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EMFT

FRAUNHOFER RESEARCH INSTITUTION FOR MICROSYSYTEMS AND SOLID STATE TECHNOLOGIES EMFT

ANNUAL REPORT 2020

Fraunhofer EMFT

Annual Report

FOREWORD

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

2020 was undoubtedly a challenging year for all of us. But as I look back over the past few months, there's one thing that stands out particularly positively for me: I was impressed at how flexible, pragmatic and creative our employees were in their response to the pandemic situation. For me, this bears out the fact that we possess the qualities that are essential to research and innovation, too: the capacity to think outside the box, look for solutions beyond the tried and tested, and not lose motivation even when things get challenging.

We continued to hone our strategic focus last year: thanks to digitalization, phenomena such as autonomous driving, fully automated production and individualized telemedicine are no longer dreams of the future. But this also requires us to entrust networked systems not only with extremely sensitive data, but – as in the case of autonomous driving – even our physical safety. Understandably, we will only be prepared to do this if the electronics are absolutely safe and reliable: in other words, trustworthy. Trusted electronics is primarily associated with software solutions, but for Fraunhofer EMFT the focus is on hardware. In the Fraunhofer TRAICT project, for example, our researchers are working on analyzing purchased security modules of the highest classification and detecting Hardware Trojans. You can find out more about this project on page 35. Other activities are dedicated towards tamper protection of assemblies and entire devices using protective films, as well as in-house development of critical chips.

And there's another aspect that will be integral to every single area of innovation in a few years' time: sustainable and resource-saving technologies are becoming increasingly important. Sensor research is right at the heart of the action here. Firstly, sensors themselves have to be energy-efficient – or preferably even energy-autonomous. Secondly, the use of sensors contributes to greater sustainability: sensors help make production processes more energy-efficient, by means of networked monitoring, for instance. Last but not least, microelectronic components themselves have to become "greener" – for example by means of environment-friendly production processes and materials. There is enormous potential to be tapped into here when it comes to enhancing sustainability.

I now invite you to take a look back over the year 2020 at Fraunhofer EMFT and I wish you a fascinating and inspiring read. As always, I look forward to receiving your suggestions and feedback!

Best regards,

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

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FRAUNHOFER EMFT

Fraunhofer EMFT buildings on Hansastraße, Munich

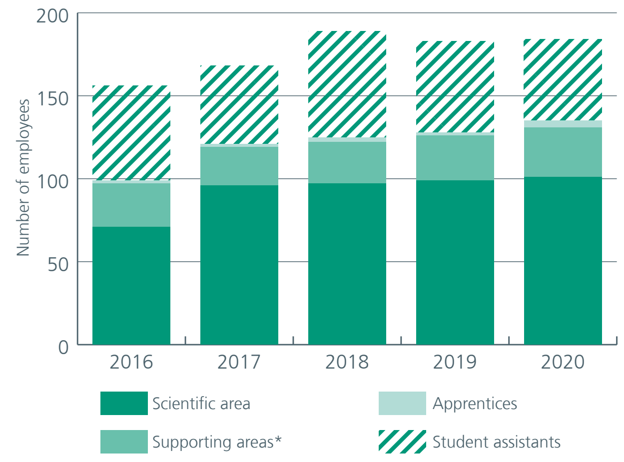
Fraunhofer EMFT employees in summer 2019

PEOPLE, FACTS AND FIGURES

We at Fraunhofer EMFT stand for outstanding expertise from all over the world: Our team comes from a total of 22 different countries. Together, we drive forward research and development of sensor systems and actuators for human beings and the environment. Our multicultural background is a key advantage, enabling us to look at scientific issues from a diverse range of perspectives. We make the most of this opportunity to inspire each other in terms of our mindset and our problem-solving strategies.

Austria
Belarus
Bulgaria
Canada
China
Columbia
Czech Republic
El Salvador
Finland
Germany

Greece
India
Israel
Italy
Kazakhstan
Morocco
Netherlands
Romania
Russia
Slovenia
Turkey
Vietnam

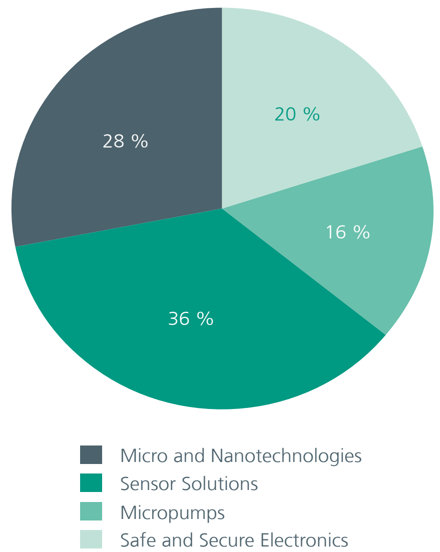


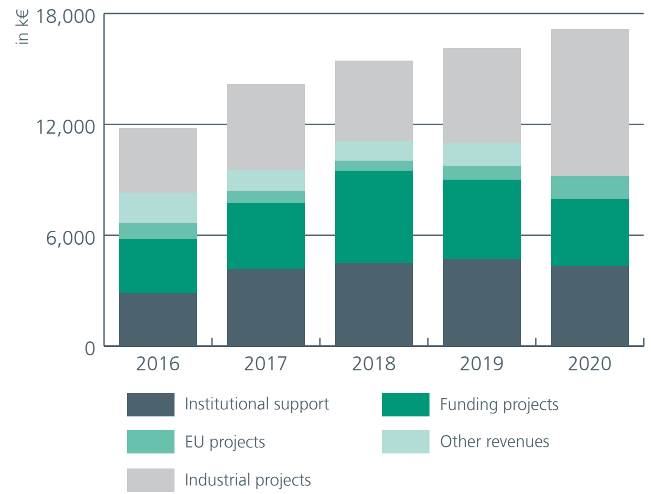
* Marketing, IT, Administration, Technology, Quality Management, Organization and Services

As compared to the previous year, the permanent staff at the institution increased by seven in 2020, with a total of workforce of 135 as of the end of the year: of these, 101 people are employed in the scientific area and 30 in support areas. The latter are made up of marketing, IT, administration, technology, quality management, organization and services. In addition, the Fraunhofer EMFT team is supplemented with five trainees.

Another 49 student assistants from a wide range of educational institutions were employed at Fraunhofer EMFT in the course of the year, writing their final thesis and/or working on Fraunhofer EMFT research topics.

In 2020, the Fraunhofer EMFT team was able to make its contribution to tackling the current challenges facing society with a total of 103 projects. Almost one third of the projects – 28% to be precise – can be attributed to the area of expertise Micro- and Nanotechnologies. This in turn forms the basis for Sensor Solutions, Micropumps, and Safe and Secure Electronics. It is precisely the interdisciplinary interaction between these areas of expertise that helps us produce forward-looking solutions for people and the environment.





Fraunhofer EMFT's total budget amounted to EUR 17.3 million in 2020, with industrial orders generating a total volume of approx. EUR 4.4 million. This is a 26.6% share of the operating budget.

COMPETENCES, APPLICATIONS AND PROJECT EXAMPLES

Design of high-speed ADC in 22-nm CMOS FD-SOI for automotive radar SoC

Sensor materials for combined in-line measurements

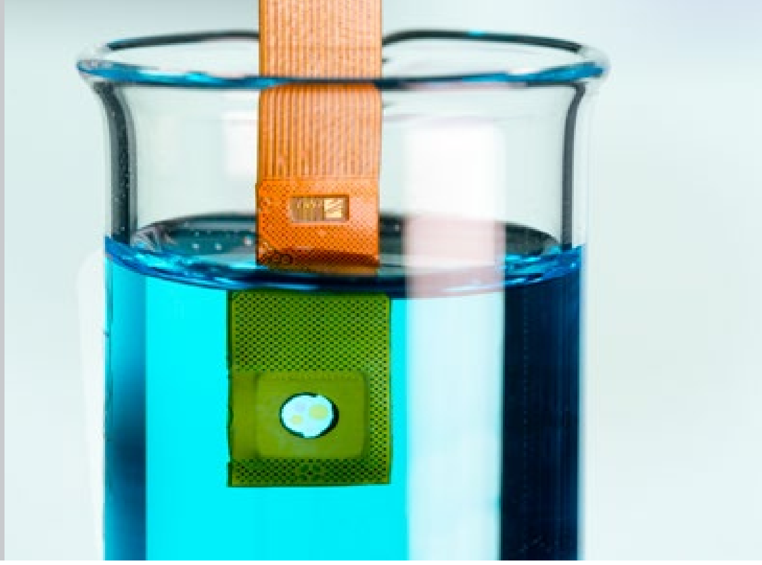
SENSOR SOLUTIONS

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 of 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 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 sensor technology
- Characterization and validation
- Combined sensor systems



Hermetically sealed CMOS ion- sensitive field effect transistor (ISFET) in a hybrid foil package for use as a pH or ion sensor

EXAMPLES OF PROJECTS AND APPLICATIONS

Innovative sensor technology for monitoring the heart

Cardiovascular disease remains the leading cause of death in Europe – with more than 6 million new cases in the EU every year. Reliable monitoring systems that detect intermittent abnormalities and identify critical cardiac behaviors would be an effective tool to combat the horror of sudden death from heart disease.

The aim of the EU project SmartVista (Smart Autonomous Multi Modal Sensors for Vital Signs Monitoring) is to develop and demonstrate a next-generation, low-cost, intelligent multimodal sensor platform to reduce the incidence of sudden death from cardiovascular disease. Key innovations in SmartVista include the integration of 1D/2D nanomaterial-based sensors to monitor the heart, thermoelectric energy harvesters to harvest energy from the body’s temperature to power the system, and printable battery systems capable of storing this energy. These go together to create a self-powered device that autonomously monitors the patient’s electrocardiograph, respiratory flow, oxygen flow, stress indicators in sweat and temperature. This information is then wirelessly transmitted for the purpose of online health processing, enabling continuous recording of vital parameters over 24 hours or more without the patient’s freedom of movement being impeded by interfering cables.

Here, Fraunhofer EMFT contributes the heterogeneous system integration of the various components on thin, flexible films and the development of a 2D sensor in nanotechnology for the chemical analysis of components in human sweat.

The project is being funded under the Horizon 2020 program, funding reference 825114.

Project partners: Tyndall National Institute, University College Cork, National Centre for Scientific Research (CNRS), Novosense AB, Analog Devices

Biosensors detect plant viruses

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

The Fraunhofer project BioPat involves Fraunhofer EMFT researchers working alongside the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and the Fraunhofer Center for Systems Biotechnology CSB to develop highly specific and robust in-field sensor components for the detection of plant diseases.

By creating novel biosensors, the team aims to enable fast, simple and simultaneous detection and differentiation of a wide range of viral genomes at an early stage of infection. The work being done on BioPat will focus on the analysis of viruses that are most relevant to the main crop plants in Chile and Germany, namely the grapevine and the potato.

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

The project is supported and funded by the Fraunhofer Executive Board.

Project partners: Fraunhofer Institute for Molecular Biology and Applied Ecology IME, Fraunhofer Center for Systems Biotechnology CSB.

Power-saving chips for neuromorphic computing

Neuromorphic computing is considered a key technology for future AI applications. Here, the sophisticated nerve network of the human brain serves as a model. A central challenge facing research is the very high level of power consumed by the chips due to the complex computing required. As part of the ECSEL project TEMPO (Technology & Hardware for Neuromorphic Computing), the German consortium with participation of Fraunhofer EMFT is working on the development and evaluation of low-power neuromorphic computing chips in the 22 nm

Fluorescent indicator dyes

FD-SOI technology node. The researchers apply new integrated memory technologies in innovative concepts for the realization of analog and digital neuromorphic circuits. Memory and chip development is conducted at all levels of exploitation – from applied research and IP generation through to integrated systems. The chips designed and manufactured in connection with the project are to be used for classification tasks in image recognition systems, e.g. for autonomous driving, as well as for processing other sensor data such as the data generated by radar systems.

Fraunhofer EMFT's contribution will focus on developing key IPs for analog and mixed-signal signal processing for neuromorphic structures. The goal is to develop signal processing for existing mobile and portable sensor systems, enabling a reduction of power consumption by several orders of magnitude.

The project is funded by the EU under reference 826655 as part of the ECSEL initiative and by the BMBF under reference 16ESE0407.

Integrated optical gas sensors for VOCs

The joint project "Integrated-optical detection of volatile organic compounds using functional polymer coatings (COLODOR)" coordinated by the Austrian Institute of Technology GmbH AIT addresses the need for compact measuring systems for so-called "volatile organic compounds" (VOCs). This is to be achieved by researching a novel optical multi-parameter gas sensor concept using polymers doped with indicator dyes.

Quantitative detection of such compounds is of enormous importance in a broad range of applications. VOCs have key role to play in the food industry in particular. Detection of VOCs during food preparation in combination with the appropriate optimization of the boiling and cooking processes can help avoid the formation of toxic organic products, thereby generally reducing the fat content in food. For this purpose, the VOC measurement systems being developed by the project are to be integrated in food preparation equipment for end consumers.

In addition to its high level of integration, the proposed COLODOR concept allows operation at room temperature with low power consumption, thereby ensuring compatibility with cost-effective mass production technologies. COLODOR taps into the potential offered by VOC measurement by exploring dye-doped polymers for optical multi-parameter gas sensors. For this purpose, the aim is to investigate novel sensor materials and their local deposition on sensor chips, create compact optical gas sensor chips and demonstrate the function of the new optical VOC measurement principle. Since three industrial companies are involved – specializing in photonic components, local functionalization and kitchen appliances – the entire value-added chain is covered, so it will be possible to fully exploit the findings at a later stage.

The project is funded by the Federal Ministry of Education and Research BMBF under the funding initiative M-ERA.NET 2015, funding reference 13N14242.

Mobile test system detects SARS-CoV-2 infections at an early stage

Rapid tests to detect infection are an important component in overcoming the coronavirus pandemic. Together with the Fraunhofer Institutes IME, ISIT, IBMT and ENAS, Fraunhofer EMFT researchers are working on a mobile test system for rapid detection of the SARS-CoV-2 virus or existing immunity.

