

Annual Report 2021

Sensors and Actuators for People and the Environment

#WeKnowHow

Fraunhofer EMFT

Customized Solutions

for customers &
cooperation partners

//

Our range of offers reflect the diversity of Munich's corporate landscape, which includes everything from large-scale corporations to highly creative start-ups. Rather than off-the-peg products, we aim to offer our customers tailor-made solutions that are as straightforward as possible while at the same time reflecting a high level of sophistication. It isn't the size of the project that matters: what really counts is how we can help our customers achieve success. The customer grows in the market and we grow with them as their technology partner – that's what I regard as a win-win situation. The result is often years of very sound collaboration with exciting customers."

Prof. Christoph Kutter
Director of Fraunhofer EMFT



Welcome Message

Dear Fraunhofer EMFT partners, customers and sponsors,

These are certainly interesting times we're going through right now. For almost two years, we've had to face challenges that probably none of us could ever have foreseen. It has been a painful experience for us to see how the dependence on international supply chains has slowed down our economy – and with it our capacity for research and innovation.

At this point, it is vital for us to take this as an opportunity to make strategic adjustments that are long overdue: Germany and Europe must become more independent again. Firstly, this means doing more to take the production of chips and semiconductor components back into our own hands. But it also means reflecting on our strengths: our expertise in the development of microelectronic components and systems for future applications such as next generation computing, quantum technologies, resource efficiency and bioeconomy. Here, developments will focus on the aspects of the performance capacity and

energy efficiency of both the systems as a whole and the underlying chips. As such, the expansion of systems and circuit technology will be a key future pillar for the success of Fraunhofer EMFT. In the area of Circuit Design, we were able to boost both our expertise and our team considerably last year. Fraunhofer EMFT has also had a second director at the helm since September 2021: Professor Amelie Hagelauer, who has an impressive track record in the areas of integrated RF and analog circuit technology. —> For further details, see page 6 of this annual report.

An integral part of this is both the protection of this valuable know-how and the certainty that these components will be absolutely reliable and tamper-proof in use. Hardware-based security has been an important mainstay of our portfolio for many decades, and we can be justifiably proud of our long-standing partnerships with renowned customers in this field.

We are therefore all the more delighted that in 2022 we will be able to reap the rewards of the intense preparatory work we completed in

2021: Munich Quantum Valley and the Trusted Electronics Center Bavaria are currently being established, two top-class research centers in which we will be able to advance the two major areas of quantum computing and trusted electronics together with colleagues at other Bavarian Fraunhofer institutes as well as a number of universities and non-university research institutions in Bavaria – with generous funding provided by the Bavarian Ministry of Economic Affairs of around 60 million euros in total.

Our scientists do great things every day – more than we could ever fit into this brief foreword. Nonetheless, there are two more highlights from 2021 we wouldn't want you to miss out on: in September, we presented our ROADAR

system for early detection of aquaplaning and black ice at the IAA Mobility show, including a live demonstration. —> See page 59 for some visual impressions. In November, we also had the pleasure of congratulating the team of the EU project Serene IOT on receiving the PENTA Innovation Award. This project involved the development of an IoT-enabled mobile analyzer for MRSA detection (—> see page 39 for details).

We now invite you to browse through the pages that follow and find out about what we do and did in 2021 – we wish you an intriguing read!

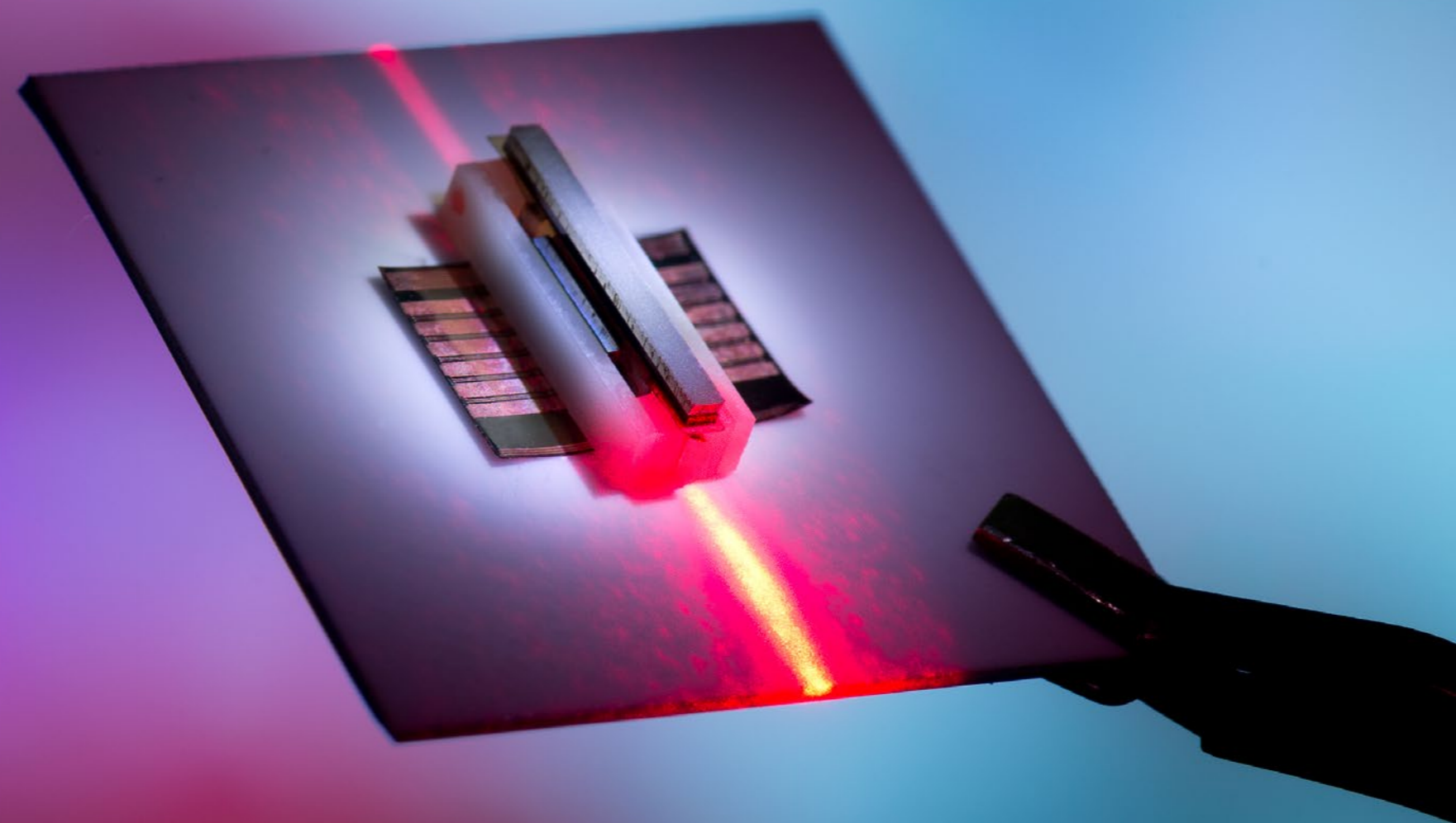
Best regards,

Prof. Dr.-Ing. Amelie Hagelauer

Prof. Dr. rer. nat. Christoph Kutter

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Electro-optical 3D subsystem for optical data transmission in the Tbit/s range with high-performance, flexible 3-chip-on-foil interposer

Innovation Through Complementary Competence

Prof. Dr. Amelie Hagelauer

Consistently advancing new subjects and coming up with answers to the complex challenges of our time – thanks in part to her strong pioneering spirit, Amelie Hagelauer is able to look back on an impressive career. Since September 2021 she has been head of Fraunhofer EMFT together with Christoph Kutter, and she was also appointed to the Chair for Micro- and Nanosystems Technology at the Technical University of Munich. Prior to this she held the Chair of Communications Electronics at the University of Bayreuth.



Circuit and chip design fascinated Amelie Hagelauer early on during her mechatronics studies at the University of Erlangen (FAU), where she also obtained her doctorate in 2010 with a thesis entitled “Loss mechanisms in BAW components for mobile communications”. She remained at FAU as an academic councilor, taking on responsibility for project management and personnel planning for the department in addition to her research and teaching activities.

