.10.031

Nagarajan Palavesam, Sonia Marin, Dieter Hemmetzberger, Christof Landesberger, Karlheinz Bock, Christoph Kutter
Roll-to-roll processing of film substrates for hybrid integrated flexible electronics
Flexible and Printed Electronics, February 2018, pages 1-18; http://iopscience.iop.org/article/10.1088/2058-8585/aaaa04

Frank Vanselow, Bernadette Kinzel, Linus Maurer, Erkan Isa
A non-isolated asynchronous low power high voltage boost converter for discontinuous conduction mode and portable applications
2018 IEEE Applied Power Electronics Conference and Exposition (APEC), March 4 - 8, 2018, pages: 1940 - 1943, San Antonio, USA; DOI: 10.1109/APEC.2018.8341283

Bernadette Kinzel, Frank Vanselow, Erkan Isa, Linus Maurer
A novel current-mode actuator driver for enhanced piezoelectric reliability
2018 IEEE Applied Power Electronics Conference and Exposition (APEC), March 4 - 8, 2018, pages: 234 - 237, San Antonio, USA; DOI: 10.1109/APEC.2018.8341015

C. Landesberger, A. Drost, R. Faul, W. Hell, S. Scherbaum, D. Bonfert, A. Ott, R. Hotopan, R. Böhnke
Novel chip embedding and interconnection technology for mm-wave System-in-Package (SiP) applications
SSI Smart System Integration Conference, Dresden, Germany, April 11 - 12, 2018

Jamila Boudaden, Armin Klumpp, Christine Hecker, Ignaz Eisele, Yvonne Joseph
Functionalized nanoparticles for CO2 sensors
Functional Nanostructures Proceedings, May 1, 2018; www.onecentralpress.com/functional-nanostructures-proceedings

Prajith Kumar Poongodan, Pragoti Pran Bora, David Borggreve, Frank Vanselow, Linus Maurer
A Low Power, Offset Compensated, CMOS Only Bandgap Reference in 22 nm FD-SOI Technology
IEEE International conference on Modern Circuits and Systems Technologies (MOCAST), May 7 - 9, 2018, Thessaloniki, Greece; https://ieeexplore.ieee.org/document/8376639/

T. Diederichs, Q. H. Nguyen, M. Urban, R. Tampé, M. Tornow
Transparent Nanopore Cavity Arrays Enable Highly Parallelized Optical Studies of Single Membrane Proteins on Chip
Nano Letters 18, 3901 (2018), May 9, 2018
DOI: 10.1021/acs.nanolett.8b01252

Jamila Boudaden, Matthias Steinmaßl, Hanns-Erik Endres, Andreas Drost, Ignaz Eisele, Christoph Kutter and Peter Müller-Buschbaum
Polyimide-Based Capacitive Humidity Sensor
Sensors 2018, 18(5), 1516; May 11, 2018; https://doi.org/10.3390/s18051516

Jamila Boudaden, Stephan Altmannshofer, Robert Wieland, Michael Pittroff and Ignaz Eisele
An Approach to Reduce Greenhouse Gases in the Semiconductor Industry Using F2 Dissociated in Plasma for CVD Chamber Cleaning
Appleby: Sci. 2018, 8(6), 846; May 23, 2018; https://doi.org/10.3390/app8060846

M. Zinkl, L. Sauer, S. Azzam and J. Wegener
Monitoring the Toxicity of Bisphenol A using Multiple Impedance-Based Cellular Assays
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/zinkl/Abstract-IBCA2018_Zinkl.pdf

F. Urban, K. Hajek, G. Bernhardt, J. Wegener
Transepithelial permeation of bioactive molecules determined online by impedance-based monitoring in a co-culture setup
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/urban/Abstract-IBCA2018_Urban.pdf

J.A. Stolwijk, C. Kade, M. Skiba and J. Wegener
Increased Throughput in GPCR Screening using Impedance Assays: Inspiration from Organ Studies
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/stolwijk/Abstract-IBCA2018_Stolwijk.pdf