Like the PCR tests established as the gold standard, the new test system is based on amplification of viral RNA. Here, however, partners use the LAMP (loop-mediated isothermal amplification) method for this purpose. Compared to PCR, LAMP offers a high degree of robustness and sensitivity and can detect disease at a low viral load. In addition, the duplicating process runs at a constant temperature, not only accelerating the processing time but also signifcantly reducing the amount of energy required. With these properties, LAMP offers an attractive alternative to PCR, especially for point-of-care applications. In connection with this project, Fraunhofer EMFT researchers are responsible for the measurement sensor technology. The microvolume/miniature measurement system they developed consists of a sensor array for quantifying the amount of nucleic acid and monitoring the melting curve analysis.

To detect viral infestation, a sample (e.g. throat swab) is dissolved in a buffer, a primer and LAMP reaction mix are added and the sample is heated to approx. 65 °C for 30 – 45 minutes. A change in the sensor signal means a positive test result. The signal is digitally recorded by the biosensors even as the measurement is being carried out. Among other things, the researchers use a pH transducer on which the LAMP reaction takes place. Just like the other biosensors used, this one is developed and fabricated at Fraunhofer EMFT. To enhance validity, the amplificates are subjected to a melting curve analysis. This enables false positives to be identified. With conventional methods, special fluorescent dyes and expensive laboratory equipment are used for quantification and melting curve analysis. The use of the biosensors saves both costs and the space required for virus diagnosis.

Working with cell samples in a sterile bank

The test system provides reliable feedback on the infection status within one hour and is capable of straightforward adaptation to other viral diseases.

Mobile monitoring of the health status of patients

Even mild progressions of COVID-19 disease can be treacherous, since a patient's condition can deteriorate rapidly within a few hours. To be able to prevent severe complications in such cases, fast action is crucial. Here, the earlier a deterioration in the patient's condition is detected, the better the treatment options.

In the M3Infekt project, Fraunhofer EMFT is working with nine other Fraunhofer institutes and four medical partners to develop a flexible and mobile solution that is as suitable for use on normal hospital wards as it is in nursing and retirement homes or in the patient's own home environment: a modular sensor wristband that allows monitoring of relevant biosignals for early detection of a deterioration in condition in the case of infectious diseases such as COVID-19. The modular and mobile design of the planned system with standardized, open interfaces enables simple integration into other platforms and application to a range of diseases such as influenza, pneumonia and sepsis.

The Fraunhofer EMFT researchers' work package covers the areas of system integration and flexible electronics: the selected sensors for measuring the disease parameters are integrated onto a thin, flexible circuit carrier. An overall concept for power management, energy storage and energy harvesting enables the system to function self-sufficiently in terms of energy. The integration of an energy-efficient communication interface is essential in order to be able to transfer the data online to a central database for purpose-specific analysis and further processing.

New assay concept for vaccine development

The COVID-19 pandemic illustrates how quickly the development of new vaccines can become a race against time: until a new vaccine is ready for approval, it must first be tested for efficacy and freedom from side effects. This involves complex and often lengthy processes.

Researchers at Fraunhofer EMFT and the University of Regensburg are working on an assay concept in the Covirep project that could make the efficacy testing of vaccine candidates both faster and more robust.

The aim of this collaborative project funded by the Fraunhofer-Gesellschaft and involving the Fraunhofer EMFT group Cell-Based Sensors Technology headed by Professor Joachim Wegener as well as the working group under Professor Ralf Wagner at the Institute of Microbiology and Hygiene at the University of Regensburg is to develop a conceptually new assay for detecting neutralizing antibodies against SARS-CoV2. The concept makes very low-threshold viral manipulation of cell physiology detectable using intrinsic biological enhancement mechanisms, enabling an automated, electrical readout that is scalable to high throughputs. In contrast to the methods used to date, the response of the host cells to the virus infection is recorded continuously in real time and not just at a single point in time.

New method in the fight against viruses

In the ViroSens project, scientists from the Fraunhofer Institute for Biomedical Engineering (IBMT) in Sulzbach/Saar and Fraunhofer EMFT in Regensburg are collaborating with the companies nanoAnalytics GmbH (Münster) and innoMe GmbH (Espelkamp) on a new method for measure the effectiveness of vaccines. For this purposes, the test cells are placed on multi-electrode arrays that allow fully automated detection of the state of infection using electrochemical measurement methods. This eliminates the time-consuming coloration reactions of conventional tests, thereby saving both time and cost.

But the new method has another advantage, too: cells are continuously monitored over an extended period of time. In previously related coloration detections, they are analyzed only at a specific point in time. This gives researchers additional information about the progression of the cell reaction over time – information that was previously inaccessible. The consortium has set itself the goal of looking into setting up a complete system comprising the measuring device and the relevant analysis software and electrode arrays required for cell observation, and implementing this in laboratory set-ups so as to pave the way for a later market launch.

The project ViroSens receives total funding from the German Federal Ministry of Education and Research (BMBF) under the KMUinnovativ program.

Original prototype of the early warning system for detecting aquaplaning and black ice undergoing testing

Early warning system for detecting aquaplaning and black ice

Black ice and aquaplaning make roads dangerously slippery, frequently resulting in severe accidents. In a joint initiative with Intel, Fraunhofer EMFT is working on a solution to the problem at the High Performance Center for Secure Intelligent Systems (LZSiS). A real-time warning system is designed to detect the potential danger of water or ice on the road surface, enabling predictive detection of road conditions. The warning system's hazard detection is based on the interpretation of the optical properties of water and ice, which makes the system more reliable and secure than previous methods. Data from near-infrared (NIR) and polarization sensortechnology together with AI-supported evaluation enable clear detection and localization of weather-related hazards on road surfaces. By using commercially available image sensors based on CMOS technology, combined with optical filters, the system remains mechanically simple and cost-effective.

Particularly in the context of autonomous driving, such an assistance system integrated directly into the vehicle control system could ensure greater safety in slippery road conditions.

Intelligent food packaging

Foods with a high degree of freshness such as raw meat and fish products are susceptible to microbial decomposition processes. But in the case of packaged products, it is not possible to see how fresh the food really is. Assessing the actual microbiological load of food could help increase product safety and reduce food waste at the end of the supply chain. As such, real freshness monitoring would contribute significantly to the sustainable use of Resources.

In the joint BMEL-funded FRESH project, Fraunhofer EMFT and Fraunhofer IVV are working with industrial partners to develop intelligent packaging with an integrated sensor function to indicate the microbiological quality of food. To this end, sensor materials are being integrated into food packaging that change color (optical chemosensors) and respond well below the odor threshold to the presence of biogenic amines. Microbial spoilage of meat and fish products produces volatile gases, and these are used as to indicate freshness. The sensor packaging is to show a clear color reaction when a limit value for this type of gas is exceeded, thereby reliably informing the consumer of the actual product quality simply by glancing at the packaging and without the need for any further equipment. In this way, intelligent packaging allows rapid quality and safety assessment of food products.

Artificial intelligence in the sensor node

Nowadays, sensor data is usually analyzed in the cloud. But as digitization continues, the amount of sensor data being collected and analyzed is growing rapidly. Even modern mobile networks and wired communication networks will be overwhelmed by the transmission of such immense amounts of data in the foreseeable future. At the same time, the requirements in terms of data security and protection are becoming increasingly rigorous. Keeping raw data at the edge of the network is a promising way of reducing data volumes while at the same time increasing data security.

In the project KIS, researchers at Fraunhofer EMFT are working on fitting sensors and actuators with AI. The goal is to be able to perform intelligent (pre-)processing and aggregation of data in Edge. To this end, various methods are being investigated that allow Machine Learning (ML) models to be trained in such a way that they can be executed in an intelligent sensor node. The research team is also seeking to conceptualize and develop an intelligent environmental monitoring station. This is to be installed on the roof of the Fraunhofer EMFT, where it will monitor the environmental impact of traffic and industrial plants in the Munich city area. In the project, the measuring station serves firstly to supply measurement data, with data being collected in such a way that it can be used for training ML models; secondly, the data acts as a vehicle for investigating and testing ML models integrated in the sensor node.

A second transfer demonstrator for AI-controlled microdosing will then be developed to evaluate the transferability of the lessons learned. In addition, further transfer demonstrators will be defined together with industry partners to demonstrate the methods that have been developed.

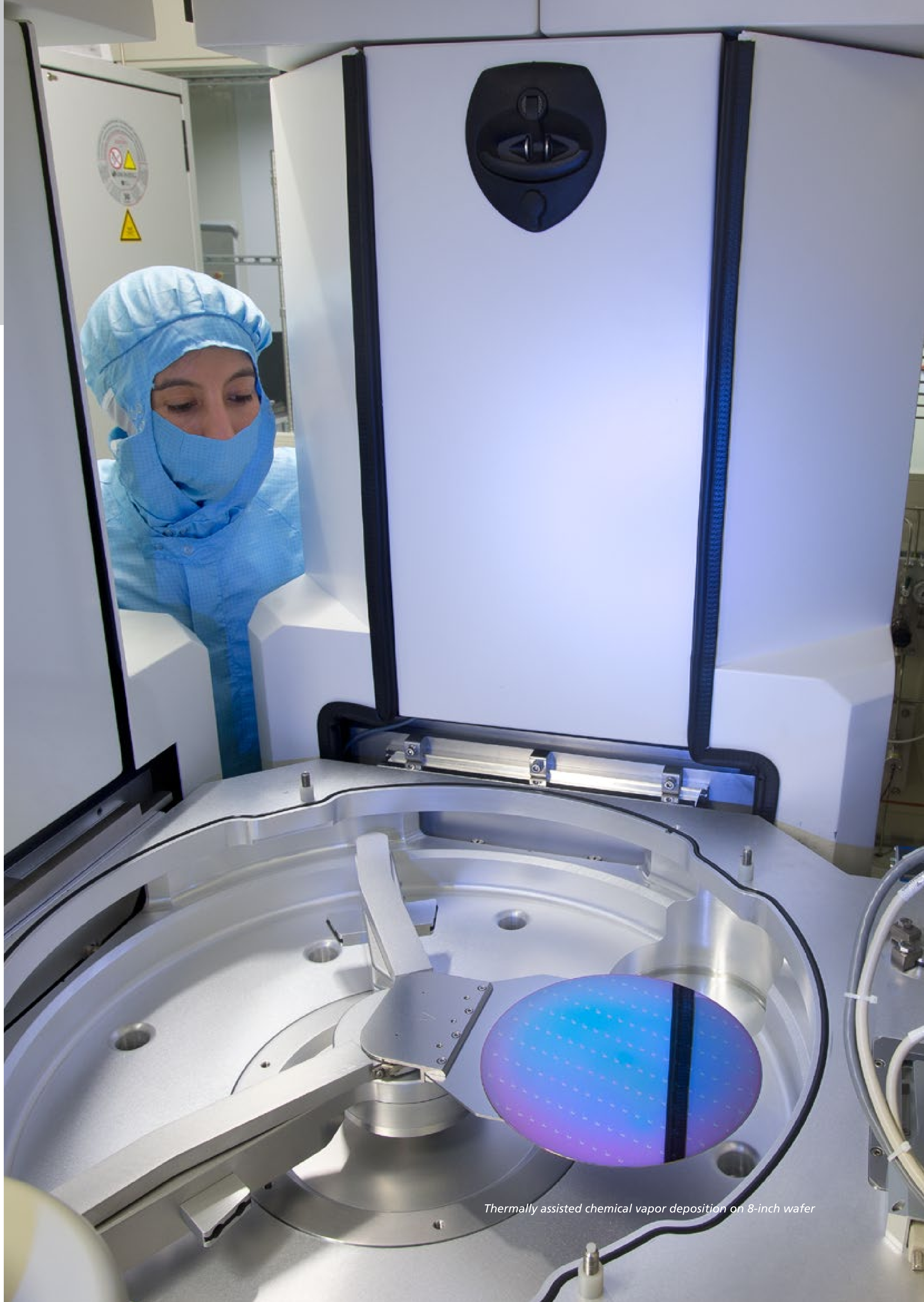
The project is funded by the Bavarian State Ministry of Economic Affairs, Regional Development and Energy.

Energy-efficient brain-like computing

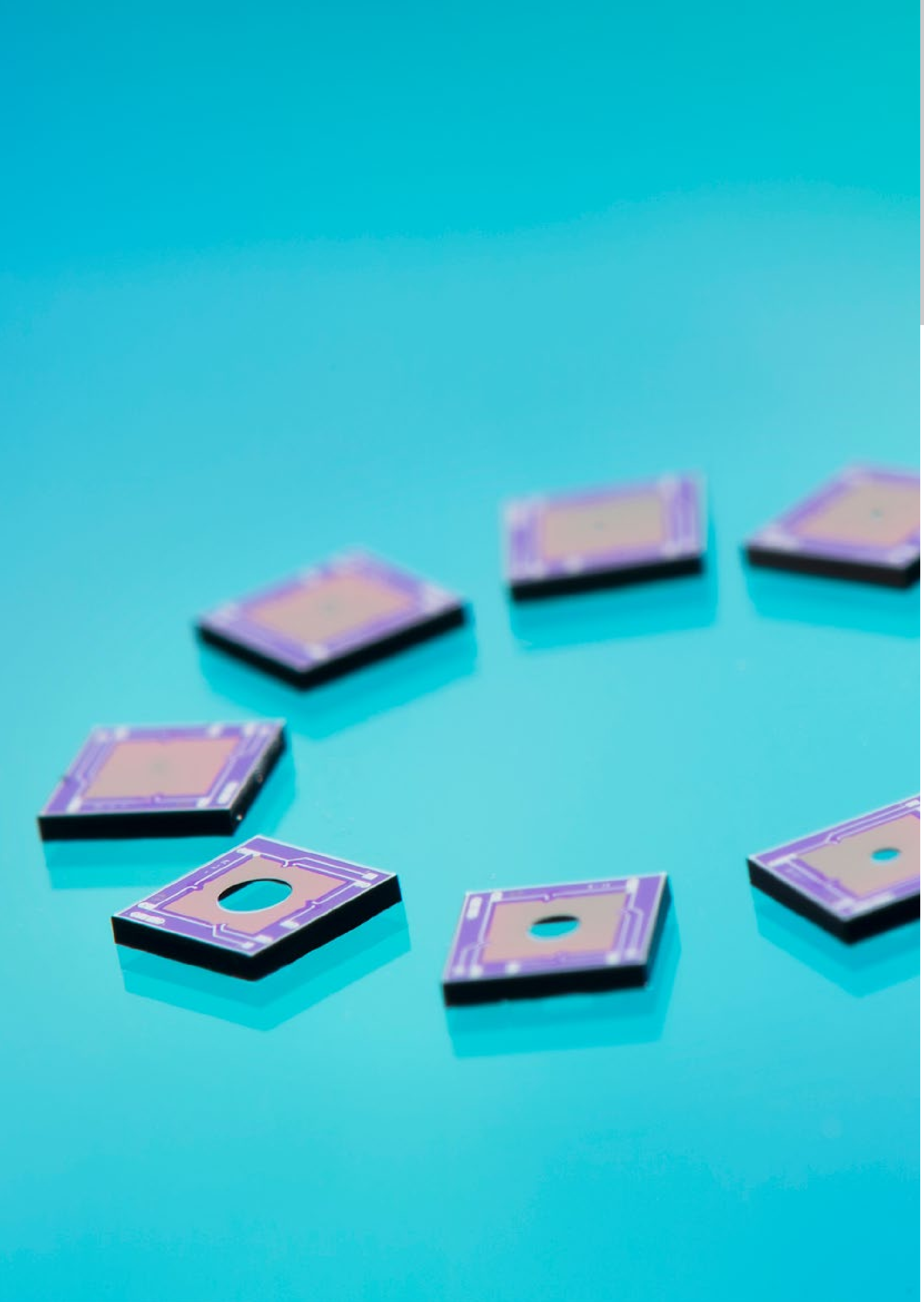
Nature sets a high bar: our brain is capable of processing and storing huge amounts of information without using more energy than a 20-watt light bulb. This is a good reason for researchers worldwide to take the human brain as a model for circuits on so-called neuromorphic chips.