Her research interests include RF chip design for communications and radar applications, analog and mixed-signal integrated circuits for AI applications, and microacoustic components for cellular applications. Hagelauer is very well connected in the scientific community: she sits on various committees of the IEEE UFFC-S, MTT-S and EuMA and is involved in organizing international conferences, as well as being an associate editor for the IEEE Transactions on Microwave Theory and Techniques.

Prof. Christoph Kutter

Research and industry – Christoph Kutter is at home in both worlds. He started his career as a guest researcher at the Max Planck Institute for Solid State Research at the High Field Magnetics Laboratory in Grenoble, France, before going on to obtain a doctorate in semiconductor physics and electron spin resonance at the University of Konstanz in 1995. The decision to study physics gave him something of an exotic status within his own family, which for generations was firmly established in the area of gardening and landscaping.



But breaking new ground is in Christoph Kutter's blood, as he proved over the next 17 years in various management positions in product development at Infineon Technologies AG and Siemens AG: among other things, he was head of development for the communications division and the chip card, and was in charge of the company-wide innovation initiative.

He was able to contribute his knowledge and experience when he joined Fraunhofer EMFT as its new director in 2012. At the same time, he was appointed to the professorship in the field of solid-state technologies at the University of the Federal Armed Forces.

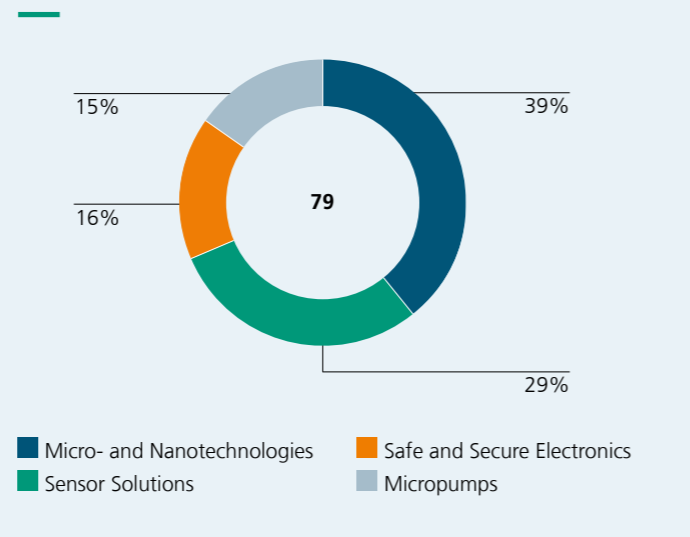
Christoph Kutter also holds several other positions: he is spokesperson of the Strategic Partnership for Sensor Technology e.V., a member of the VDE Supervisory Board, a member of the VDI/VDE IT Supervisory Board, a member of the Board of Trustees of the Eduard Rhein Foundation and a member of the scientific advisory board of the Bavarian Research Foundation.

People, Facts and Figures

79
Projects

Under the direction of this top-class duo, (→ page 6 f.), the Fraunhofer EMFT team was able to make its contribution to tackling the current challenges facing our society in 2021 with a total of 79 projects. More than one third of these – 39% to be precise – can be attributed to the area of expertise of Micro- and Nanotechnologies. This in turn forms the basis for the competences Sensor Solutions, Micropumps, and Safe and Secure Electronics. It is exactly this interdisciplinary interaction between these areas that helps us produce forward-looking solutions for people and the environment. (→ more about competences and projects from page 14)

Share of Research Projects by Competence

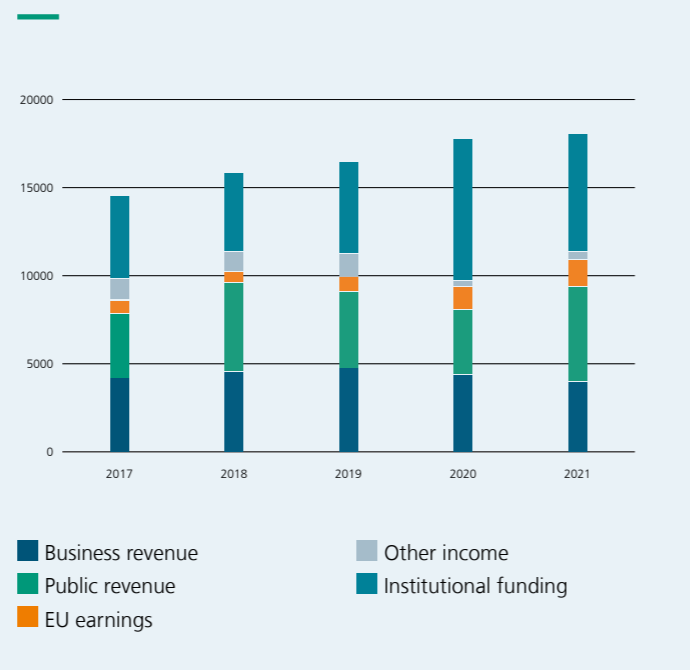


16.7 M€
Total Budget

24.5% share of the operating budget.

Research activities in 2021 resulted in a total budget of approximately 16.7 million euros. A total volume of approximately 3.96 million euros was generated through industrial contracts. This was

Financial Budget



139+
Employees

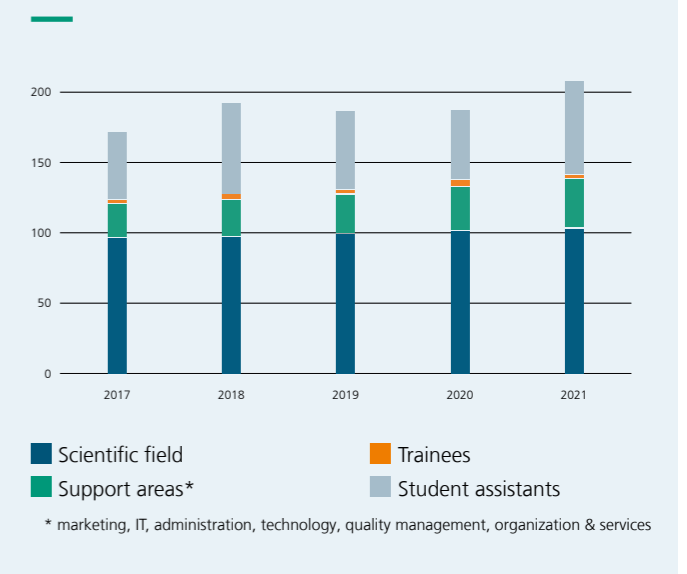
In order to achieve this, you need a strong team: as compared to the previous year, the permanent staff at the institution increased by four and consisted of 139 people in total at the end of 2021. Of these, 103 people are employed in the scientific area and 34 in support areas. The latter are made up of marketing, IT, administration, technology, quality management, organization and services. In addition, the Fraunhofer EMFT team has been supported by two trainees.

Another 66 student assistants from a wide range of universities and other higher education institutions were employed at Fraunhofer EMFT over the course of the year, either involved in Fraunhofer EMFT research activities and/or working on their final thesis (→ see page 42 f.).

At Fraunhofer EMFT, we stand for outstanding expertise from all over the world: our team comes from a total of 17 different countries. Together we drive forward research and development of sensor systems and actuators to the benefit of people 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.

→ For details of individuals to contact, see page 64 ff.

Team Size



Knowledge from Around the World



Fraunhofer EMFT

Pursuing research to shape the world



Fraunhofer EMFT stands for applied research with a strong industrial focus. Within national and European research alliances, we drive forward key forward-looking areas of research so to ensure prosperity and quality of life for future generations.

Our position at the interface between preliminary research and industry offers ambitious researchers an incredibly diverse and fascinating field of activity: this ranges from completely new subjects where preliminary research has to be conducted at the university with various solutions being investigated so as to establish underlying principles, through to tried-and-tested *ready-to-market solutions* where we are involved in adding the finishing touch. Thanks to this broad spectrum, we're able to help shape new solutions from start to finish while being able to draw on an ideally positioned network."

Prof. Amelie Hagelauer,
Director of Fraunhofer EMFT

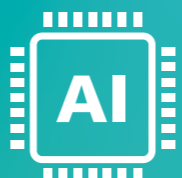
Strategic Research Topics

The motivation and common goal at Fraunhofer EMFT is to make a difference! Employees make targeted use of their longstanding experience and extensive expertise in microelectronics and microsystems technology to contribute actively to tackling the current challenges facing our society.