M. Skiba and J. Wegener
Impedance Analysis of Heterogeneous Cell Populations: Impact on Data Analysis and Modeling
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/skiba/Abstract-IBCA2018_Skiba.pdf

L. Sauer, R. Meier and J. Wegener
Impedance-based Characterization of pH-dependent Cell Behavior
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/sauer/Abstract-IBCA2018_Sauer.pdf

S. Ruckdäschel and J. Wegener
Expanding the information depth of impedance based assays by using piezoelectric growth substrates
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/ruckdaeschel/Abstract-IBCA2018_Ruckdaeschel.pdf

Titanium valves

P. Pütz, M. Lemberger and J. Wegener
Cells in Contact to Carbon Dots: A label-free, impedance-based and multidimensional approach
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/puetz/Abstract-IBCA2018_Puetz.pdf

Frank Ansorge, Christian Baar, Ixchen Elias Ilosvay, Christof Landesberger, Christoph Kutter
Sensorics for intelligent connectors in automobiles
Automobil-Sensorik 2, published by: Springer Berlin Heidelberg, 2018

S. Michaelis and J. Wegener
'Instant ECIS': A concept for storing frozen cells on electrode surfaces for instant use
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/michaelis/Abstract-IBCA2018_Michaelis.pdf

C. Kade, J. Stolwijk, S. Michaelis and J. Wegener
Time-resolved Response Profiles of GPCR Activation: Combining Two Independent Impedance-Based Approaches
4th International Conference on Impedance-Based Cellular Assays, IBCA 2018, June 6 - 8, 2018, Edinburgh, Scotland; http://fhgonline.fhg.de/bibliotheken/emft/kade/Abstract-IBCA2018_Kade.pdf

P. Ramm, J. Weber, M. Fernandez-Bolanos, A. Muller
Advanced Sensor Systems by Low-Temperature 3D Integration Processes
Int. Conference on Design, Test, Integration and Packaging of MEMS/MOEMS – DTIP, June 25, 2018, Rome, Italy
DOI: 10.1109/DTIP.2018.8394203

M. Steinmaßl, J. Boudaden, H.-E. Endres, I. Eisele, C. Kutter, P. Müller-Buschbaum
Smart Monitoring System for Air Quality Control with Capacitive Sensors
17th International Meeting on Chemical Sensors – IMCS 2018, Proceedings, page 298-299, July 15 - 19, 2018, DOI: 10.5162/IMCS2018/GS8.2

Indranil Bose, Nagarajan Palavesam, Christian Hochreiter, Christof Landesberger, Christoph Kutter
Low Profile Open MEMS and ASIC Packages manufactured by Flexible Hybrid Integration in a Roll-to-Roll compatible process
2018 48th European Solid-State Device Research Conference (ESSDERC), September 3 - 6, 2018, Dresden
DOI: 10.1109/ESSDERC.2018.8486868

Armin Klumpp, Asmir Adrovic, Jamila Boudaden
Enzymatic Sensor Based on Dye Sensitized TiO_2 Electrode for Detection of Catechol in Water
Eurosensors 2018 Conference, September 9 - 12, 2018 Graz, Austria; DOI: 10.3390/proceedings2130737

J. Weber, M. Fernandez-Bolanos, A.M. Ionescu, and P. Ramm
3D Integration Processes for Advanced Sensor Systems and High- Performance RF Components
Symposium "Materials, Formulation, and Processes for Semiconductor, 2.5 and 3D Chip Packaging, and High Density Interconnection PCB", 2018, Cancun, Mexico; http://publica.fraunhofer.de/documents/N-515397.html

Johannes Weber, Rita Fung, Richard Wong, Heinrich Wolf, Horst A. Gieser, Linus Maurer
Comparison of CDM and CC-TLP robustness for an ultra-high speed interface IC
2018 40th Electrical Overstress/Electrostatic Discharge Symposium (EOS/ESD);
DOI: 10.23919/EOS/ESD.2018.8509761