In the EU project NeurONN, Fraunhofer EMFT and five European partners are developing a neurologically inspired computer architecture. This involves encoding information from coupled oscillating elements that are interconnected to form a neural network. Analogous to the brain, the two key components of the neuron and synapse replicate the distributed computational and memory units. New elements based on vanadium oxide that are potentially 250 times more efficient than state-of-the-art digital oscillators serve as neurons. So-called memristors – a combination of 'memory' and 'resistor' – based on new 2D nanomaterials are used as synapses. The tiny devices are to be up to 330 times more efficient than current technologies in terms of switching speed, lifetime and energy consumption.

The neuromorphic chips are to be used wherever energy efficiency and low latency are particularly important – where a device is battery-powered, for example, or there is no time to send data to the cloud and wait for a response. This includes sensor data processing in connection with autonomous driving and satellite applications, as well as predictive maintenance and condition monitoring in Industry 4.0. Another major advantage of neuromorphic hardware is that information is stored locally rather than in the cloud: this enhances both device security and data protection. Last but not least, neuromorphic chips serve as the basis for edge AI applications.



Thermally assisted chemical vapor deposition on 8-inch wafer



Silicon flow sensors

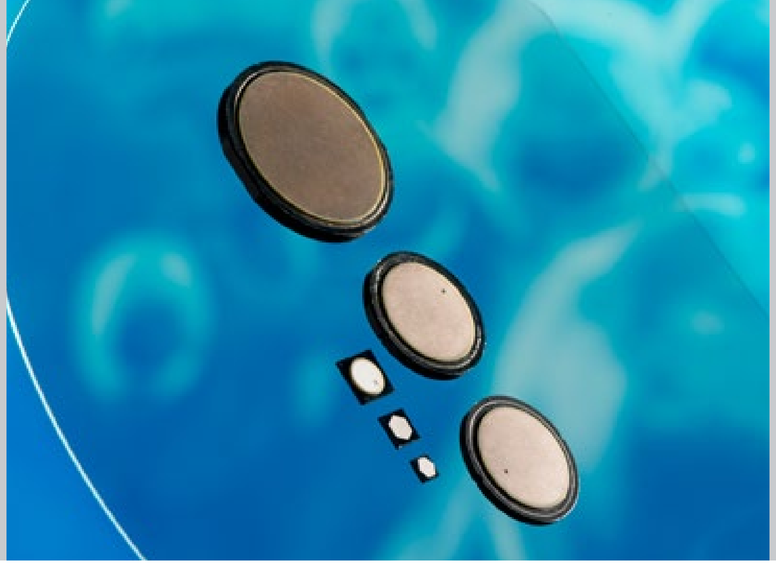
MICROPUMPS

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 microdosing 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, stainless steel and titanium micropumps for 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 key focus just now 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 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 microdosing components in this research area, and the team possesses extensive system expertise, too. Microdosing 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 microdosing system.



Fraunhofer EMFT micropump family

EXAMPLES OF PROJECTS AND APPLICATIONS

Technology platform for innovative medical devices

How can we succeed in counteracting incessantly rising costs in the healthcare system while at the same time ensuring patients receive the best possible care? Researchers from 66 companies, universities and institutes in 12 European countries are meeting this challenge in the joint project Moore4Medical.

By pooling their expertise, the partners aim to accelerate the development of innovative medical devices. The focus is on reducing the need for hospitalization, supporting personalized therapy, and implementing intelligent point-of-care diagnostic tools.

Fraunhofer EMFT is contributing its expertise in microdispensing systems and pump design to this project. One of the project's aims is to create a chip box for growing cell cultures. An integrated micropump ensures a constant flow in the culture medium, thereby ensuring an optimum supply of nutrients to the cell cultures. The researchers are also collaborating on an autoinjector for monoclonal antibodies that will be used in the field of autoimmune diseases. The intelligent micropump control enables precise, active dosing of the medication.

The project is being funded under the ECSEL JU program in collaboration with the Horizon 2020 framework program run by the EU and national authorities under reference H2020-ECSEL-2019-IA-876190.

Active implants – reliable and powerful

From drug dosage to artificial sphincters: in the future, micropumps could be used as active implants for a wide range of medical applications. At the High Performance Center for Secure Intelligent Systems (LZSiS), researchers working on the Active Implants project are evaluating the risks involved in using micropumps as medical implants. The various applications require very varied pump specifications, but what they all have in common is their extremely rigorous safety requirements. Active Implants focuses on two fundamental safety-related issues.

Firstly, interaction between the pump and the medium being supplied (e.g. medication) is investigated in order to ensure long-term dosing stability without micropump failure. Secondly, scientists are investigating the possibility of reducing the pump's operating voltage. At present it is several hundred volts, which is a very high level. For this purpose, tests are carried out to see whether the actuator – currently a single-layer piezoceramic – can be replaced by a multilayer drive. This multilayer technology could potentially enable a substantial reduction of the voltage required to operate the pump. This would make it easier to achieve reliable insulation.

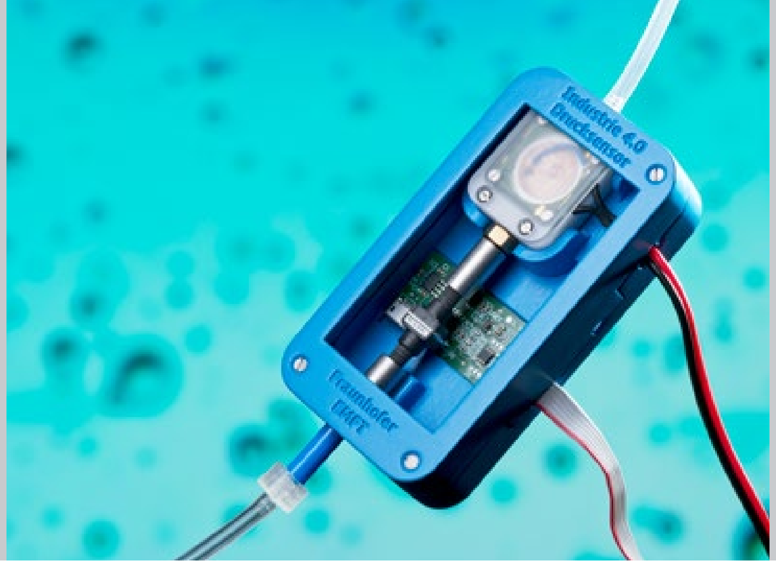
AI-assisted prophylaxis of pressure ulcers

Those who are bedridden or paralyzed, as well as diabetes sufferers, are subject to an increased risk of pressure bedsores and pressure ulcers on the foot (decubitus or foot ulcus). These not only impair quality of life, they can ultimately result in the need for limb amputation in a worst-case scenario if left untreated. Incipient or infected chronic wounds are often not noticed by patients due to diminished nerve and pain perception, or else they are not reported to medical staff due to shame or lack of knowledge. But in outpatient care in particular, it is impossible to ensure constant monitoring of sufferers.

The aim of the project KIPRODE is to use adapted sensor technology and automated prediction methods based on artificial intelligence (AI) to detect the development of wounds at an early stage and ultimately prevent them. To this end, researchers at Fraunhofer EMFT are collaborating with scientists from the Technical University of Munich at Klinikum Rechts der Isar, Fußnetz Bayern e.V. and Monks Vertriebsgesellschaft mbH on a prophylaxis tool which has sensor patches and a telemedical interface between medical professionals and those undergoing treatment.

The first step is to develop flat sensor patches with wearable electronics that record various parameters in the area of the patient's tissue at risk, such as levels of oxygen saturation, pressure, movement and temperature. In conjunction with telemedicine solutions, it might be possible to enable direct transmission sensor system data from the caregiver to a panel of experts, whether in an outpatient or an inpatient context.

Here the Fraunhofer EMFT team is developing the wearable sensor system to collect data from various commercial sensors, which will be worn by various patients in the clinical trials. After anonymization in accordance with data protection regulations and transmission via telemedical specialist Monks, the data obtained in this way is to be analyzed at



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

Fraunhofer EMFT using AI methods (machine learning algorithms for time series analysis) so as to derive a prophylaxis tool.

The project is being funded by the Federal Ministry of Health under reference ZMVI1-2520DAT50A.

SARS-Cov-2: Using established medication for effective therapy

The fight against the SARS-CoV-2 pandemic is a race against time: in addition to the vaccination campaign, effective medications are needed – in particular to be able to get the more severe disease progressions under control. As part of the project DRECOR (Drug Repurposing for Corona), researchers from eight Fraunhofer institutes, including Fraunhofer EMFT, are taking a pragmatic approach: the team is using existing drugs with known safety profiles to rapidly develop new therapeutic approaches. The researchers compiled a library of around 5,500 components, of which a large proportion have already been subjected to clinical testing. From this portfolio, researchers select test items to be studied in more detail. The goal is to identify molecules that can prevent coronavirus infection of human cells with sub-µM or µM activity. The most promising drugs are prepared and encapsulated for inhalation using suitable processes.

Together with Fraunhofer ITEM, researchers from Fraunhofer EMFT are optimizing a drug nebulizer for the inhalation of encapsulated active ingredients as part of the project. The aim is to deliver controlled amounts of active ingredient in the range of 10-30 µl per breath, while at the same time increasing inhalation efficiency. This is to be realized by means of a stainless steel micropump developed by EMFT and a breathing cycle detection system.

In order to be better prepared for pandemic scenarios in the future, the project will also establish a multidisciplinary network of experts from relevant disciplines.

The project is coordinated by the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and the internal program Fraunhofer vs. Corona, Funding Phase II.

Safety Pump – reliability of microdosing systems

In the Safety Pump project, EMFT researchers are working on pattern recognition of sensor-monitored disturbance variables to ensure improvements in the operational safety of microdosing systems for applications with very high service life requirements. Thanks to the modeling competencies of TU Munich and the microfluidics and actuator competencies of Fraunhofer EMFT, functional reliability is enabled by means of predictive maintenance for early failure prediction. The investigations into operational safety are being carried out in cooperation with the Bavaria-based SME Rausch & Pausch GmbH as the industrial partner for the manufacture of the metal micropump. Pilot applications include a promising application in the field of continuous sample delivery for gas sensors. The aim here is to ensure that the hardware can be serviced or replaced at an early stage, in particular without functional failure. For this purpose, various parameters are to be monitored by sensors in a laboratory test and, in particular, a pressure pulse monitoring system is to be evaluated with regard to its suitability for use in predictive maintenance. The sensor data allows information to be inferred on the major causes of micropump failure during the period of operation so that, based on the appropriate pattern recognition, it is possible to provide an early warning. In this way, fault cases such as particle contamination or changes in material properties due to degradation can be detected at an early stage.

ESD system test with broadband measurement of the secondary discharge current

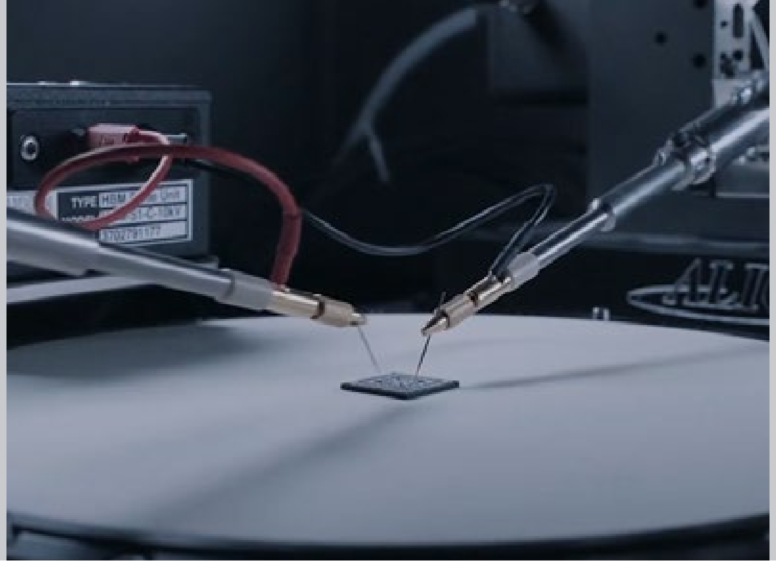
SAFE AND SECURE ELECTRONICS

Internet of Things, Industry 4.0, Big Data – there is no question that digitization 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. The words "safe and secure" have various facets here.