But what does this mean in concrete terms? Based on issues of current and future relevance to society, Fraunhofer EMFT identifies precisely those topics where its expertise really can generate added value. In short: the strategic research topics pursued by Fraunhofer EMFT, and by the Fraunhofer-Gesellschaft in general, are derived from where there is an **overlap** between the **challenges** to be met and the **expertise** that is available. As a result, these research topics are by no means static: they shift over time depending on the issues and problems to be solved as well as their degree of relevance and urgency. To this end, Fraunhofer maintains ongoing dialogue with policymakers, funding bodies and industry.

R&D activities recently focused on the following strategic research topics:

- Trusted Electronics
- Microelectronics for Quantum Technologies
- Neuromorphic Computing
- Sensors and Actuators for Smart Medicine
- Resource Efficiency in Microelectronics
- Sensors and Actuators for Smart Farming
- Artificial Intelligence (AI) for Sensor Technology



More Info

www.emft.fraunhofer.de/research-topics

Trusted Electronics

Electronics are trusted when they meet all of our expectations in terms of functionality and specifications while at the same time leaving no loopholes that would make them vulnerable to attack. Trusted electronics are essential, especially in sensitive areas of application such as medical technology, the automotive industry and aerospace technology. Fraunhofer EMFT expertise in the field of **Safe and Secure Electronics** enables research into the causes of complex faults and reliability problems, monitoring of electrical connections and development of concepts for hardware security and tamper protection in electronic systems.

Microelectronics for Quantum Technologies

Quantum technologies have the potential to be extensive game changers in areas such as quantum sensing for high-precision and high-performance sensors, as well as in quantum computing to solve computational problems where today's supercomputers fail. Nonetheless, there are still some challenges when it comes to the practical implementation of quantum technologies – and this is precisely where the Fraunhofer EMFT competences of **Micro- and Nanotechnologies** and **Safe and Secure Electronics** come into play as enablers. In the newly established Munich Quantum Valley (MQV), Fraunhofer EMFT's R&D activities seek to pursue reliable and scalable development and production of qubit chips, as well as their integration and miniaturization, so as to realize the smallest possible high-performance, reliable and energy-efficient quantum systems.

Neuromorphic Computing

Neuromorphic computing uses neural networks as algorithms for integrated circuits to enable parallel computation of data in distributed memories. This makes neuromorphic chips much faster and more efficient than existing processors. Fraunhofer EMFT is currently applying its expertise in **Micro- and Nanotechnologies** to carry out research into aspects such as neurologically inspired computer architectures with memristors based on new 2D nanomaterials, and to develop new memory technologies to realize analog and digital neuromorphic circuits.

Sensors and Actuators for Smart Medicine

One of the most multifaceted fields of innovation for the future is health research using smart solutions. As a research topic, smart medicine offers enormous potential for affordable health as well as advancements in medical care based on novel diagnostic and treatment options. Fraunhofer EMFT R&D activities are concerned with the development of innovative therapy solutions based on **Micropumps**, for example, as well as research into novel methods and systems for improved diagnostics using smart **Sensor Solutions**.

Resource Efficiency in Microelectronics

Resource conservation, energy efficiency and a significant reduction of the CO₂ footprint in microelectronics production are the main motivations behind the strategic research topic of Resource Efficiency in Microelectronics. Fraunhofer EMFT conducts research into the use of alternative, more environmentally friendly materials in **Micro- and Nanoelectronics** and their transfer to industry. Development of energy-efficient chips, monitoring of the energy consumption of semiconductor processes using smart sensor technology, and innovative abatement concepts and systems are other important research areas dedicated to more sustainable microelectronics.

Sensors and Actuators for Smart Farming

Ensuring a sustainable supply of food for the population is a fundamental challenge at the global, national and regional level. In order to enable more efficient and at the same time more environment-friendly food production in the future, Fraunhofer EMFT conducts research based on its expertise in smart **Sensor Solutions** and **Micropumps**, including phenotyping of plants, emission analysis in animal husbandry and monitoring of supply chains in the food industry.

Artificial Intelligence (AI) for Sensor Technology

Sensors already have a key role to play as data suppliers in numerous application areas. If the collected raw data can be analyzed and processed directly at the sensor node instead of being uploaded to the cloud, this enhances the data security, energy efficiency and response speed of the system as a whole. Fraunhofer EMFT combines its expertise in the field of **Sensor Solutions** with AI methods such as machine learning to develop such items as smart sensor nodes for environmental monitoring, medical wearables and production process monitoring.

Success Driven by Core Competences

Competences

Fraunhofer EMFT's R&D activities are based on **four core competences**: Micro- and Nanotechnologies forms the basis for the other three competences, namely Micropumps, Safe and Secure Electronics and Sensor Solutions. It is the interdisciplinary interplay between these areas of expertise in particular that gives rise to pioneering solutions.

On the pages that follow, we present our competences in detail, combined with information about selected **reference projects** that reflect the successful transfer of our expertise to application. This clearly illustrates the added value offered by our research, both for people and the environment.

For an overview of **scientific findings published by Fraunhofer EMFT in 2021**, please refer to page 40 "Scientific activities".



Micro- and Nanotechnologies

Fraunhofer EMFT has an extensive, state-of-the-art technology park as well as comprehensive expertise in the field of micro- and nanotechnology: from process analytics and electronic component development to foil electronics, circuit design, heterointegration and system integration. This know-how forms the basis for the institution's research activities. → further details + projects from page 17

Micropumps

The metering of gases and liquids to the nearest nanoliter is a key area of expertise at Fraunhofer EMFT. The portfolio includes highly miniaturized silicon, stainless steel and titanium micropumps as well as metering system solutions. The spectrum of applications ranges from medical technology and industrial applications to consumer electronics. → further details + projects from page 23

Safe and Secure Electronics

Fraunhofer EMFT has versatile expertise in both the reliability and tamper-proofing of electronic components and systems. R&D activities include failure analysis, ESD testing and protection concepts, reverse engineering and hardware-based tamper protection technologies. → further details + projects from page 29

Sensor Solutions

A key area of expertise at Fraunhofer EMFT is the design of novel, high-performance sensor solutions that enable perfect interaction between sensor technology and its environment. In this area, in-house developments are sometimes combined with existing solutions. → further details + projects from page 35



More Info

www.emft.fraunhofer.de/competences

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, and include:

Detailed view of a foil system to measure temperature during processing

Technology and process analytics: In the area of technology and process analytics, Fraunhofer EMFT offers an industry-compatible technology platform for testing new process media and optimizing selected process stages, thereby increasing performance and efficiency, for example.

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

Foil electronics: Flexible electronics offers new possibilities for a wide range of smart high-performance products. In-house roll-to-roll production 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.