N. Palavesam, E. Yacoub-George, W. Hell, C. Landesberger, C. Kutter and K. Bock
Dynamic Bending Reliability Analysis of Flexible Hybrid Integrated Chip-Foil Packages
20th IEEE Electronics Packaging Technology Conference, December 4 - 7, 2018, Singapore

Talks

Joachim Wegener
Using Label-Free Approaches to Profile the Function of Membrane Proteins in Living Cells.
Drug Discovery Chemistry, April 5, 2018, San Diego

Dr. Hanns-Erik Endres
(Bio)chemical microsensorics for gases and liquids
Colloquium series in the summer semester 2018, Deggendorf Institute of Technology, April 9, 2018, Deggendorf

J. Boudaden, M. Steinmaßl, H-E. Endres, A. Drost, H. Gieser, I. Eisele, C. Kutter, P. Müller-Buschbaum
Polyimide Capacitive Humidity Sensor for Implementation in Various Applications
Smart System Integration, April 12, 2018, Dresden

Heinrich Wolf
ESD robustness of IoT devices: Are we going to face new challenges?
Invited Talk, EOS/ESD Symposium, Workshop on Robustness of IoT Devices, September 26 - 27, 2018, Reno, NV, USA

Peter Ramm, Indranil Bose and Christoph Kutter
Vision 2030 – Flagship Proposal Health-EU
Conference on Artificial Intelligence in Medical Technology, October 11, 2018, Munich

C. Landesberger, I. Bose, C. Kutter
Towards R2R Manufacture of Flexible Hybrid Electronics – Technology Roadmap at Fraunhofer EMFT
FlexEurope Conference, organized by Semicon Europa, November 13 - 14, 2018, Munich, Germany

Jamila Boudaden, Hanns-Erik Endres
Miniaturized System for Sensing RH/CO2
5th Symposium 2018, "Intelligente Sensorik/Analytik und sichere Sensornetze: Innovative Technologien und neue Anwendungsfelder" (Intelligent Sensors/Analytics and Secure Sensor Networks: Innovative Technologies and New Fields of Application") November 14 - 15, 2018, Karlsruhe

Lab for in vitro culture of animal cells

BACHELOR THESES

Ellen Jirutkova
Design and Characterization of Mercury Wetted Reed Relay for High Speed Transmission Line Pulsing Applications
Bachelor thesis, Technical University Munich
Supervisor: Johannes Weber

Raisa Romanov Geleta
Development of an assembly method for microchips with self-assembly
Bachelor thesis, OTH Regensburg
Supervisor: Sabine Scherbaum

Syrine Soussi
A Graphical User Interface for Application-Specific Guidance through Cyclic Voltammetric Measurement
Bachelor thesis, Technical University Munich
Supervisor: Jamila Boudaden

Chiu Jia Hui
Programming of Impedance Analyser E4990 in CVI Language to Characterize Interdigitated Sensors
Bachelor thesis, Technical University Munich
Supervisor: Jamila Boudaden

Faiz Basir
Characterization and Reliability of Capacitive Relative Humidity Sensors
Bachelor thesis, Technical University Munich
Supervisor: Jamila Boudaden

Johannes Schwarz
Transient simulation of a multi-phase through the fluid channel of a micro-bellow actuator
Bachelor thesis, Munich University of Applied Sciences
Supervisor: Claudia Durasiewicz

MASTER THESES

Prajith Kumar Poongodan
Design of a Sub 1V Bandgap Voltage Reference in FD-SOI CMOS Technology
Master thesis, Hamburg University of Technology
Supervisor: Pragoti Pran Bora

Daniel Reiser
Investigation of a charge-sensitive sensor for chemical and biological applications
Master thesis, Technical University Munich
Supervisor: Martin Heigl and Karl Neumeier

Philipp Frischauf
Detection of microbiological contamination in solutions containing biological substances
Master thesis, Munich University of Applied Sciences
Supervisor: Dr. Jennifer Schmidt

Marc Huppmann
Design of a ∑Δ Modulator for a Wireless In-Cabin Communication System's 4.3GHz Fractional-N PLL in 22 nm FDSOI Technology
Master thesis, Technical University Munich
Supervisor: David Borggreve