Firstly, electronic systems have to be one hundred percent 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 of "safe and secure" 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-based 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 of "safe and secure" 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.



Novel 2-pin test system for electrical tests

EXAMPLES OF PROJECTS AND APPLICATIONS

Novel 2-pin test system for electrical tests

In sensitive application areas such as medical technology, communications, automotive and aerospace, the reliability of the electronic systems used is absolutely crucial. That is why the semiconductor industry and manufacturers of electronic components and systems test their products with enormous care to ensure they function flawlessly. An important aspect is testing tolerance of the chips to ESD (electrostatic discharge): this because miniaturization makes semiconductor components sensitive to damage from the electrical pulses caused by electrostatic charges.

Fraunhofer EMFT and High Power Pulse Instruments GmbH (HPPI), a manufacturer of ESD measurement equipment, have jointly developed a novel 2-pin test system for electrical testing that offers a range of benefits for the semiconductor industry. The two partners have long-standing expertise in the field of ESD testing and protection and have contributed their respective expertise to the development project.

The test system uses two separate samples to contact the chips on a wafer (wafer-level test) or the electronic components (component-level test). They can be controlled independently, allowing greater flexibility to suit different electrical test scenarios. In addition, the system uses linear drives, enabling extremely accurate positioning of the test specimens. The system also shows fewer parasitic elements than the relay-based test systems that are most commonly used today. What is more, the system supports multi-die testing, thereby saving time and effort in the testing process.

Since the system can be combined with various measurement systems, it is able to cover most current ESD test and characterization needs, including standard TLP and very fast TLP as well as Human Metal Model (HMM), Human Body Model (HBM) and Charged-Coupled TLP (CC-TLP).

Design and test methodology for robust and reliable high-performance ICs

Applications in future areas such as autonomous driving, robotics and Industry 4.0 require high-performance IC components for data processing and transmission. In order to meet the rigorous demands in terms of reliability and robustness, application-specific microcontrollers or components of older production generations have mostly been used up to now – but this results in reduced performance of these systems as compared to mobile radio or computer systems with modems and CPUs of the latest production generation, which are capable of processing a vastly higher data rate.

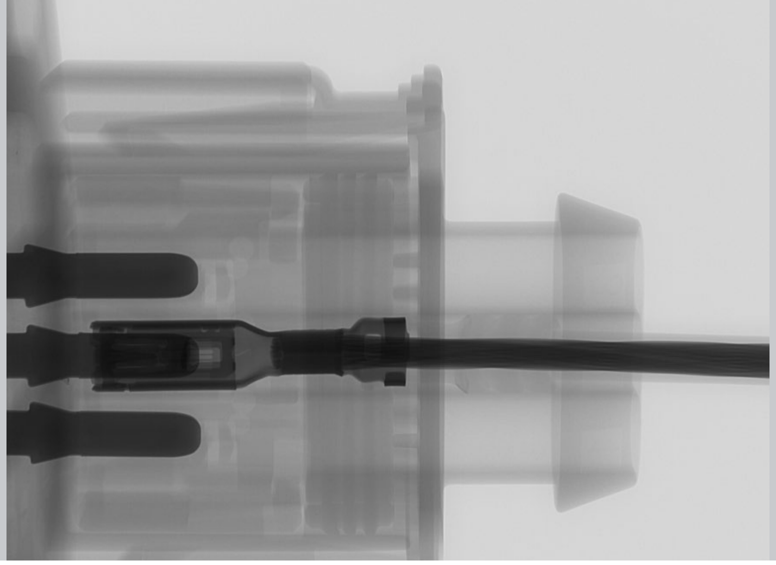
This is where the project ROBUSTNE comes in: researchers at Fraunhofer EMFT are working with TU Munich and Intel to specifically adapt the robustness and reliability of high-performance, high-volume components at critical points. Using the example of a current 4G/5G modem module, an efficient development method is to be elaborated that allows use of high-performance semiconductor components from the cost-sensitive consumer area in for highly reliable Industry 4.0 applications without have to undertake a costly, comprehensive redesign.

The Fraunhofer EMFT research team is contributing its expertise in analysis and testing to the project. For this purpose, the researchers are developing test methods for modules and IC devices that identify the pulse parameters relevant to the loads in the application: these serve to extract electrical and thermal parameters for modeling and simulating the function and aging of devices based on suitable measurements.

Reliable detection of Hardware Trojans

In areas where personal or security-critical data is processed in particular – such as medical technology, autonomous driving and critical infrastructures – trustworthy electronic ICT components and systems are becoming increasingly important as digitalization gathers pace.

Researchers at Fraunhofer EMFT primarily focus on the hardware level here: in the BMBF-funded projects SyPASS (reference: 16KIS0669) and RESEC (reference: 16KIS1008), Infineon AG, Raith GmbH, TU Munich and Fraunhofer EMFT are collaborating to develop methods for the retrograde preparation of highly integrated safety circuits so as recover layout information. Comparison with design data is to ensure reliable detection of Hardware Trojans. The particular



X-ray image of a plug-in system for analysis of damage and aging response

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. AI methods are also increasingly being used in this context.

The technical prerequisites for these projects are systems for nanoscale preparation and analysis, which were procured primarily through the BMBF-funded project Research Fab Microelectronics Germany FMD (reference: 16FMD01K), and a safety lab set-up as part of SyPASS certified according to Common Criteria EAL6 so as to be able to examine safety components of the very highest classification. The TRAICT project, funded by the Fraunhofer-Gesellschaft as part of the COVID InnoPush Initiative 2020, enabled successful synergetic networking of several Fraunhofer institutes to demonstrate various analytical methods using the example of a current 5G router with a central 7 nm CMOS device. This was coordinated as part of TRAICT by Fraunhofer EMFT. Cross-network follow-up projects are envisaged to address this complex subject in the long term with the aim of providing "trustworthy electronics" in an international environment, too, in the face of growing technological challenges.

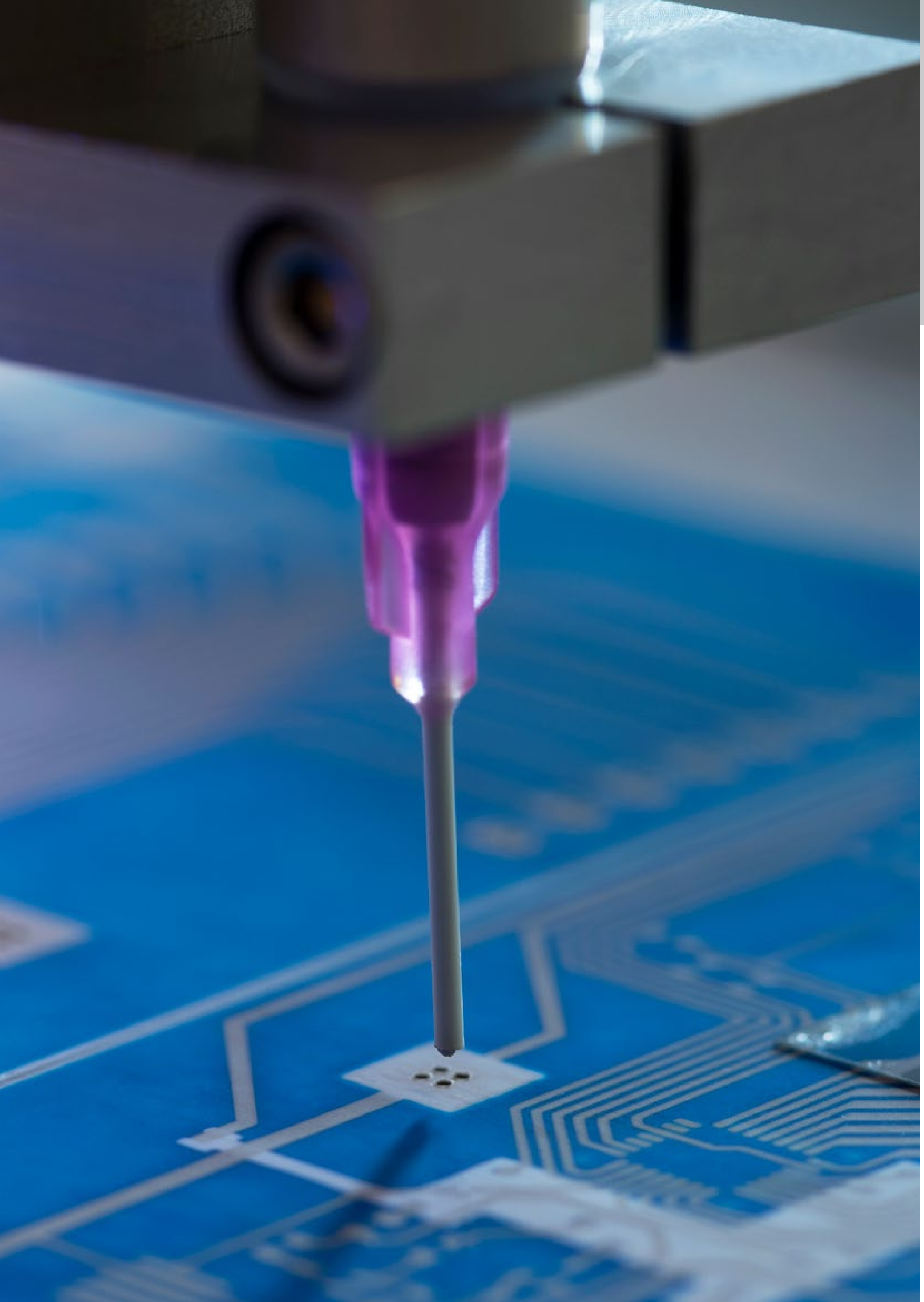
Better understanding of the causes of connector wear

Electrical connector systems are the interface between the assemblies/modules of mechatronic or electrical systems, for example in automobiles. Up to now, only the electrical properties from the data sheet have been taken into account prior to installation: environmental impact such as vibration during later operation has not been assessed. This can lead to premature wear and, in the worst case, costly recalls.

In the StroBA project, a Fraunhofer EMFT research team at the Oberpfaffenhofen site is taking a closer look at the effects of environmental impact on connector systems in cooperation with Ostwestfalen-Lippe University of Applied Sciences: the aim here is to look at how damage and aging response is influenced by different types of micromotion (rotation and translation) and by design features and line routing.

The findings will be used to produce two guides on structural design and on the selection and testing of connectors. These are intended to make it easier for development engineers to apply design measures that minimize potential damage patterns during the design stage. For users of connectors, the suggestions developed enable reliable selection of the right connector for the task at hand. In turn, this should not only shorten the time required to test new connectors but also increase the reliability and performance of the products.

The project is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) and the German Federation of Industrial Research Associations (AiF) under reference 20139 N.



Detailed view of a foil system for temperature measurement during processing

MICRO AND NANOTECHNOLOGIES

Fraunhofer EMFT is equipped with extensive cutting-edge technological facilities in the area of microelectronics and micro/nanotechnology that are maintained by experienced researchers and microtechnologists and used to develop customer-specific solutions. These technologies 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 electric components developed at Fraunhofer EMFT include complex fluorescence modules, conventional PIN photodiodes, sensitive silicon photo-multipliers 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 systems enable low-cost processing of foils and other flexible substrates to develop bendable, 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, 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 millimeter-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.

Deep learning algorithm verification for neuromorphic hardware implementation

EXAMPLES OF PROJECTS AND APPLICATIONS

Intelligent diagnostic interfaces for networked IoT systems

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 and Munich are working on a new generation of active "intelligent" plugs, so-called Cyber Physical Connectors. The aim is to integrate miniaturized sensor systems in the plugs so as to be able to monitor the quality of the connection, for example. The idea goes further in that the built-sensors perform a kind of condition monitoring for the connected devices, also registering energy consumption, for instance. For the sensors to be used efficiently, the data they generate has to be capable of being converted and analyzed directly in the plug. Here, R&D activities focus on the requirements involved in terms of the miniaturization and integration of sensors. For example, miniaturization must not result in any compromise in terms of quality or durability. What is more, the sometimes heterogeneous components have to be combined to form a reliably functioning overall system. In terms of both miniaturization and integration, researchers are pursuing innovative solutions from the wide-ranging Fraunhofer EMFT technology portfolio, 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. There has been cross-department development, and some testing, of a modular concept that puts the housings of connectors to mechatronic use. The optimized solution arrived at a hybrid of a rigid PCB with the required computing technology prepared for AI applications and a flexible PCB with high-density wiring layers to accommodate the respective required sensor technology.

The two go together to form a cyber-physical connector, which is to be found industrially under the name SmeC (Smart mechanical electrical Connector). Initial testing of these systems has been very promising. At the same time, work was carried out on an integrated automation concept. Potential combination with efficient roll-to-roll equipment will allow automation in future generations.

The limits at which a damaged connector ought to "sound the alarm" were evaluated in a separate work package entitled "Highly Reliable Onboard Network Monitoring".
For this purpose, the scientists developed a basic model covering a wide range of temperatures (RT, up to 120°C), relative humidity levels (20% RH to 85% RH), contact forces (0.1 times to 3 times normal load) and automotive-relevant movement frequencies and deflections, allowing the estimation of a worst-case scenario. At the same time, critical positions of the two contact pieces of a connector (blade and bell) relative to each other were subject to close study. It was possible to identify areas where the material is subject to intense disintegration and others where the damage can be attributed to adhesive wear. Both effects together have a significant influence on the basic characteristic of a power connector, namely the secure transmission of high currents.