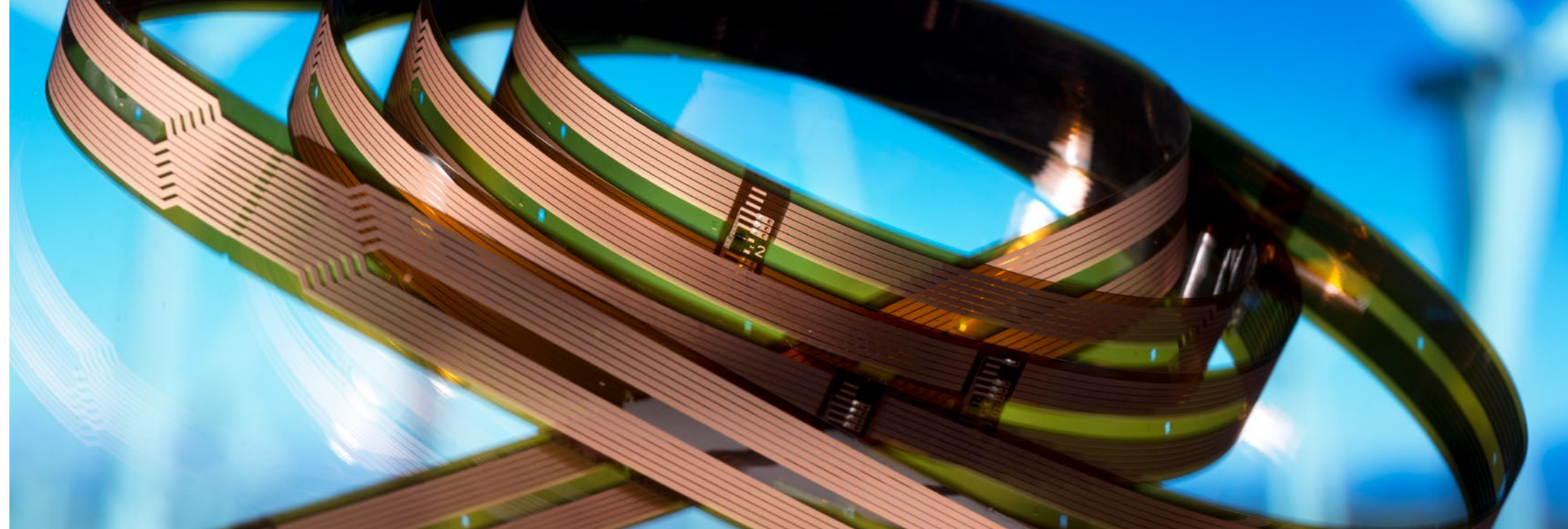
More Info

[www.emft.fraunhofer.de/
mikro-nano-technologies](http://www.emft.fraunhofer.de/mikro-nano-technologies)



Projects

Micro- and Nanotechnologies



UV-Steril – Sterilization of air filter systems by means of UV-C LED irradiation

Air filtration systems are considered an effective measure to reduce the risk of infection from SARS-Cov-2 indoors. However, the HEPA filters that have commonly been used to date are high-maintenance and costly.

Together with Helmholtz Munich, OSRAM Opto Semiconductors GmbH and MANN+HUMMEL GmbH, researchers at Fraunhofer EMFT are pursuing a new, energy-efficient approach in the joint project UV-Steril: here, self-sterilizing filter elements based on integrated LED chips are used for air purification. These special latest-generation LEDs made by OSRAM emit high-energy UV-C irradiation which is highly efficient in inactivating viruses such as SARS-COV2.

In order to be able to use such LEDs in ventilation systems for the purpose of disinfection, the project involves mounting them on flexible and geometrically very variably configurable foil strips or foil nets. One focus of project work at Fraunhofer EMFT is the design and manufacture of such film structures and their subsequent integration in ambient air filter systems. To this end, the team is establishing and characterizing various assembly techniques for unpackaged LED chips on foil conductor paths. In addition to a local reflow

bond process, particular attention is being paid to adhesive processes, such as anisotropic conductive adhesives for mechanical and electrical contacting of the chips on the foil conductor paths.



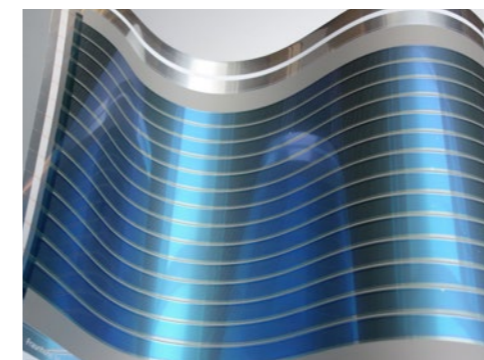
Non-enclosed UV-C LED mounted on a foil conductor path

Further scientific and technological questions concern the effective dissipation of the heat generated by the LEDs via the foil, as well as an assessment of which foil materials can withstand the high-energy UV-C radiation for a sufficiently long period of time.

The project is funded by the Bavarian Ministry of Economic Affairs, Energy and Technology under reference DIE-2010-0007//DIE0132/04.

Sustainable production of conductor foils for the solar industry

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 conductor paths on large-area surfaces fitted with electronics) that enables resource-efficient and cost-effective production of large-area conductor path patterns. Such conductor path patterns are also needed for solar cells as electrical contacts to dissipate photocurrent.



Flexible applications: organic solar module produced in a roll-to-roll process
© Fraunhofer ISE

The scientists use a thin laser-structured aluminum layer as a mask for the electrodeposition of the electrical conductors. This 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 50-100 µm wide, galvanically reinforced conductor paths 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.

Next-generation computing: sensors instead of the cloud

How will it be possible to manage computing close to the sensor in the future rather than in the cloud? And how can machine learning

Long foil strip with several flat pressure sensors for measuring pressure ratios on large surfaces

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 Arrival. The focus is on neuromorphic, energy-efficient hardware components and AI algorithms for decentralized learning, as well as data protection.



Neuromorphic computing
© Fraunhofer IGD

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.

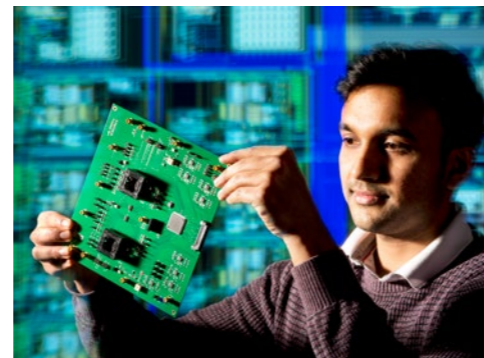
In this project, researchers aim to develop neuromorphic accelerators requiring vastly lower levels of power consumption and optimize these for AI algorithms. At a later stage, two use cases will be implemented based on this hardware: (I) speech recognition (keyword spotter + audio event detector) and (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 being funded internally as a Fraunhofer lead project.

Ultrasound-based proximity sensors for human-machine interaction

Intelligent interactive systems for human-machine interaction (MMI) are increasingly being

used in a wide range of applications in the sectors 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. In response to increasing demands in terms of performance capacity, energy efficiency and functionality, researchers at Fraunhofer EMFT are working with three other Fraunhofer institutes to build a modularized MEMS technology and sensor platform.



Test board for an eight-channel ultrasonic transceiver chip

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 and ultrasound-based methods have proved to be the most suitable here. 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 ProtaktiUS 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 unit 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.

Electro-optical system enables data rates in the terabit range

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 comprising scientists at 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.



© Syda Productions – Fotolia

For this purpose, the researchers 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 FDSOI 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 FDSOI 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.

More Projects

www.emft.fraunhofer.de/projects



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.

Multilayer connections of the stainless steel micropump

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 $3.5 \times 3.5 \times 0.6 \text{ mm}^3$, 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 be able to manufacture the components themselves in high volumes subsequent to technology transfer.

In addition to the micropumps, the Fraunhofer EMFT R&D portfolio also includes a very diverse range of microdosing components in this competence 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.

More Info

[www.emft.fraunhofer.de/
micropumps](http://www.emft.fraunhofer.de/micropumps)



Projects

Micropumps



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 smart 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.

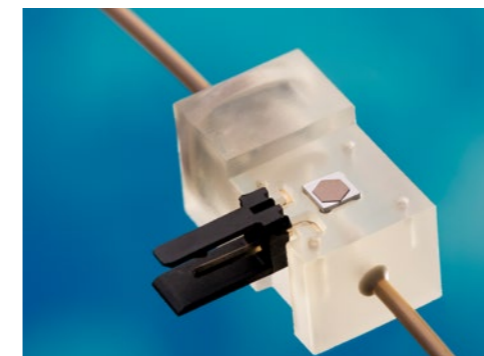


Dosage chip, silicon micropump and flow sensor

Smart catheter for cell-based heart attack therapy

About 10% of the population of the western world have to undergo angioplasty surgery at some time, due to cardiac arrhythmia or for a heart valve replacement. These minimally invasive procedures on the heart are supported by numerous intelligent imaging and sensor catheters acting as the surgeon's "eyes and ears". Researchers at Fraunhofer EMFT have further developed a micropump implemented into this type of smart cardiac catheter in the

future. By means of this pump, stem cells could be transported to damaged heart tissue so that it regenerates.



Silicon micropump measuring 3.5 x 3 mm

Despite the fact that these intelligent instruments are absolutely indispensable and indeed life-saving, there have been very few innovations in the recent years due to the mostly small production volumes. As a result, the level of demand among hospitals for instruments with improved functionality is very high. The EU project Position-II offers a unique solution to this problem.