Qinyu Zhuang
Numerical Simulation of Electrostatic Microactuator
Master thesis, University of Stuttgart
Supervisor: Henry Leistner

Asmir Adrovic
Enzymatic Sensor Based on Dye Sensitized TiO_2 Electrode for Detection of Catechol in Water
Master thesis, Ludwig Maximilian University Munich
Supervisor: Dr. Armin Klumpp

Roxana Künzel
Modeling and optimization of the fluidic properties of the passive membrane valves of a titanium micropump
Master thesis, Technical University Munich
Supervisor: Christian Wald and Dr. Sebastian Kibler

Sabrina Brahm
Development of Impedance- and Fluorescence-based Cell-Assays for Bitter Taste Detection
Master thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

MIKROAUG, eye pressure control system

DOCTORATES

Christoph Jenke
Performance and reliability of micropump based liquid dosing systems

Doctoral dissertation (Dr.-Ing.) at the Faculty of Electrical Engineering and IT, Bundeswehr University Munich.

The doctoral dissertation was completed from 2013 to 2017 at Fraunhofer EMFT in Munich. The dissertation was submitted to the Faculty of Electrical Engineering and IT, Bundeswehr University Munich, on May 8, 2018 and accepted on June 13, 2018. The oral examination took place on November 23, 2018.

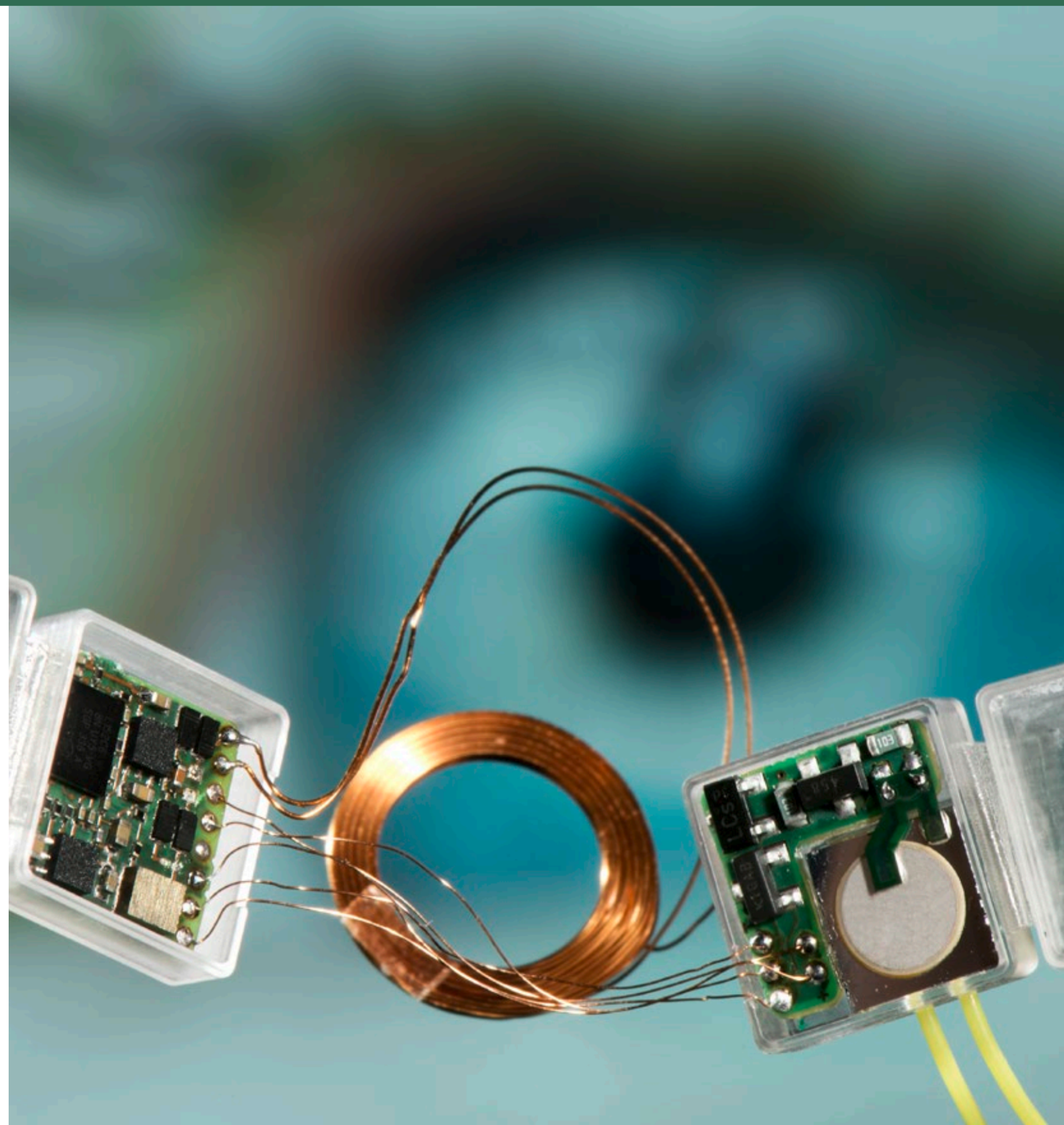
The dissertation was supervised by Prof. Dr. Christoph Kutter.