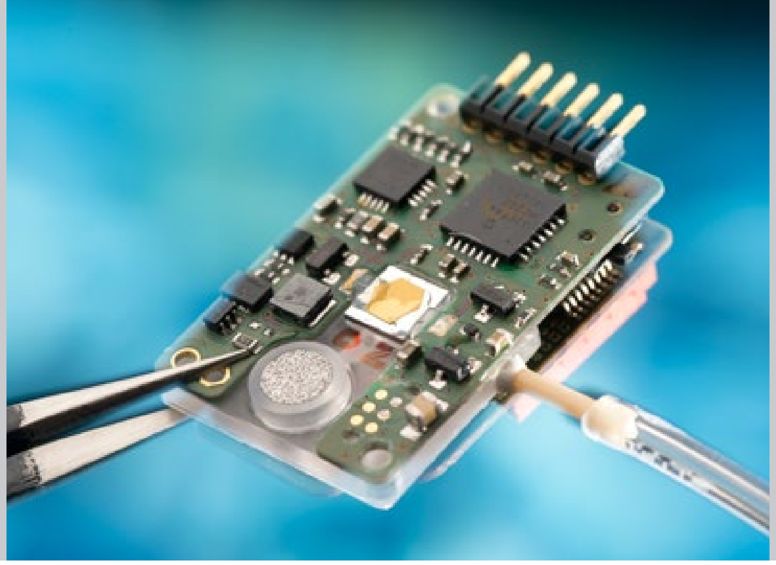
The project is funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy under reference AZ 43-6622/532/4.

Next-generation computing: sensors instead of the cloud

How will it possible to manage computing close to the sensor in the future rather than in the cloud? And how can machine learning take place on distributed systems in this type of setup? Researchers at Fraunhofer EMFT are addressing these highly topical issues in partnership with eleven other Fraunhofer institutes in the innovation project SecLearn. The focus is on neuromorphic, energy-efficient hardware components and AI algorithms for decentralized learning, as well as data protection.

Today's von Neumann-based computing architectures require enormous amounts of energy, so a massive expansion of computing to the Edge would not make sense. In this project, researchers aim to develop neuromorphic accelerators requiring vastly lower levels of power consumption and optimize these for AI algorithms. At a later stage, two use cases will be implemented based on this hardware: (I) speech recognition (keyword spotter + audio event detector) and (II) image recognition (automotive or autonomous driving). Here, the machine learning is to take place in the distributed systems without the basic data having to be passed on to the central cloud. In this way, sensitive data can remain in the local systems, thereby ensuring more effective data protection.

The work is to be continued in the coming years as a Fraunhofer lead project.



Prototype of a fine dust particle sensor based on the capacitive measurement principle for the measurement of PM10, PM2.5 and PM1.0 particles. It consists of a fluidic module including filter, micropump and fluidic channel for aerosol supply, and the sensor module for particle detection.

European pilot line for multifunctional electronic systems

Europe – and especially Germany – have particular strengths in microelectronics in the areas of automotive, energy, security and industry. In the EU project EuroPAT-MASIP, partners from nine countries are pooling their expertise to lay strategic foundations for the development of innovative and complex electronic systems. The aim here is to secure and significantly increase the competitiveness of Europe's microelectronics industry at the global level. The German consortium is focusing on multifunctional electronic systems, energy-saving power electronics, design of complex systems and innovative production technologies.

As part of this project, Fraunhofer EMFT is showing how it is possible to perform pick & place processes with self-assembly. For this purpose, the researchers are adapting the wetting properties of surfaces by means of low-pressure plasma: metal surfaces become hydrophilic, while the surrounding areas made of polyimide become hydrophobic. In the production process, the chips are then adjusted to the (metallic) target areas by means of a liquid.

The project is funded by the EU under reference 737497 as part of the ECSEL initiative, and by the BMBF under the funding reference 16ESE0260S.

Data rates in turbo mode

Data rates up to the TBit/s range – such is the ambitious goal of the internal Fraunhofer project EOS. In order to get within reach of such extremely high data rates, the research team from Fraunhofer HHI, Fraunhofer IIS and Fraunhofer EMFT is seeking to convert several 56 Gbit/s digital-electrical message signals directly and without power-hungry signal processors (DSP) into a multi-stage, optically complex modulation signal.

For this purpose, the scientists are marrying the optical modulator and electrical driver components – previously developed independently of each other – to form a closely dovetailed and precisely tuned functional unit. With indium phosphide (InP) for the photonic IC (PIC) and the 22 nm FD-SOI CMOS electronics with lower power dissipation as compared to SiGe, the most efficient and fastest material systems available are heterogeneously combined in a novel modular structure to create a new electro-optical (e/o) subsystem.

The main task of the Fraunhofer EMFT team is to fabricate fine metal structures on very thin, flexible foil substrates and to integrate the InP and silicon 22nm FD-SOI ICs together with several other components at very demanding distances. The researchers also carried out a detailed analysis of the thermal reliability of the modular integration design using FEM (finite element method) simulations. In addition, analyses of the ESD load and strength were carried out during assembly and testing.

High-performance modules for the Internet of Things

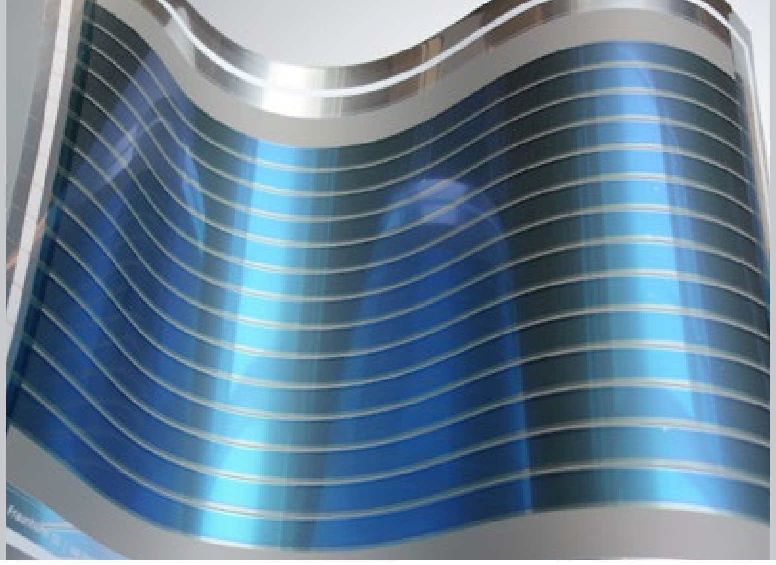
How can the vision of a highly connected society be realized with minimum impact on future energy resources? One possible answer is provided by the Fraunhofer lead project "Towards Zero Power Electronics". This project involves nine Fraunhofer institutes engaged in building a technology and methodology platform to realize highly integrated, extremely energy-efficient modules for the Internet of Things (IoT). 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 MEMS sensor 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.

This is a Fraunhofer lead project, supported and funded by the Fraunhofer Executive Board.

Project partners: Fraunhofer Institute for Cognitive Systems IKS, Fraunhofer Institute for Applied Solid State Physics (IAF), Fraunhofer Institute for Integrated Circuits (IIS), Fraunhofer Institute f for Integrated Systems and Device Technology (IIBS), Fraunhofer Institute for Integrated Circuits, Division Engineering of Adapted Systems (IIS-EAS), Fraunhofer Institute for Photonic



Flexible solar cells from the roll

Microsystems (IPMS), Fraunhofer Institute for Silicon Technology (ISIT), Fraunhofer Institute for Reliability and Microintegration (IZM).

Large-area conductor track patterns for photovoltaics

In order to drive forward the development of solar modules with higher efficiency and new properties such as optical transparency and mechanical flexibility, researchers at Fraunhofer EMFT and Fraunhofer Institute for Solar Energy Systems ISE are working on a process in the project LEO (platform technology for the resource-efficient production of conductive tracks on large-area surfaces equipped with electronics) that enables resource-efficient and cost-effective production of large-area conductive track patterns. Such track patterns are also needed for solar cells as electrical contacts to dissipate photocurrent.

The scientists use a thin laser-structured aluminum layer as a mask for the electrodeposition of the electrical conductors. The process is not only cost-efficient, it is also environment-friendly and resource-saving: aluminum is relatively easy to filter out of wastewater, and the small amount produced in the process can be fully recycled.

The technology can be used to produce flexible and transparent organic solar cells in a roll-to-roll process that can be integrated in a wide variety of applications. For example, the team has already been able to use the newly developed process sequence to produce 20-µm wide, galvanically reinforced conductor tracks on film substrates for flexible organic solar cells.
A second application scenario targets the production of novel, high-efficiency hetero-junction solar cells: cold metallization as developed using the LEO method could make their production much more cost-effective in the future.

The project is being funded under the internal Fraunhofer program WISA.

Innovative chip integration in human-machine interaction systems

Intelligent interactive systems for human-machine interaction (MMI) are increasingly being used in a wide range of applications in the fields of Industry 4.0, Smart Health, Smart Security and Automotive. In this context, sensor systems for the nonverbal exchange of information in the near-distance and contact range are essential for both functionality and safety.

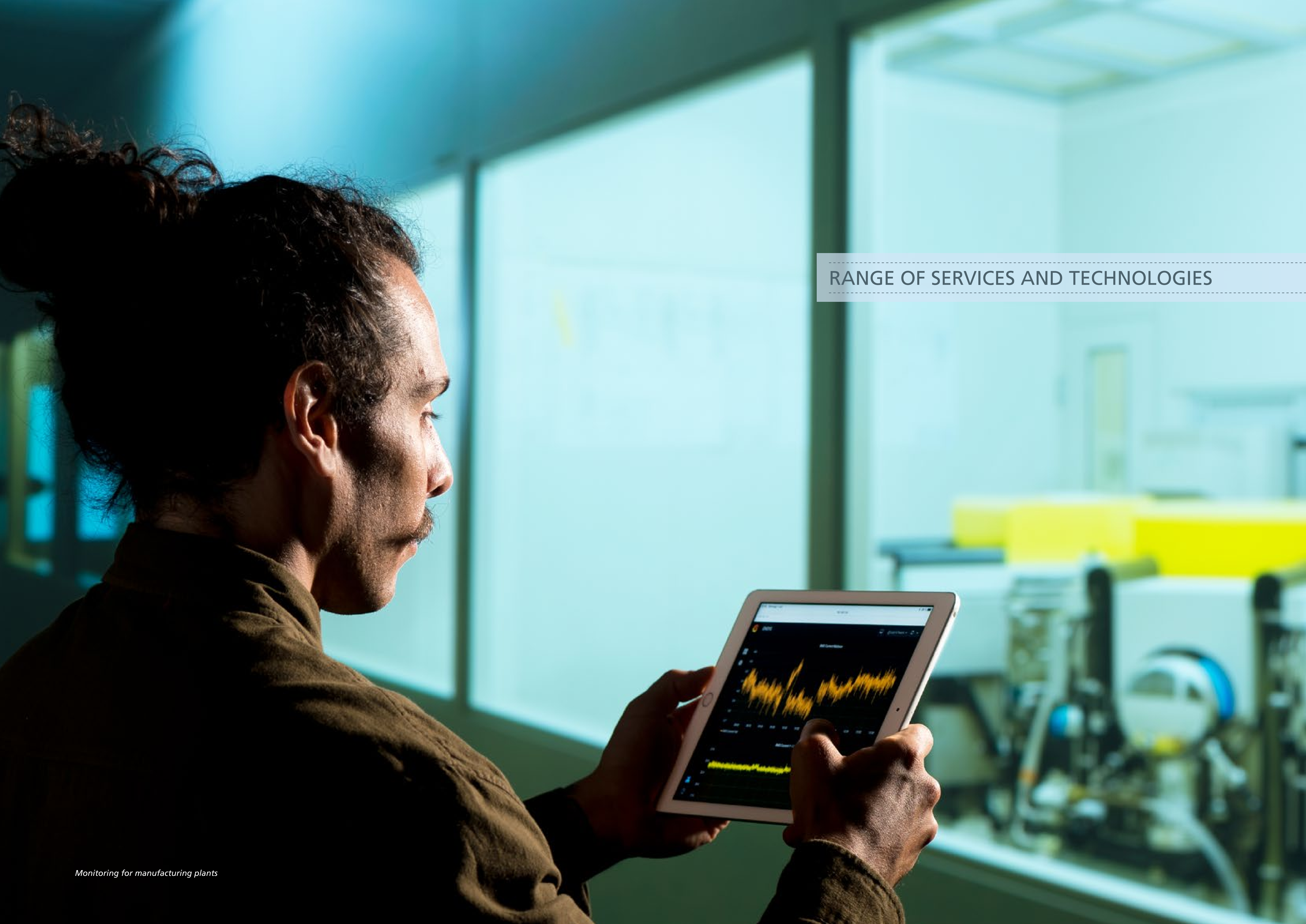
The approaches used to date for monitoring surfaces and objects are based on individual solutions involving tactile or proximity sensors with differing physical operating principles. Capacitive techniques and ultrasound-based methods have proved to be the most suitable. Current drivers of sensor development are the acquisition of high multimodal information density using miniaturized sensors and real-time response of the overall system for use in robotics, prosthetics, and the consumer market. Here, technical reproduction of the human hand and the flexible gripping processes ("reactive gripping") that this enables are key competencies for the manufacturing industry and medical technology. However, MMI requirements for energy-efficient three-dimensional detection with increasing lateral (< 700 µm) and axial (< 1 mm) resolution as well as fast signal utilization (> 20 Hz) cannot be met using the currently available solutions.

The project ProtaktilUS addresses these growing market requirements in the field of tactile proximity sensing, providing an innovative modularized MEMS technology and sensor platform for a new business area within the Fraunhofer-Gesellschaft. Fraunhofer EMFT researchers are working with the Fraunhofer Institutes IPMS, IKTS and IFF on the first chip integration of high-resolution capacitive and ultrasound-generating elements on the CMOS-compatible platform. As part of this project, a demonstrator is being developed for the use case of reactive gripping in robotics for the handling and identification of objects with different properties.

This innovation of the developed module platforms MEMS, electronics and signal processing is expected to pave the way to further fields of application in industry, medicine, consumer products and safety in the future.

The project is funded under Fraunhofer's internal MAVO program.