Within the project, 43 European companies and research institutions are working under the coordination of Philips to establish a distributed pilot line for smart catheters and implants. The partners intend to realize five

demonstrators to indicate the innovation potential in existing markets as well as laying the foundations for penetrating new markets.

A research team from Fraunhofer EMFT is working with partners alphaSIP, Ciber, Cicautxo, Philips, Johnson Matthey, Universidad Zaragoza, Universidad Complutense de Madrid and Fundación Centro de Cirugía de Mínima Invasión Jesús Usón to develop a cell therapy catheter that transports stem cells into dead heart muscle tissue.

The centerpiece is a dosing unit that pumps the cells through the catheter to the heart without the pressure in the heart and the additional fluidic counter pressure impairing the accuracy of the dosage. This is to be taken care of by a piezoelectric micromembrane pump measuring just 5 x 5 x 0.8 mm³ which was developed at Fraunhofer EMFT. For use in a cardiac catheter, the scientists adapted the pump chamber and optimized the piezo assembly so as to achieve the required pressure and flow.

The limits of the drive voltage are also being investigated in order to further optimize the pump characteristics. The Fraunhofer EMFT research team is aiming to find out at what negative field strengths degradation occurs (due to depolarization of the piezoceramic). In order to prove the stability of the flow rate,

Portable miniature infusion system fitted with Fraunhofer EMFT micropumps

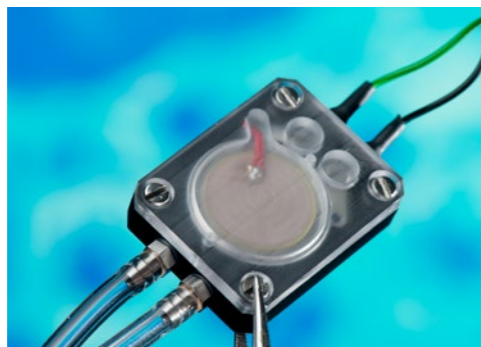
the pumps are characterized in detail (air and water flow with and without counter pressure, influence of temperature) and the results are compared with estimates and calculations during the design process.

As part of the technology platform, the pump optimized for this project also offers potential for use in many other biomedical applications such as medication dosing and cell culture applications.

Before the smart catheter can actually be used for treatment, it has to be developed to product maturity and then undergo the necessary clinical tests for approval.

Safety Pump – reliability of microdosing systems

In the Safety Pump project, Fraunhofer 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 expertise of TU Munich and the microfluidics and actuator expertise 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.



Microdosing system with stainless steel micropump made at Fraunhofer EMFT

Pilot applications include a promising application in the field of continuous sample feeding

of 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, enabling an early warning to be provided based on the appropriate pattern recognition. In this way, fault cases such as particle contamination or changes in material properties due to degradation can be detected at an early stage.

Medical drone provides first aid in disaster areas

Natural disasters, acts of war or terrorist attacks are extreme situations for rescue teams to deal with: victims frequently require first aid as quickly as possible. But very often it is impossible or extremely difficult for the emergency services to get to the injured individuals in time. This is the kind of situation where the AirDoc could be of use in the future: a team of young researchers at Fraunhofer EMFT has come up with the idea of an autonomous airborne medical assistant.

Using infrared and image recognition, people in need of help can be identified and directly targeted. The AirDoc features a medical robotic arm which has highly miniaturized and energy-efficient sensors integrated in it. One crucial element is the miniaturized actuators which move the robotic arms to perform diagnostic examinations autonomously. For example, sensors can be attached to the patient to obtain information about important vital signs. These include, for instance, pulse, EEG, ECG, oxygen saturation, body temperature and blood pressure. The diagnosis can be controlled remotely by medical professionals.

The development team also designed a sensor wristband with an integrated micropump for the purpose of arterial blood pressure measurement. The integrated piezoelectric micromembrane pump conveys air into a

plastic reservoir, which then presses onto the arteries. The systolic and diastolic blood pressure levels are recorded and diagnostically interpreted on the doctor's smartphone/tablet using specialized analysis methodology. In the future, this kind of sensor data will also be used to identify more extensive clinical patterns such as arrhythmias.



Mobile blood pressure measurement using micropumps

The AirDoc concept was developed for the ideas competition "Ramp up Resilience" run by the Fraunhofer Netzwerk Symposium on March 23 to 24, 2021, where it was ranked second (→ see page 42).

More Projects

www.emft.fraunhofer.de/projects



Safe and Secure Electronics

Internet of Things, Industry 4.0, Big Data – there is no question that digitalization has come to play a role in virtually all areas of our day-to-day lives. Safe and secure electronic systems are required as the “infrastructure” of this interconnected world. The notion of “safe and secure” has various facets here.

Firstly, electronic systems have to be one hundred percent reliable in the sense of offering fail-safe 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 smart 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 is collaborating with partners and customers on novel protection concepts at the 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 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.

ESD system test with broadband measurement of the secondary discharge current

More Info

[www.emft.fraunhofer.de/
safe-secure-electronics](http://www.emft.fraunhofer.de/safe-secure-electronics)



Projects

Safe and Secure Electronics



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 – trusted electronic ICT components and systems are becoming increasingly important as digitalization gathers pace.



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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 to recover layout information. Comparison

with design data is to ensure reliable detection of Hardware Trojans. The particular challenges confronting this project are the structures and layer thicknesses of less than 10 nm in the preparation, the stability of the mapping using scanning electron microscopy and finally the synthesis and analysis of huge quantities of data. 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 under 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 “trusted electronics” in an international environment, too, in the face of growing technological challenges.

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.



Stress test for the evaluation of the robustness of systems

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.

The project is funded by the Bavarian State Ministry of Economic Affairs, Regional Development and Energy (reference ESB-1909-0003// ESB091/002).

X-ray examination of an assembled printed circuit board

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, so they provide the basis for the functionality, simple handling and reliability of automation technology. Researchers at Fraunhofer EMFT are working on so-called Cyber Physical Connectors, a new generation of active, “smart” connectors, in a project of the same name.

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. In the long term, the built-sensors could perform a kind of condition monitoring for the connected devices, also registering energy consumption, for instance.



The contactless electronic sensor system serves as an intelligent diagnostic interface for the Internet of Things (IoT), enabling reliable condition monitoring of the environment using the example of a printed circuit board connector (Smart Mechanical Electrical Connector, SmeC)

In the subsidiary project Foil Sensors, the team developed a generally applicable process for applying (thinned) silicon-based sensor technology to flexible or rigid-flex printed circuit boards. Thanks to the high degree of miniaturization, these systems can be integrated into almost all connector housings as well as data and power networking components. The results of the reliability experiments exceed

the requirements for industrial electronics. The process can be transferred to any connector system with little effort and is available to partners in industry and research.

The subsidiary project “Foil Sensor Technology” obtained significant findings for modeling damage mechanisms on commercial connector systems. For example, trials on the Fraunhofer EMFT friction corrosion test rig indicate that the resistance of connectors increases intermittently as the friction path progresses. This behavior is observed in both the fast experiment (1 Hz to 10 Hz friction frequency) and the extremely slow experiment (0.075 Hz friction frequency). It can be explained by means of a detailed study of the contact resistances and comparison with a simultaneous measurement of the contact-normal force as a function of the relative position of the two connector halves. In this way, the knowledge gained makes a fundamental contribution to a future diagnostic model for autonomous vehicles.

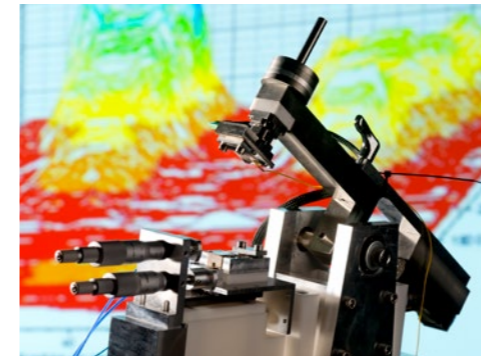
Completed at the end of 2021, the project was funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology under reference 43-6622/532/4.