Stephan Altmannshofer
Microwave plasma-supported processes for applications in silicon technology

Doctoral dissertation (Dr.-Ing.) at the Faculty of Electrical Engineering and IT, Bundeswehr University Munich.

The doctoral dissertation was completed from 2013 to 2018 at Fraunhofer EMFT in Munich. The dissertation was submitted to the Faculty of Electrical Engineering and IT, Bundeswehr University Munich, on Tuesday, June 12, 2018 and successfully defended on Tuesday, December 18, 2018.

The dissertation was supervised by Prof. Dr. Christoph Kutter.



Degasser based on micropump

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Semiconductor device and method for the manufacture of a semiconductor device
Sabine Trupp, Michael Henfling, Karl Neumeier
DE 102017 200 952

A method of sensing analytes using hybrid organic-inorganic sensing material
Jamila Boudaden, Ignaz Eisele
WO 2018 215069 162 A1

Degassing device
Martin Richter, Axel Wille, Christian Wald
DE 10 2016 220 107.7

Device and method for anisotropic DRIE etching with fluorine gas mixture
Robert Wieland
DE 10 2016 220 248

Analysis system and method for conducting an analysis
Anna Ohlander, Ronnie Bose, Aman Russom
DE 10 2016 211 357

Device with microfluid actuator
Martin Richter, Christian Wald, Yücel Congar
WO 2018 006 932 A1

Safety label for a container seal and container seal with safety label
Gerhard Mohr, Anna Hezinger, Sabine Trupp, Jennifer Schmidt, Matthias Stich
DE 10 2012 211 067 A1

Solar panel and its method of production
Dieter Hemmetzberger, Karin Potje-Kamloth, Sabine Brunklaus, Jens Wüsten
DE 10 2012 209 322 A1

Carrier wafer, method for holding a flexible substrate and method for producing a carrier wafer
Christoph Kutter, Christof Landesberger, Dieter Bollmann
US 2016/0035611

Device and method using a microfluid chip to detect the resistance of bacteria to an active agent under analysis
Jennifer Schmidt, Anna Ohlander
CES 3053646

Method and device for the phenotypic detection of carbapenemases and carbapenemase producers
Jennifer Schmidt, Sabine Trupp
DE 10 2017 004 606

Structured multi-layer composite
Christof Landesberger, Dieter Bollmann, Waltraud Hell, Gerhard Klink
DE 10 2016 213 878

Method for the detection of resistant germs and device to conduct the same
Jennifer Schmidt, Ignaz Eisele, Sabine Trupp, Karl Haberger, Wolfgang Sittel
US 10,031,080

Bipolar electrode for the impedimetric investigation and manipulation of living cells in vitro
Christian Götz, Joachim Wegener
DE 10 2016 224 865