RANGE OF SERVICES AND TECHNOLOGIES



Monitoring for manufacturing plants

Maintenance and monitoring of a cleanroom facility

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 & Small Series Production

- System design
- Layout
- Device design and construction

Analysis & Test

- Risk and problem analysis
- Development of test methods and equipment
- ESD qualification tests
- Integrated circuit analysis

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, the German federal states, the EU
- Coordination of industrial project consortia
- Consultancy for national and EU research applications

Start-Ups & Joint Ventures

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

FRAUNHOFER EMFT RANGE OF TECHNOLOGIES

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

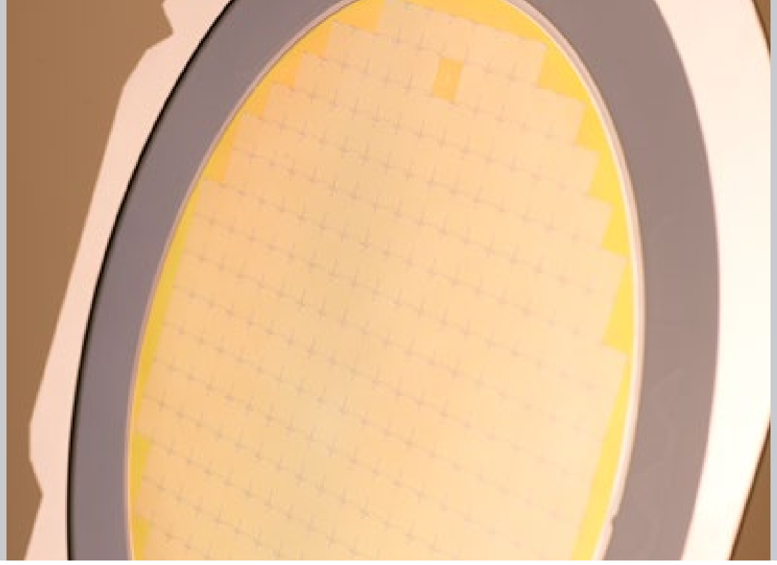
- Cleanroom technology for 150mm wafers (silicon, ceramics, glass)
- Metal coating (Cu, Ti, TiW, Pt, Au, Ni)
- Dielectric layers (Si, SiO_2, Si_3N_4, SiC, polyimide)
- Wafer bonding, bonding techniques by means of adhesion
- Structuring with mask aligner 2 µm

Substrate processing

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

Analytics & 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 prepration 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
- Measurement of minority charge carrier lifetime in semi-conductors by means of Microwave Detected Photocon-ductivity (MDP)



8" silicon wafer with low-noise varactor diodes

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

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

- Hot roll laminator for double-sided lamination
- Digital roll-to-roll direct lithography system (LED DLP)
- Sputtering system for double-sided metallization of PET and PI films with 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 & Test

- Semi-automatic wafer prober up to 300 mm with thermo chuck
- 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
- Permanent bending tester for flexible and rigid-flex structures
- Physical analysis of integrated circuit boards
- High-resolution X-ray tomography and laminography for devices and printed circuit boards
- ESA – Accepted Qualification Lab
- High-resolution scanning electron microscope with EDX analysis
- Confocal 3D laser scanning microscope
- Tension/compression material testing machine with climate chamber and video recording
- Electrodynamic oscillating system with three-axis clamping device
- Environment simulation laboratory
- Measuring device to detect ionic contamination
- Friction corrosion tests on soluble compounds
- Zwick universal testing machine with heating and cooling facility
- CC-EAL6 certified safety laboratory
- Partial housing opening and back thinning, mechanically and with laser
- Physical analyses of integrated circuit boards
- Nanoscale retrograde preparation
- Nanoscale chip scanning
- Layout extraction

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

ZVE – CENTER FOR INTERCONNECTION TECHNOLOGIES

Fraunhofer EMFT in Oberpfaffenhofen, the building that houses the ZVE (Center for Interconnection Technologies)

Training room with 16 fully fitted workstations for practical hand soldering

ZVE soldering mobile for virtual practical training

ZVE – CENTER FOR INTERCONNECTION TECHNOLOGIES

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, press-fit and crimping are still an integral part of connection technology for electronic modules: these methods guarantee a high level of quality and reliability. With more than 30 years of experience, the ZVE in Oberpfaffenhofen has become well established as a training and professional development center.

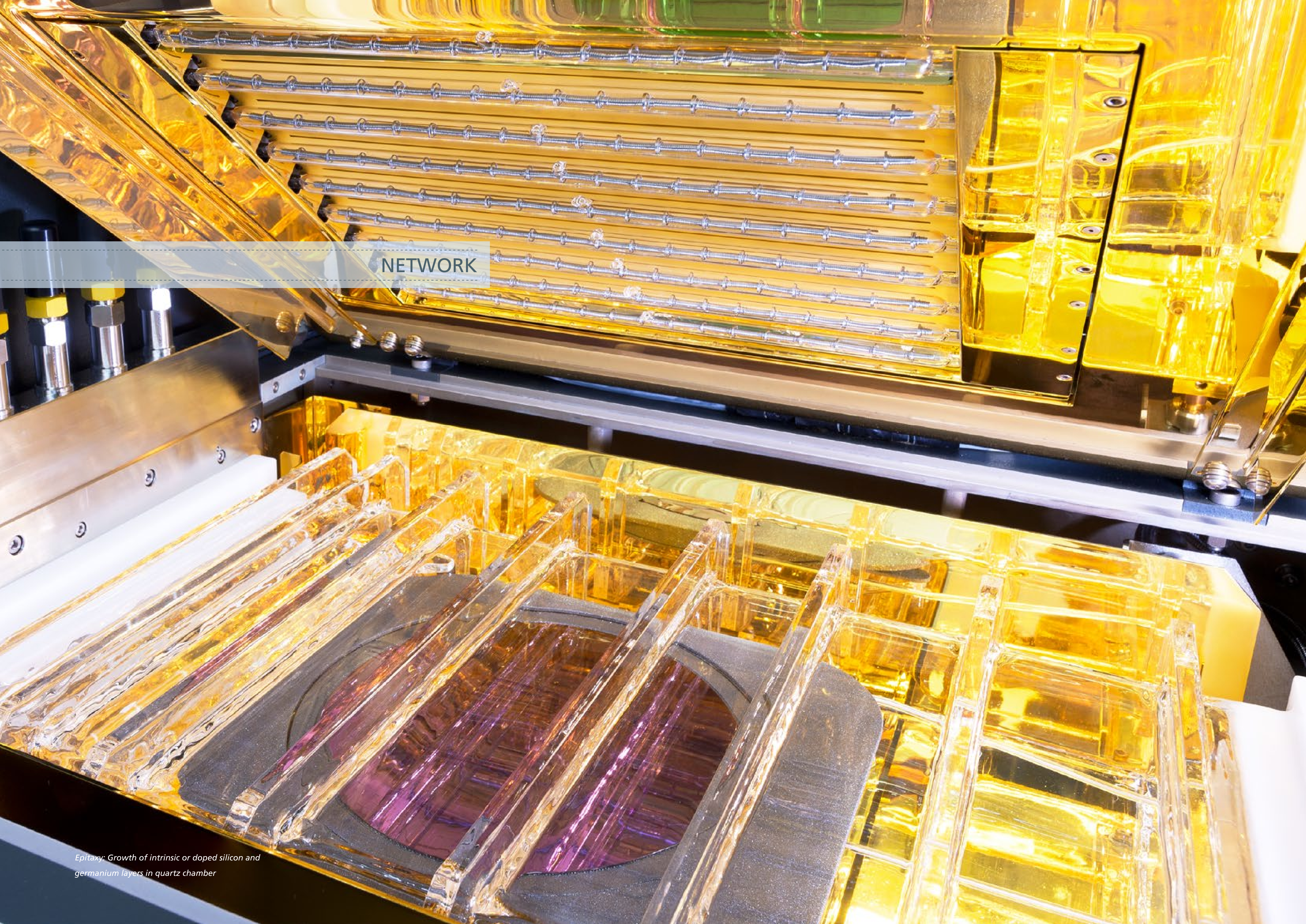
The modern training concept used by the team in Oberpfaffenhofen is based on the fact that it is virtually impossible to separate learning and work in the modern working environment. The "knowledge worker" is now long-established at conventional production plants, too: ongoing professional development 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 needs. iAcademy learning apps produced by the Fraunhofer Academy are used for seminar preparation and follow-up. The spectrum of course topics ranges from manufacturing technologies and information on installation and production (soldering, crimping and press-fit technology) through to repair and maintenance procedures. The knowledge imparted is fed directly from current R&D activities on the production of electronic assemblies and electrical-mechanical connection techniques (such as screws, plugging, press-fitting, insulation displacement connections and many more) into the training curriculum.

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, fretting corrosion test stands, high-current loading for cable harnesses and a well-equipped metallography lab. Longstanding contacts with the automotive and aerospace industries mean that the qualification of electronic modules under tough environmental conditions is one of the training center's core areas of expertise. In times of the COVID-19 pandemic, targeted hygiene concepts and online training enabled us to successfully continue our training in all essential areas. With the newly designed soldering mobile, it was even possible to conduct remotely monitored practical training: the fully equipped mobile soldering station is put into operation at the customer's premises via a standard 220V connection. The trainer's live presentation can be synchronized with the user's own exercise session, while four observation cameras even enable "eye contact" from different positions.

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 – especially in safety-sensitive areas such as autonomous driving.

Training and professional development to the very highest standards:

- The ZVE is accredited as an initial training and instruction center for highly reliable solder and crimp connections by both the European Space Agency ESA (cf. ESA STR-258) and the Association Connecting Electronics Industries IPC.
- In 2019, the training center team passed their regular audit as an ESA-accredited training center with flying colors. Two of the ZVE trainers are certified as Category I instructors – the highest level according to ESA criteria.
- The ZVE is part of the modular training system of the soldering training association Ausbildungsverbund Löttechnik Elektronik (AVLE) and offers vocational training for soldering specialists.
- For all training courses offered by the ZVE, the trainers also hold the IPC-recognized qualification as Master Trainer.



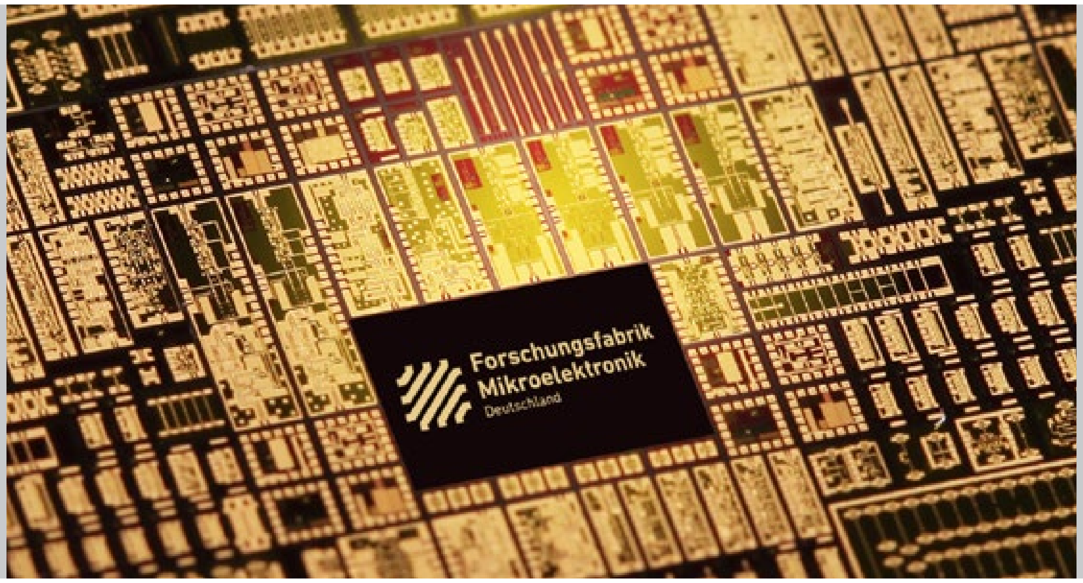
Epitaxy: Growth of intrinsic or doped silicon and germanium layers in quartz chamber

RESEARCH FAB MICROELECTRONICS GERMANY (FMD)

One-Stop-Shop: From basic research to customer-specific product development
Since April 2017, Institute XY and 12 other member institutes have formed the cross-site collaboration Research Fab Microelectronics Germany (FMD). With over 2000 scientists from the Fraunhofer Group for Microelectronics and the Leibniz institutes FBH and IHP, this research association is the largest and world-leading R&D group for applications and systems in micro- and nanoelectronics.

Consolidating the FMD
The FMD, with the aim to conduct research and development in Germany across several locations, was in its inauguration phase until 2020, supported by the Federal Ministry of Education and Research (BMBF) with around 350 million euros. This mainly involved modernising the research equipment of the 13 participating institutes of the Fraunhofer-Gesellschaft and the Leibniz Association. With a new concept for sustainable operation, the FMD is now entering the productive phase after the initial project period.

Versatile cooperation opportunities
In addition to the range of services for its customers from industry, FMD also offers a wide variety of cooperation opportunities for its partners in science. Among the highlights are services that aim directly at processing research questions cooperatively, for example through collaborative work in joint projects and the operation of so-called Joint Labs. In addition, it is possible to commission FMD institutes to test basic research concepts in the institutes' facilities with regard to their suitability in more application-oriented environments. Good examples of cooperation between FMD and universities as well as other institutions of higher education include the ASCENT+ project, the "iCampµs" research collaboration and the SmartBeam-Lab Joint Lab in Duisburg.



LZSiS – HIGH PERFORMANCE CENTER FOR SECURE INTELLIGENT SYSTEMS

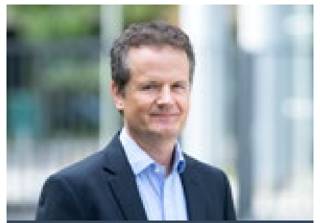
Clustered competences and versatile know-how for secure intelligent systems: that's what the LZSiS is all about! As a joint initiative involving six Fraunhofer institutes (AISEC, EMFT, IBP, IGCV, IKS, IVV), the Technical University of Munich, the Bundeswehr University and Munich University of Applied Sciences, LZSiS brings together university and non-university research in the relevant subject areas so as to make digitization available to customers from a wide range of industries.