Better understanding of the causes of connector wear

Electrical connector systems are the interface between the assemblies/modules of mechatronic or electrical systems in automobiles, for example. Up to now, only the electrical properties from the data sheet have been taken into account prior to installation: anticipated environmental impact during later operation such as vibration 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) as well as by design features and line routing.



Fretting corrosion: Determination of the electrical properties of contacts, plugs and connectors under defined load by contact force, contact temperature, humidity, amplitude and frequency of frictional movement.

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

More Projects

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Sensor Solutions

As the “sense organs of things”, sensors have a key role to play in future applications in the area of the Internet of Things (IoT). Yet while their potential uses are diverse, the demands made on these tiny electronic helpers in the various concrete applications are both highly complex and very specific. In many instances, standard solutions commonly available on the market are not able to meet this wide range of needs.

Sensor materials for combined in-line measurements

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 also 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

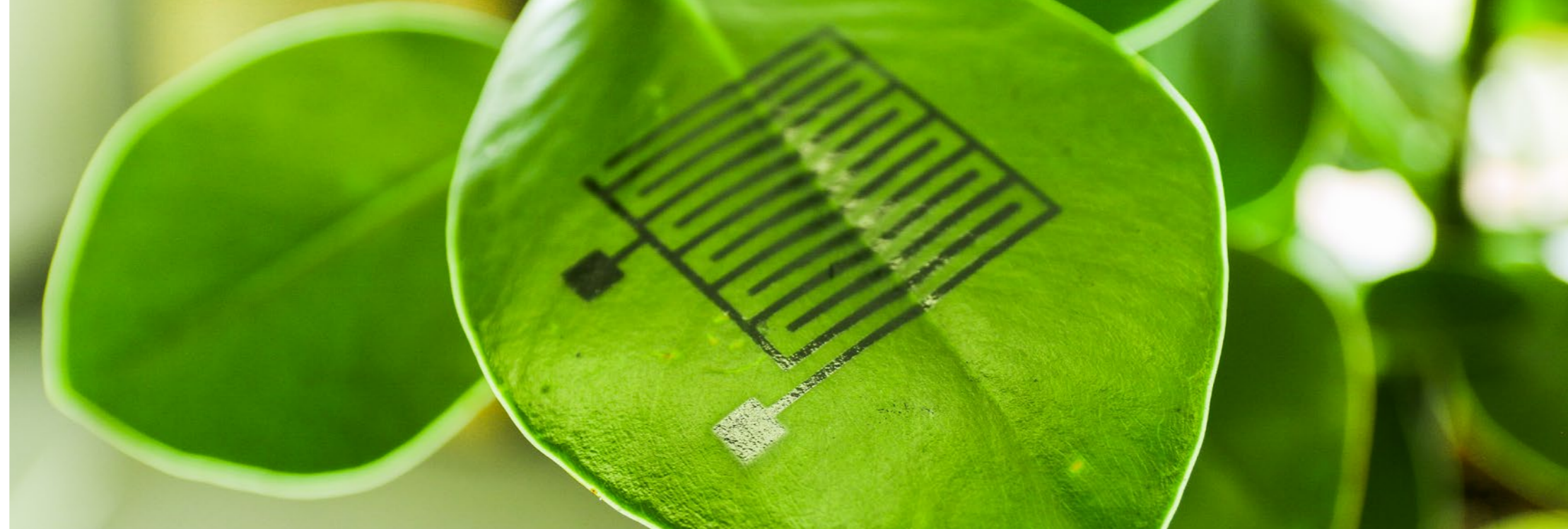
More Info

[www.emft.fraunhofer.de/
sensor-solutions](http://www.emft.fraunhofer.de/sensor-solutions)



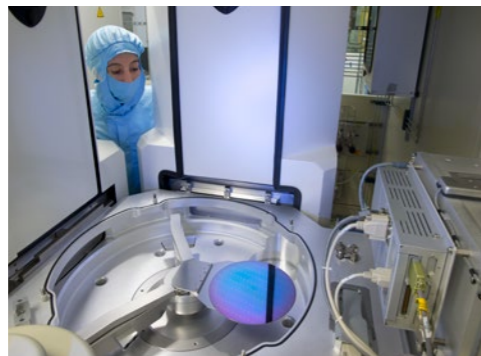
Projects

Sensor Solutions



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.



Thermally assisted chemical vapor deposition on 8-inch wafer

The EU project NeurONN is a collaborative venture in which the Fraunhofer EMFT is working with six European partners to develop 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.

The project is being funded under the Horizon 2020 program, reference 871501.

Development of an analog accelerator for inference in the edge

Edge computing is seen as key to new IoT applications. In order to create fundamental artificial intelligence for future edge products, Fraunhofer EMFT researchers are collaborating with the Fraunhofer institutes IIS and IPMS on the EU project ANDANTE to develop innovative mixed-signal artificial neural network (ANN) accelerators with computation-in-memory (CIM) capability. These are to enable solid hardware and software platforms to be built for the development of AI applications.

The resulting IoT devices are expected to combine energy efficiency with robust neuromorphic computing capabilities. Drawing on close collaboration between major European manufacturing facilities, chip design companies, system providers, application development companies and research partners, the project will build and expand the European ecosystem around the definition, development, manufacturing and application of neuromorphic integrated circuits.

In the context of this project, Fraunhofer EMFT is contributing its studies on AI building blocks, methods and tools for creating a flexible yet efficient mixed-signal ANN circuit architecture. In addition, the Munich-based researchers are developing tools that support resource-aware planning of an ANN model for

the available hardware in the edge products. The focus is on the aspects of computing accuracy, data throughput and performance trade-offs. Furthermore, various circuit blocks for neural networks are being developed at Fraunhofer EMFT with a focus on high configurability and low power consumption.

The project as a whole is funded under the European ECSEL initiative, reference 876925, while the subsidiary project receives additional funding from the German Federal Ministry of Education and Research BMBF, reference 16MEE0117.

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 FDSOI technology node. The researchers are applying new integrated memory technologies in innovative concepts

Sensors based on organic semiconductors enable monitoring of plant vitality and serve as indicators of parasitic infestation

to realize 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 primarily for classification tasks in image recognition systems, e.g. for autonomous driving, as well as for processing other sensor data such as that generated by radar systems.



Deep learning algorithm verification for neuromorphic hardware implementation

Fraunhofer EMFT's contribution will focus on developing key IPs for analog and mixed-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.

Machine learning for predictive maintenance of transmission oils

Lubricating oils make a significant contribution to minimizing friction, thereby ensuring reliable operation of production plants. The project Smart Gear involves researchers at Fraunhofer EMFT developing solutions to detect a drop in the performance of lubricating oils using sensor technology and machine learning methods so as to be able to predict when the oil needs to be changed.

Lubricants have to be changed regularly in production plants: the performance of the gear oils used declines over time, whether due to aging of the base oils, degradation of the additives they contain, or else external influences such as the ingress of foreign substances. If the oil is not replaced in time, the machinery may fail. Up to now, external laboratory analyses have been carried out at regular intervals to provide a reliable indication of the condition of the lubricating oil. A large number of different influencing variables are determined directly or indirectly by means of chemical analysis, but this procedure is time-consuming and costly.

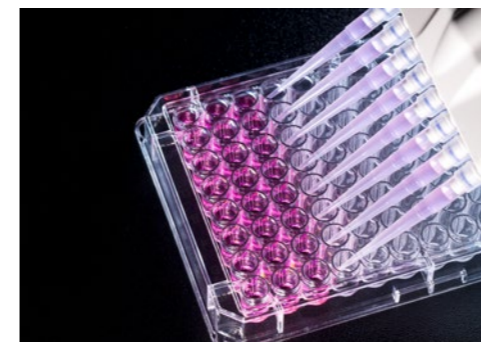
Together with lubricant manufacturer Klüber Lubrication, a Fraunhofer EMFT research team is now pursuing a new, efficient approach: by combining sensor technology and machine learning methods, the aim is to establish predictive maintenance. Here, the development partners draw on existing approaches to online condition monitoring, where sensors and a secure IT infrastructure are used to monitor the current condition of a system – or in this case the lubricant. If a previously defined limit is exceeded, the production management receives a warning with a recommendation for action. While this only takes current and past figures into account, however, the new system is designed to forecast when the next maintenance will be due. The aim is to make optimum use of a lubricating oil's service life in the interests of a sustainable, resource-conserving economy. The correlation between the system's power consumption and the oil aging is also taken into account so as to be able to arrive at an economical assessment of whether it better to go on using the oil or replace it.