CONTACT

Wireless intelligent circuit board connector for the continuous measurement of contact temperature and power load of an individual contact as basic data for preventive maintenance

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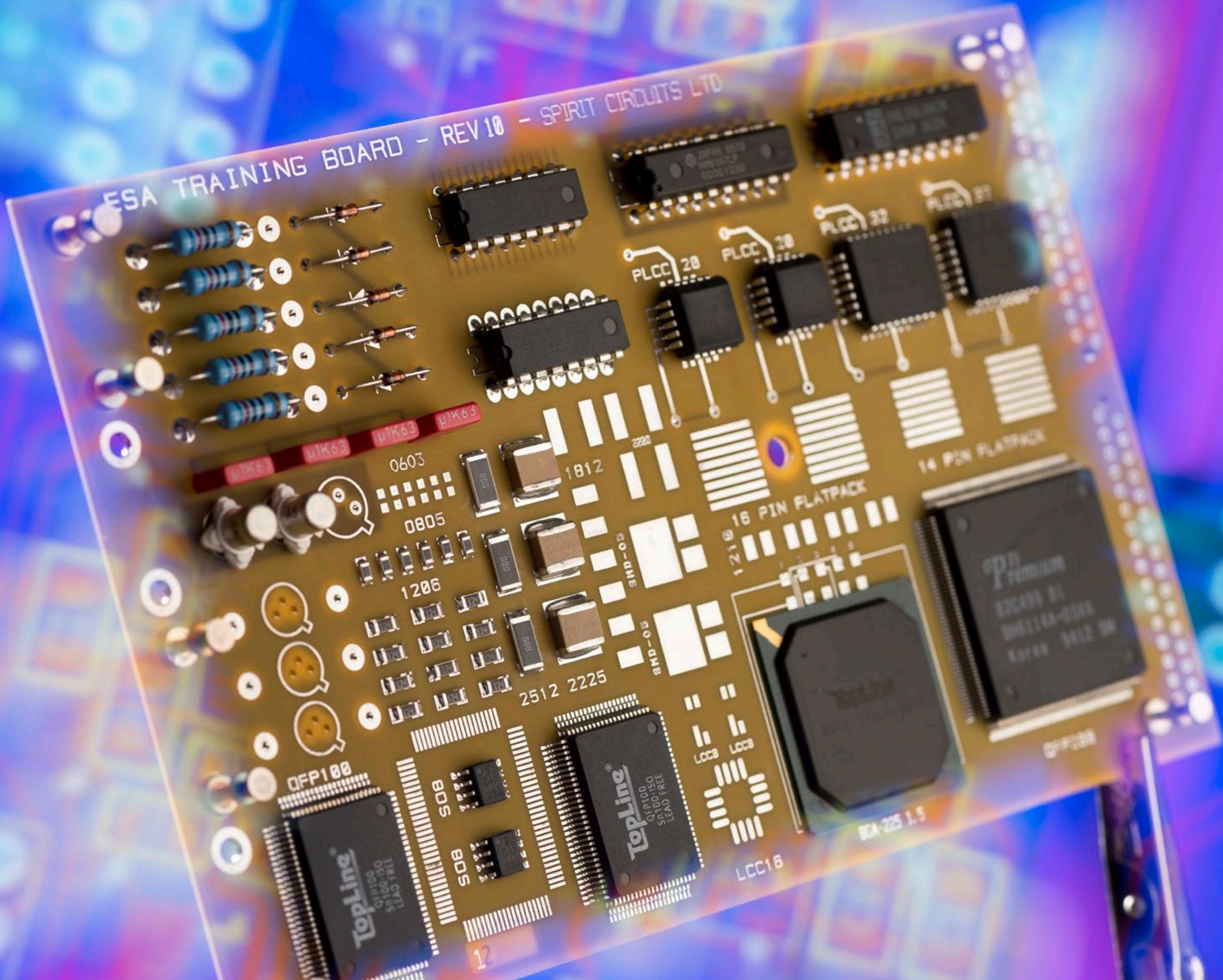
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