LZSiS supports transformation processes in all phases – from conception through to the implementation of digital process chains and new business models. Particular attention is paid to the comprehensive security of the system solutions: a secure path from sensor to cloud. The overriding objective is to identify digitization potential in the various sectors in collaboration with partners and customers and translate this potential securely into practice. Individually tailored, secure system solutions are provided through synergetic, cross-disciplinary and cross-industry cooperation and a powerful network. Cooperation with LZSiS as a neutral and manufacturer-independent partner institution enables companies – from start-ups and SMEs through to large-scale corporations – to identify digitization potential within the framework of funding initiatives or direct orders and implement this securely in accordance with their own requirements. The services offered range from innovative, intelligent sensor system solutions to company-wide cyber security concepts and customer-specific workshops or training courses. The High Performance Center offers extensive technological expertise in the areas of cyber and hardware security, innovative sensor technology, intelligent networking and AI. In addition, a unique research infrastructure (e.g. cyber security laboratory, clean room environment etc.) is available for project participants. In combination with outstanding industry expertise in such application fields as food and packaging, foundry and construction, the center is a powerful partner when it comes to digitization.

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 notes 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
- Conception, evaluation and validation of new communication architectures and technologies for vehicle environment networking that offers real-time capability, reliability, safety and security
- Testing conformity, performance and security in dedicated test environments and customer scenarios

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 (in retirement since 2020). 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.

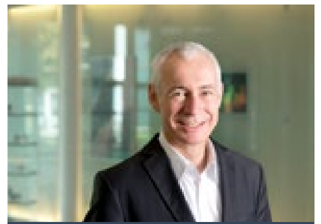
Dresden University of Technology

Prof. Peter Kücher

Dresden University of Technology 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: Prof. Peter Kücher's courses at the Institute of Semiconductor and Microsystems Technology (IHM) focus on the relationship between technological and economic challenges in microelectronics. Globalized competition requires specialization and resegmentation of the value chain.

For this reason, current trends in microelectronics/nanoelectronics – from "More Moore" to "More than Moore" – are the main focus here.

Bundeswehr University Munich



Prof. Christoph Kutter

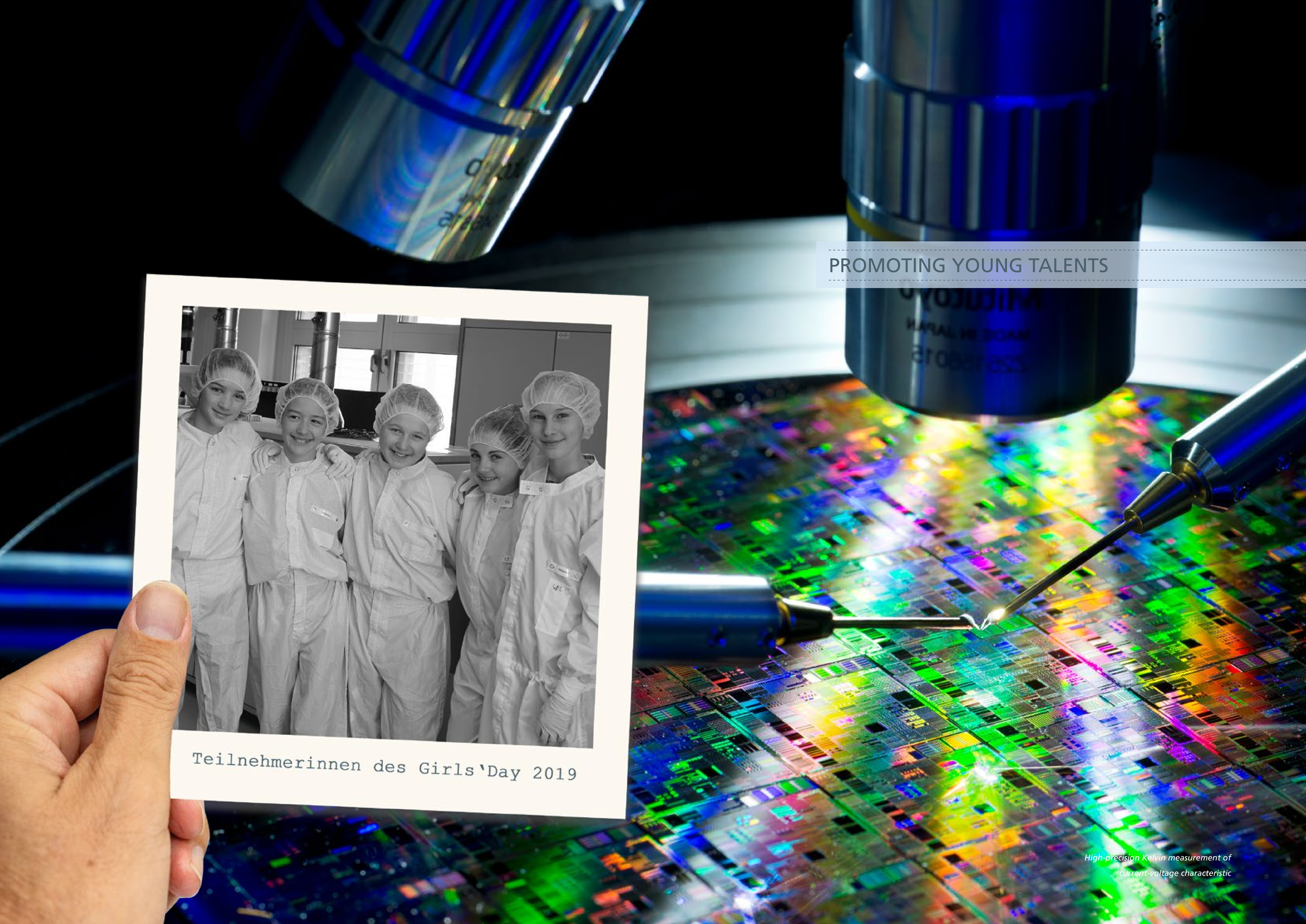
Prof. Linus Maurer

Prof. Ignaz Eisele

There are close links 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 up until 2020 headed up the business area Silicon Technologies and Devices at Fraunhofer EMFT.

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.

PROMOTING YOUNG TALENTS



High-precision Kelvin measurement of current-voltage characteristic

Eva-Maria Korek, former master's degree student
© Fraunhofer EMFT

STUDENT ASSISTANT AT FRAUNHOFER EMFT – THE WILLINGNESS TO LEARN IS A KEY SUCCESS FACTOR

Interview with former master's degree student Eva-Maria Korek

"I decided to do my final thesis at Fraunhofer EMFT because here you get an insight into both research and industry. That's a great help when you come to make a decision later about what direction you want to take."

What did you do at Fraunhofer EMFT?

Eva: I wrote my master's thesis here at Fraunhofer EMFT in the Silicon Technologies and Devices department as part of the EU Smart Vista project. If found the project fascinating, not least because of its very specific relevance to day-to-day life: the aim is to be able to detect the most common cause of death in Europe – cardiovascular disease – early on and prevent it as far as possible.

How did you end up coming to Fraunhofer EMFT?

Eva: I found out about Fraunhofer EMFT through a fellow student who highly recommended the working environment here. I first applied as a research assistant in the micropumps department. For my master's thesis, I wanted to get to know a different specialist area, so I applied to the neighboring department via the online platform. That's how I came to do my master's thesis.

What does Fraunhofer EMFT have to offer students?

Eva: I chose Fraunhofer EMFT because the topic areas here are really fascinating – it's a combination of science and industry, if you like: the things you develop relate directly to practical applications and potential use cases. And there's the advantage of being able to earn a small income too, of course. Another great aspect was the opportunity to establish really good contacts all over Europe, especially when working on the EU project.

What is your advice to students who want to apply to Fraunhofer EMFT?

Eva: If you want to apply here to be a student assistant or do a thesis, it's very helpful if you can show you're willing to learn. This is much more important than knowing everything perfectly before you get here. You work in a team here, you can get help from your supervisor and there's plenty of time to learn the ropes. If you're willing to learn, all you need to do is apply!

CAREERS AT FRAUNHOFER EMFT

I joined the Analysis & Test group as a placement student in August 2020. My tasks are very varied, ranging from software development for measuring stations, specifications and data analyses to lab tests. But I'm involved in project planning and management, too. I like the fact that you get the opportunity to contribute a lot of your own ideas at EMFT. That's why I can well imagine staying here for longer.

Igor Rzhin

Since October 5, 2020 I've been working in the Microdosing Systems department for my internship semester. My activities are very varied. I carry out metrological tasks, for example: for these I'm allowed to do independent analyses and create short reports, both for internal purposes and for customers. I also solder electrical components and program device drivers. I particularly like the fact that I can take on smaller project tasks on my own responsibility. I really enjoy working at EMFT because it gives me excellent insights into a wide range of themes and projects, and I'm also involved in internal processes. Not only do I learn a lot in terms of my technical training, I'm also getting all kinds of valuable experience for my future career. I mainly owe this my great colleagues: they're always very supportive and take time to answer any questions I have. My next career goal is to get my bachelor's degree.

Jan Lützelberger

I haven't been here that long: I started as a master's degree student in the Microdosing Systems department on December 1, 2020. My master's thesis is an investigation of the mechanical resilience of MEMS actuators. After about three months here, my overall impression is very positive: it's nice to have a lot of freedom and have a say in how you pursue your work and your research. I also really like the atmosphere here.

Doris Zhou

I've been employed as a research assistant in Business Development since April 20, 2020. In my work at Fraunhofer EMFT, I'm helping to develop a new process for patterning copper-based conductive tracks for microelectronic applications, with the aim of combining sustainability with cost-effectiveness. During my time at Fraunhofer EMFT, I've found my colleagues to be enormously helpful and supportive. I particularly like the open cooperation, good communication and flat hierarchies at EMFT. I can organize my working hours flexibly, so that makes it easier to strike a good balance between university studies and work. I also have the opportunity to learn from the vast experience of a diverse, international team, and I'm very grateful for the feedback and mentoring I get from colleagues. My next career goal is to complete my master's degree in Management & Technology at the Technical University of Munich.

Konstantin Hauser

I started in July 2019 as a placement student in the Microdispensing Systems department and have been a master's student there since July 2020. In my master's thesis I'm looking into the leakage rates of silicon and stainless steel micropumps. My aim is to develop a model system that will enable description and assessment of leakage rates based on certain design parameters. I really appreciate the friendly atmosphere at EMFT. It's exciting to be able to work in a team alongside so many expert colleagues. At Fraunhofer, you also get a great insight into the "real world" beyond academia. There is also a flexible approach to working methods and hours which suits me very well as a student.

Philipp Maier

In September 2020 I started my training in microtechnologies at Fraunhofer EMFT in the Microtechnology and Devices department. Here I'm learning how the various processes work, which substances are used and what their properties are. The training curriculum also covers the various machines and appliances: in addition to finding out how they function, this also includes knowing how to repair a device when something goes wrong or doesn't work at all. When a process is completed, the measurement data is then analyzed. I find the training very varied: it's not limited to one subject – there's a bit of everything. My trainer and my colleagues take a lot of time for me: you always get a detailed explanation of why things are the way they are. I also think it's great that the people here place a lot of trust in the trainees. You get to hold expensive or fragile things in your own hands, for example. The atmosphere is pleasant and supportive.

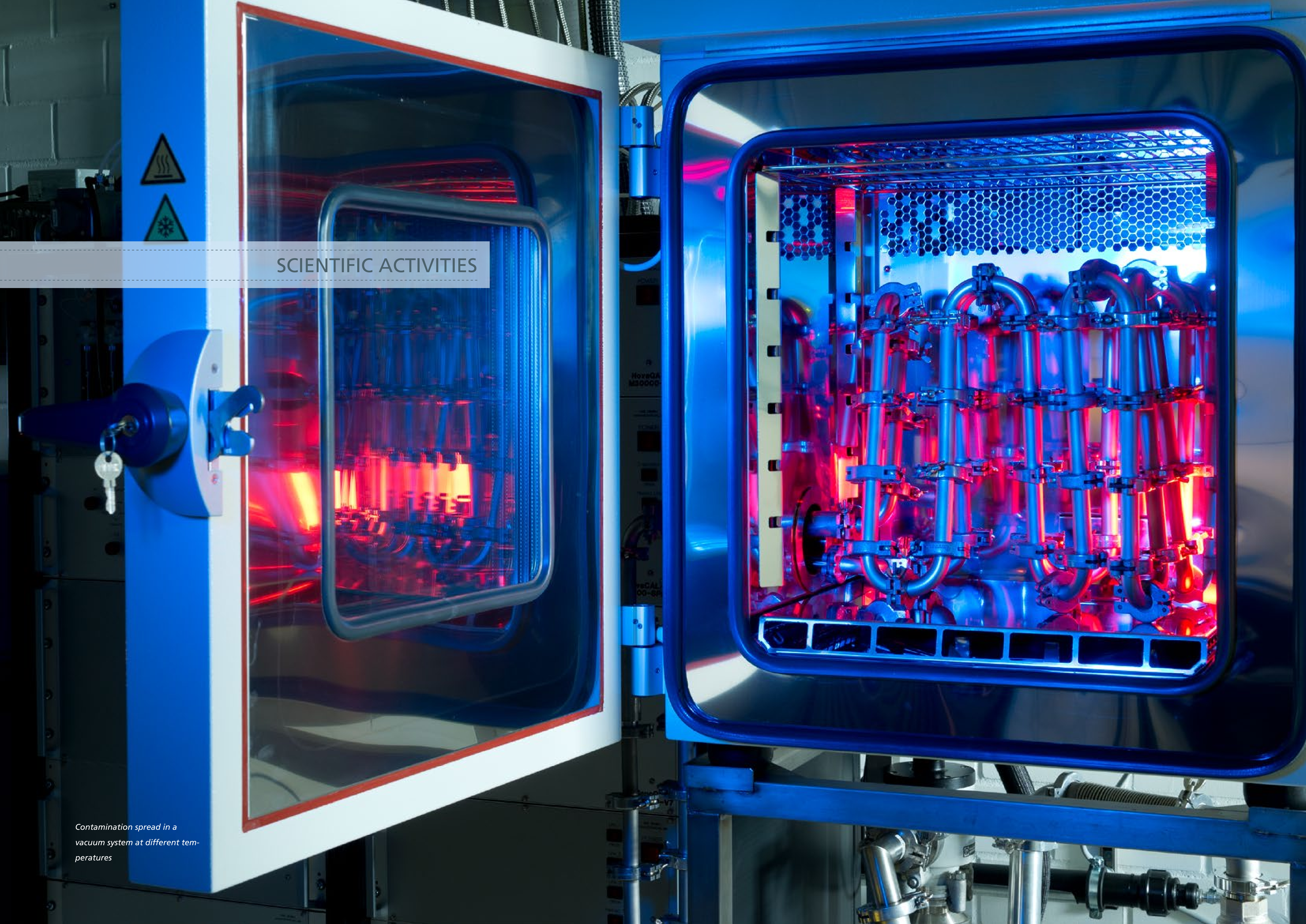
Saskia Heinze

As part of my studies I started work as a placement student in the Silicon Technologies and Devices department on October 1, 2020. In my team I help with wafer prober and layer thickness measurements in the cleanroom. I also perform analyses with Python and help automate the control of certain machines. I really like my work at Fraunhofer EMFT because there are so many different and fascinating areas. It's great to get to see how things work in a cleanroom while at the same time being able to expand my programming skills. At the moment I'm in the first the semester of my master's degree program so my initial aim is to get my master's.