The project is funded by the Bavarian Research Foundation under reference AZ-1523-21.

New assay concept for vaccine development

Before 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 venture funded by the Fraunhofer-Gesellschaft – which involves the Fraunhofer EMFT group Cell-Based Sensor Technology headed by Professor Joachim Wegener and 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.



Virological neutralization tests in 96-well format

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.

Securely networked sensors in the healthcare sector

The Internet of Things offers huge potential for the healthcare sector – ranging from diagnostics to patient safety and optimized logistical processes. 21 European partners are involved in the project SERENE IoT, which aims to lay the basic foundations for IoT applications in healthcare. In this project, the German consortium under the coordination of

Fraunhofer EMFT is developing an IoT-capable mobile analysis device to detect multi-resistant Staphylococcus aureus (MRSA). The detection method (being developed in the project MRE Test, funded by the Bavarian Ministry of Economic Affairs and Media, Energy and Technology as part of the Mikrosystemtechnik Bayern program, reference MST-1308-0001//BAY189/001) is to be transferred to an overall system with connectivity capability which can run on batteries. The basis is provided by new application-specific memory chips with a very low level of energy consumption. The research project is focusing on the development of a secure software architecture for IoT networking of medical devices and the secure transfer of confidential data. The concept of IoT-networked medical devices is being tested in Germany by Munich University Hospital using various demonstrators (mobile MRSA detector, device to detect postoperative infections, food pump, fall detector to identify and prevent falls).

The project SERENE IoT receives funding of 5.1 million euros from the EUREKA cluster PENTA; 67% of this amount is provided through the Federal Ministry of Education and Research (BMBF).

More Projects

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Scientific Activities

Since we are an institution for applied research, academic excellence is a key promise of quality in terms of our research activities and collaborative ventures. On the pages below you will find an overview of the following accomplishments at EMFT in 2021:

- Awards
- Bachelor's and master's degree theses
- Doctorates
- Talks
- Publications
- Patents

Secured and networked on-site MRSA detector



Awards

PENTA Innovation Award for the Serene-IoT project coordinated by Fraunhofer EMFT

The Serene-IoT project received the **PENTA Innovation Award 2021** at the virtual EF ECS event on November 24. The European EUREKA cluster PENTA aims to promote research, development and innovation in the field of micro- and nanoelectronics. 21 European partners were involved in the project SERENE IoT, which aims to lay the basic foundations for IoT applications in healthcare. In this project, the German consortium under the coordination of Fraunhofer EMFT developed an IoT-capable mobile analysis device to detect multi-resistant Staphylococcus aureus (MRSA). This was achieved in half the time normally allotted to this type of medtech project. At Fraunhofer EMFT, Dr. Erkan Isa, Dr. Sabine Trupp, Christian Hochreiter and Jennifer Schmidt made major contributions to the success of the project. —> see page 39o for detailsf

Dieter Hemmetzberger honored as one of Fraunhofer's best training supervisors

On November 4, the Executive Board of the Fraunhofer-Gesellschaft honored the outstanding achievements of the best trainees of 2021, as well as those of their training supervisors. Dieter Hemmetzberger of Fraunhofer EMFT was presented with an **honorary certificate** in recognition of his commitment and dedication as a training supervisor. One of his trainees specializing in microsystems technology completed their training in 2021 with the top grade.



Training supervisor award presented vicariously to Dieter Hemmetzberger by Fraunhofer EMFT Director Prof. Christoph Kutter

Prof. Amelie Hagelauer receives the IEEE UFFC Early Career Investigator Award

At the IEEE International Ultrasonics Symposium, Prof. Amelie Hagelauer received the **2021 IEEE UFFC Early Career Investigator Award** on September 21. This award recognizes exceptional achievements by researchers who have less than 10 years of experience in the field ultrasound technologies and applications.



Virtual accolades for Prof. Amelie Hagelauer's research

Prof. Christoph Kutter honored with GMM Award

At the MicroSystemTechnik Congress on November 10, Prof. Christoph Kutter was presented with the **GMM Award**. This is the highest distinction awarded by the expert association GMM (VDE/VDI Society of Microelectronics, Microsystems and Precision Engineering): Prof. Kutter received it in recognition of his numerous services to GMM and his prominent status as an expert, especially in the fields of sensor technology, flexible electronics, and microfluidics.



Prof. Christoph Kutter receiving the GMM Award

Prof. Dr. Alexander Kurz, moderator Monika Jones, Lorenz Grünerbel and Agnes Bußmann at the "Ramp up Resilience" ideas competition held as part of the 2021 Fraunhofer Symposium "Netzwerk" at Fraunhofer headquarters in Munich
© Marc Müller



Agnes Bußmann and Lorenz Grünerbel ranked second in the Fraunhofer Netzwerk ideas competition "Ramp up Resilience"

In the ideas competition "Ramp up Resilience" at the Fraunhofer Netzwerk Symposium on March 23 to 24 2021, the "AirDoc" concept developed by Lorenz Grünerbel and Agnes Bußmann was awarded **second place**. The young research team impressed symposium participants with their presentation about an autonomous airborne first responder. The medical drone robot is designed to enter dangerous, contaminated, or inaccessible areas very quickly so as to provide autonomous first aid and enable remote diagnosis. The research team is now looking for cooperation partners for the implementation phase.



The development team with the AirDoc

Bachelor Theses

James Widjita
Characterization of New Generation of ISFET
Bachelor Thesis, Technische Universität München
Supervision: Leonhard Sturm-Rogon, Matthias Steinmaßl, Karl Neumeier

Sophia Güntner
Entwicklung eines Dichtdesigns für aktive NO-Ventile und Analyse des Dichtdesigns mit Parylene-C-Beschichtung bei hydraulisch aktuierten SafetyValves
Bachelor Thesis, Oberbayerische Technische Hochschule Amberg-Weiden
Supervision: Claudia Durasiewicz

Thomas Neuner
Erstellen von Messroutinen mit PyMeasure zur Charakterisierung von Pt/TiO₂/Al Memristoren
Bachelor Thesis, Technische Universität München
Supervision: Marc Tornow, Daniel Reiser

Sophie Hoffmann
Experimentelle Untersuchung der Partikeltoleranz piezoelektrischer Membranpumpen für den mikrofluidischen Transport von Zellen
Bachelor Thesis, Hochschule München
Supervision: Agnes Bußmann

Simon Meyer
Integrierte Temperaturregelung für rapide Virusdiagnostik
Bachelor Thesis, Hochschule München
Supervision: Matthias Steinmaßl

Master Theses

Joscha Erbis
Acquisition Time Reduction in Large-Area, High-Resolution Scanning Electron Microscopy-Analysis of Nanometer Integrated Circuits Through Deep Learning-Based Super Resolution
Master Thesis, Karlsruher Institut für Technologie
Supervision: Horst Gieser

Barbara Leikam
Characterisation of Passive Check Valves in Microsystems
Diploma Thesis, Technische Universität Wien
Supervision: Lorenz Grünerbel

Budi Mulyanto
Design of a Time Gain Compensation Amplifier for an Ultrasound Analog Receiver Front End Using 0.18 µm SOI Process
Master Thesis, Technische Universität Chemnitz
Supervision: Prajith Kumar Poongodan

Anne-Kathrin Mildner
Development of an Impedance-Based Neutralization Assay for SARS-CoV-2 Infection with Inherent Amplification
Master Thesis, Universität Regensburg
Supervision: Joachim Wegener

Julia Erl
Development of Impedance-Based Technologies to Monitor Photopharmacology Assays in Vitro
Master Thesis, Universität Regensburg
Supervision: Joachim Wegener

Judith Krauß
Development of Novel Impedance-based Reporter Gene Assays to Monitor G Protein-Coupled Receptor Signaling
Master Thesis, Universität Regensburg
Supervision: Joachim Wegener

Ferdinand Heinrich
Flow Disturbance Detection in Micro Diaphragm Pumps: Automated Data Acquisition Setup and Time Series Classification with Machine Learning
Master Thesis, Technische Universität München
Supervision: Thomas Thalhofer