Hannah Lange

Since December 1, 2019 I've been employed as a placement student in the Flexible Systems/ Polytronic Technologies department, where I work on various projects. I'm building a demonstrator based on a Raspberry Pi for the Secure Foil project, for instance. I'm also involved in the Ulimpia project: I test and simulate pH-sensitive wound monitoring sensors, then redesign and optimize them – a fascinating subject that I'd very much like to pursue further in my master's thesis! My impression of the work culture here is very positive: you have a lot of freedom and you can work independently. At the same time, your colleagues are very supportive and you virtually always have someone you can talk to. The fact that you're involved in different projects means that the activities are very varied. I also think it's nice that feedback is always welcome and taken on board. As I see it, my job at EMFT is a great example of how you can directly apply knowledge gained during your studies and, by the same token, learn things relevant to your studies at work.

Canbey Oguz



Contamination spread in a vacuum system at different temperatures

Miniaturized reverb-based current sensor module

PUBLICATIONS, LECTURES AND AWARDS

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Keynote Speech, 4th India ESD Workshop, Bangalore, February 26-27, 2020

Award

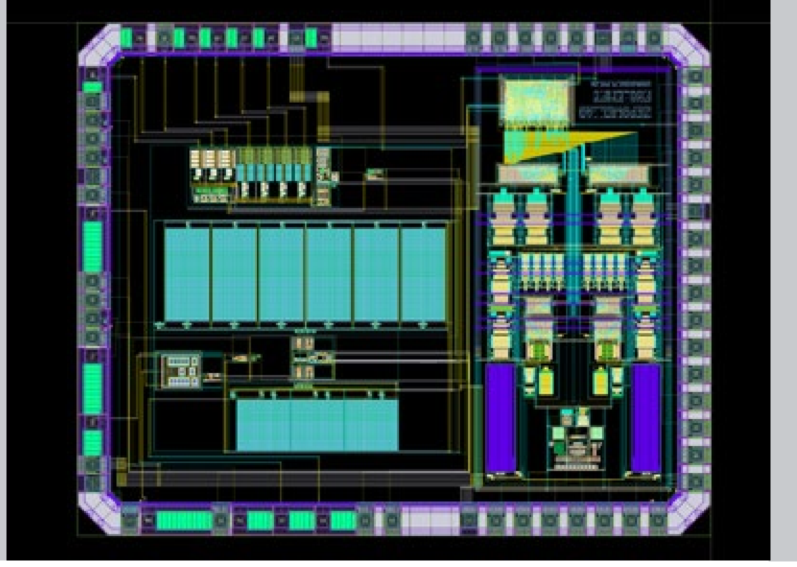
Together with his Japanese colleague Prof. Mitsumasa Koyanagi (Tohoku University), Dr. Peter Ramm was awarded the prestigious Electronics Packaging Award 2020. One of the Technical Field Awards of the Institute of Electrical and Electronics Engineers (IEEE), the world's biggest professional association in the field of technology, it honors winners for "Leadership in specific fields of interest" every year. With this distinction, the IEEE is recognizing Koyanagi's and Ramm's merits and pioneering work that led to the development and commercialization of 3DIC integration.

The awards ceremony is due to take place on June 1, 2021, at ECTC San Diego.

This award is the Electronics Packaging Society's highest honor and was established in 2002 for excellence in advancing component, electronic packaging and manufacturing technologies. Nominees are judged on a broad range of criteria, including leadership in the field, impact of work on advancing technology, originality and benefit to society.

IEEE Electronics Packaging Award 2020

Prof. Mitsumasa Koyanagi and Dr. Peter Ramm taking part in the festive Japanese tradition "Kagami Biraki" – the opening of a sake barrel (December 2019)



Layout of the Zepowel test chip with a pump driver and a particle sensor front end

BACHELOR THESES

Christine Drießlein
Derivation of phenotypic effect profile of nitrate by impedance-based assays.
Bachelor thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

Til Friebe
A measurement setup to investigate the impact on micropumps of pumping protein solution
Bachelor thesis, Technical University Munich
Supervisor: Agnes Bußmann

Ng Ming Feng
Implementation of Electrochemical Impedance Spectroscopy on Microcontrollers
Bachelor thesis, Technical University Munich
Supervisor: Matthias Steinmaßl

Lisa Tetek
Invasive and non-invasive studies on potential cytotoxicity on converting nanoparticle
Bachelor thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

Jack Qiu
Comparison of efficiency and robustness in the analysis of 14C and ^{3}H
Bachelor thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

Anna Saridis
Comparison of efficiency and robustness in the analysis of the 90Sr
Bachelor thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

Robert Jacumet
Characterization of Al-TiO2-Al and Al-Ta2O5-Al memristors
Bachelor thesis, Technical University Munich
Supervisor: Prof. Marc Tornow, Daniel Reiser

MASTER THESES

Marc Dannenmaier
Propagation of water in a vacuum system – Design and assembly of a measuring system for time-dependent detection of a water pulse
Master thesis, Technical University Munich
Supervisor: Rudolf Schönmann

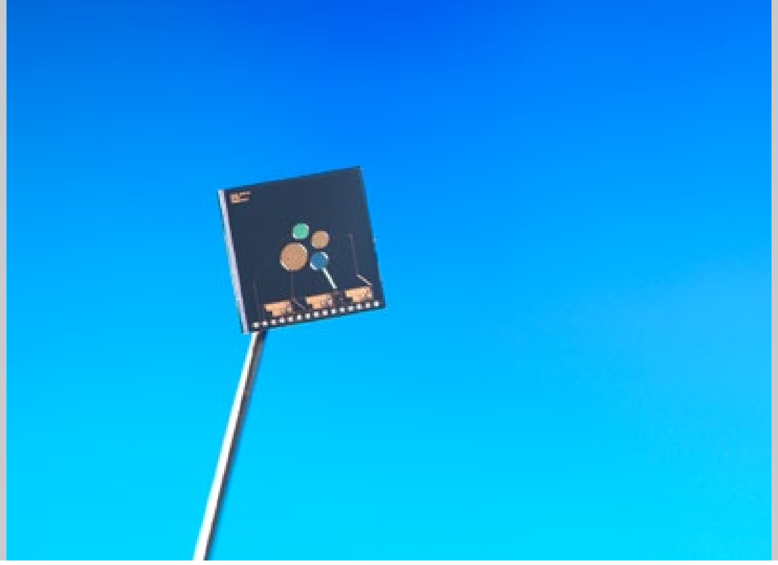
Lucas Reganaz
Capacitive transducer design for particulate matter sensor
Master thesis, Grenoble INP
Supervisor: Oleg Sakolski

Raghavendra Padmanabha
Current Sensing Network for Industry Application
Master thesis, Technical University Munich
Supervisor: Bassem Badawi

Eva-Maria Korek
Development of an Electrochemical Microsensor for Monitoring Biomarkers in Sweat for Healthcare Applications
Master thesis, Technical University Munich
Supervisor: Jamila Boudaden

Jonathan Preitnacher
Development of a detector system for measuring radioactive substances in scrap recycling
Master thesis, Munich University of Applied Sciences
Supervisor: Bassem Badawi

Tobias Naber
Extending microphysiometry to cell layers cultured on permeable substrates
Master thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener



CMOS ion-sensitive field-effect transistor with controllable floating gate (FG-ISFET)

Bettina Brechenmacher
Functional consequences of translocators protein (TSPO) overexpression or knockout / knockdown in human brain tumor initiating cells (BTICs)
Master thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

Daniel Anheuer
Fabrication and characterization of an electrostatic drive for MEMS micropumps
Master thesis, University of Stuttgart
Supervisor: Henry Leistner

Viktor Böpple
Fabrication and characterization of a piezoceramic silicon composite for MEMS applications
Master thesis, Munich University of Applied Sciences
Supervisor: Yücel Congar

Christina Patrizia Pfab
Interactions between ceftazidime and 5-fluorouracil in colon cancer
Master thesis, University of Regensburg
Supervisor: Prof. Joachim Wegener

Mauriz Trautmann
Investigation and Implementation of Machine Learning Algorithms for Condition Monitoring of Piezoelectrically Driven Micropumps
Master Thesis, Technische Universität München
Supervisor: Johannes Häfner

DOCTORATES

Christian Engst
Minority charge carriers – lifetime measurement and defect spectroscopy on silicon with a high specific resistance

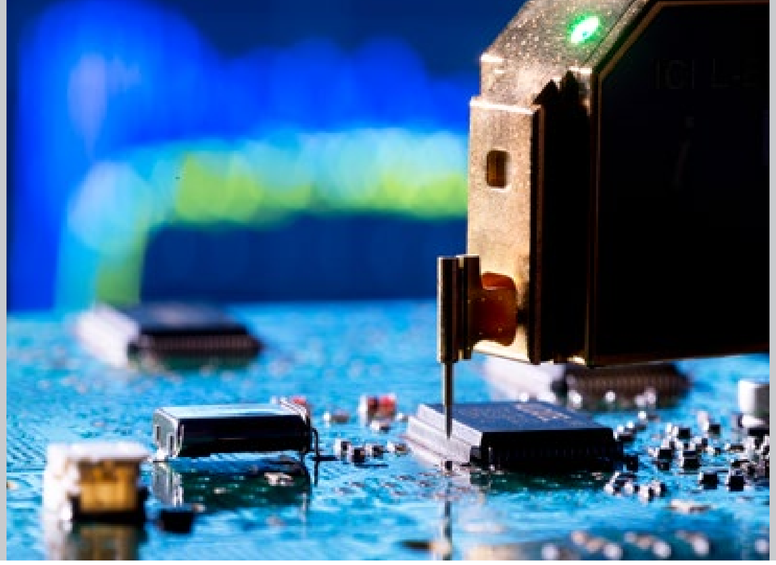
The doctoral dissertation was completed from 2016 to 2019 as part of a cooperation between Fraunhofer EMFT (Silicon Technologies and Devices) and the Technical University of Munich. The dissertation was supervised by Prof. Christoph Kutter and successfully defended on November 17, 2020.

Nagarajan Palavesam
Reliability analysis of foil substrate based integration of silicon chips

The doctoral dissertation was completed from 2016 to 2019 as part of a cooperation between Fraunhofer EMFT (Silicon Technologies and Devices) and Dresden University of Technology. The dissertation was supervised by Prof. Karlheinz Bock (Dresden University of Technology) and successfully defended on October 26, 2020.

Zlatko Paric
Development of a dual ECIS-SPR sensor platform for cell-based assays: label-free analysis of g-protein coupled receptor signal transduction

The doctoral dissertation was completed from 2016 to 2019 as part of a cooperation between Fraunhofer EMFT (Cell-Based Sensors) and the University of Regensburg.
The dissertation was supervised by Prof. Joachim Wegener and successfully defended on February 5, 2020.



Probe for the injection of stress pulses

PATENTS

Thin chip-foil package with indirect contacting
Robert Faul
DE 10 2019 202 720.2

Thin dual foil package
Robert Faul
DE 10 2019 202 718.0

A method for enabling planar thin packaging for MEMs sensors
Ronnie Bose, Christof Landesberger
US 10,752,499

Degassing device
Martin Richter, Axel Wille, Christian Wald
DE 102016220107.7

Foil-based package with distance compensation
Erwin Yacoub, Waltraud Hell
DE 10 2019 202 715.6

Flex foil package with coplanar topology for high frequency signals
Robert Faul
DE 10 2019 202 716.4

Flex foil package with extended topology
Robert Faul
DE 102019202717.2

Open jet dosage system to dispense a fluid in or under the skin
Martin Richter, Martin Wackerle, Christian Wald
US 10,792,430

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

Combined pump-sensor arrangement
Siegried Röhl, Yücel Congar, Christoph Kutter, Martin Richter
DE 10 2019 202 722.9

Microdosage system
Martin Richter, Martin Wackerle, Sebastian Kibler
US 10,550,833

Nanoparticle-based semiconductor structural element
Armin Klumpp
CES 18208574

PUF film and method for producing the same
Martin King
EP 3550623/A1

Carrier substrate and method of attaching a substrate structure
Christof Landesberger
WO2014117853

Device with protection level range for direct or indirect detection of one or more biological agents
Sabine Trupp, Jennifer Schmidt
DE 10 2019 200 595

Device and method for driving a load
Frank Vanselow, Bernadette Kinzel, Erkan Isa
WO 2018/006964

Apparatus and method for detecting gases
Trupp Sabine, Henfling Michael, Hemmetzberger Dieter, et al.
DE 10 2018 206 917.4

CONTACT

Steel micropump with piezoelectric drive

To prevent a short circuit, the disk actuator is separated from the metallic base body of the pump by an insulating foil. The micropumps can accurately dispense minute amounts of liquid, which is essential in many medical applications such as drug dosing and wound therapy.

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PUBLISHING NOTES

Fraunhofer EMFT Annual Report 2020

Publisher:
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Tel.: +49 89 54759-0
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Publication of any material is subject to editorial authorization.

Layout/typesetting:
Simone Brand
Johanna Markl

Print:
Förster & Borries GmbH & Co. KG
Industrierandstraße 23
08060 Zwickau
www.foebo.de

@ Fraunhofer EMFT
Munich, March 2021

Cover photograph:
Stress test for the evaluation of the robustness of systems

Picture on intermediate page (p. 2/3 and 90/91):
TAIKO wafer in a wafer cassette

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