Doris Zhou
Investigation of the Mechanical Loading Capacity of a MEMS Actuator
Master Thesis, Technische Universität München
Supervision: Martin Wackerle

Samudra Gupta
Low-Power Environment Sensor Platform for Tiny Machine-Learning System
 Master Thesis, Hochschule Ravensburg-Weingarten
 Supervision: Franz Wenninger, Florens Fraidling, Christian Hochreiter

Philipp Maier
Modelling of Leakage Flows Through Smallest Gaps in Microvalves
 Master Thesis, Technische Universität München
 Supervision: Claudia Durasiewicz

Konstantin R. B. Hauser
Nachhaltigkeitsorientierte Wirtschaftlichkeitsbetrachtung eines neuartigen Verfahrens in der Mikroelektronik
 Master Thesis, Technische Universität München
 Supervision: Karin Bauer, Pirjo Larima-Bellinghoven

Maren Klein
Optimization and Application of an Optical Migration Assay
 Master Thesis, Universität Regensburg
 Supervision: Joachim Wegener

Dominik Diebold
Prädiktive Analyse von zeitbasierten Gesundheitsdaten zur Früherkennung von Druckgeschwüren
 Master Thesis, Technische Universität München
 Supervision: Lorenz Grünerbel

Preethi Vigneeshva Govindraj
SAR ADC reference buffer design for next-gen RADAR SoC in 22nm FD-SOI
 Master Thesis, TU Dresden
 Supervision: Harshitha Basavaraju

Marion Vogl
Subcellular Distribution of Na⁺ in Macrophages
 Master Thesis, Universität Regensburg
 Supervision: Joachim Wegener

Ellen Jirutková
System Level ESD Testing with Capacitively Coupled Stress Pulses
 Master Thesis, Technische Universität München
 Supervision: Heinrich Wolf

Mustapha Fahem
Towards a pH measurement system on foil aided with a mixed-signal processor
 Master Thesis, Hochschule München
 Supervision: Matthias Steinmaßl

Ferdinand Pscheidl
Training Mixed Precision Neural Networks with Energy Constraints for a FeFET-Crossbar-Based Accelerator
 Master Thesis, Technische Universität München
 Supervision: Lei Zhang

Doctorates

Paric Zlatko
Development of a dual ECIS-SPR sensor platform for cell-based assays: Label-free analysis of g-protein coupled receptor signal transduction
 Cooperation with Universität Regensburg
 Supervision: Joachim Wegener

Lisa Pütz
Imaging Microphysiometry of 2D and 3D Tissue Models: Method Development and Application
 Cooperation with Universität Regensburg
 Supervision: Joachim Wegener

Maria Zinkl
Impedance-based Analysis of Adherent Cells using Interdigitated Electrodes of Subcellular Dimensions
 Cooperation with Universität Regensburg
 Supervision: Joachim Wegener

Pierre Pütz
Impedimetric Monitoring of Three-Dimensional Tissue Models: A Construction Set Approach
 Cooperation with Universität Regensburg
 Supervision: Joachim Wegener

Talks

Heinrich Wolf
Advanced TLP Applications
 International Electrostatic Discharge Workshop (IEW), May 17-20, 2021.

Johannes Weber, Ellen Jirutková, Heinrich Wolf, Horst Gieser
De-Embedding of VF-TLP/CC-TLP Systems
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Erwin Yacoub-George
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Erwin Yacoub-George
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Joachim Wegener
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Lorenz Grünerbel
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Stefanie Michaelis
Mit Fotosensibilisatoren dotierte Kultursubstrate zur automatisierten und hochparallelen Durchführung von Wundheilungsassays in vitro
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A Device for Detecting Water on a Surface and a Method for Detecting Water on a Surface

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Congar

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Peter Ramm

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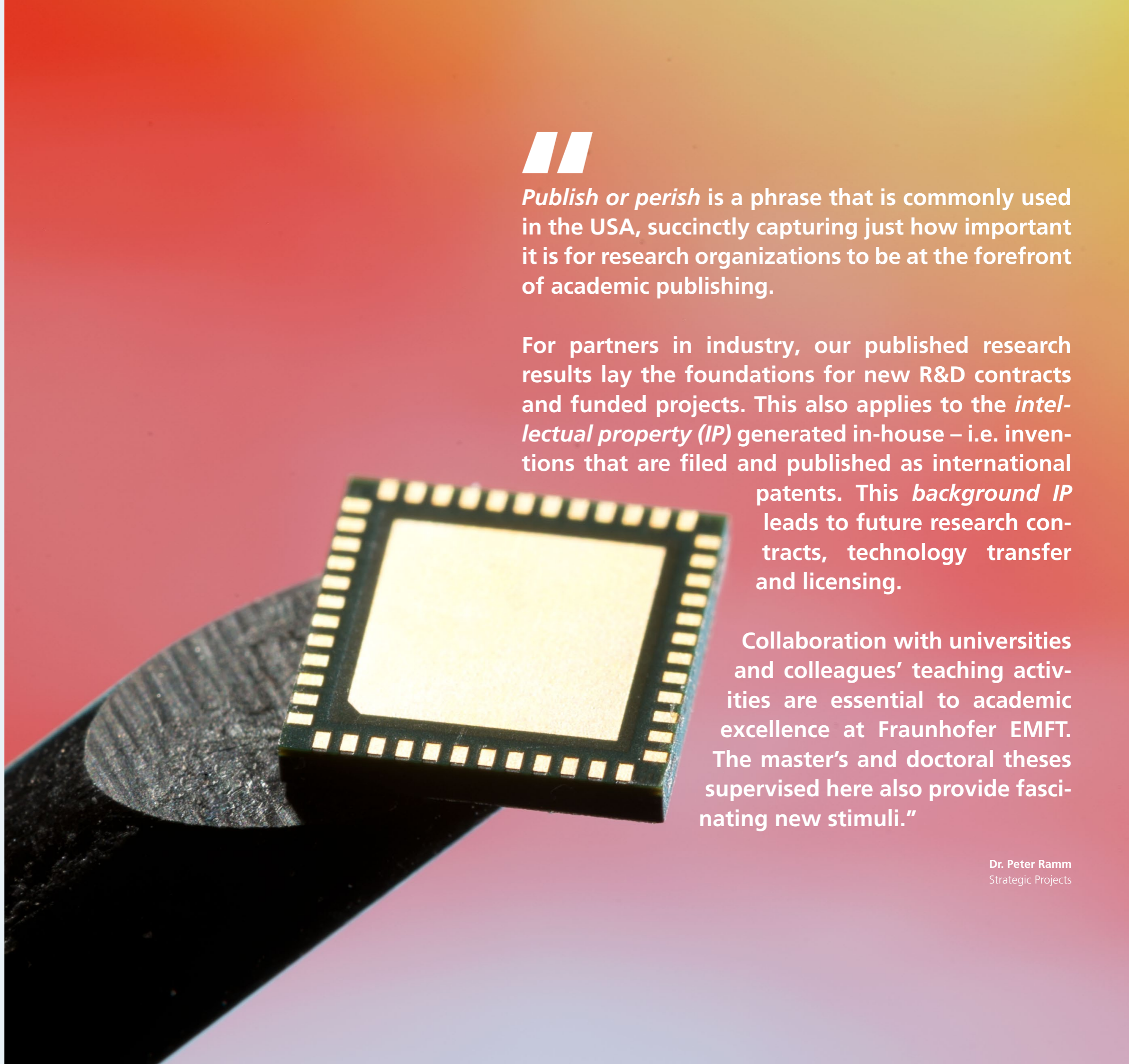


Publish or perish is a phrase that is commonly used in the USA, succinctly capturing just how important it is for research organizations to be at the forefront of academic publishing.

For partners in industry, our published research results lay the foundations for new R&D contracts and funded projects. This also applies to the *intellectual property (IP)* generated in-house – i.e. inventions that are filed and published as international patents. This *background IP* leads to future research contracts, technology transfer and licensing.

Collaboration with universities and colleagues' teaching activities are essential to academic excellence at Fraunhofer EMFT. The master's and doctoral theses supervised here also provide fascinating new stimuli."

Dr. Peter Ramm
Strategic Projects



What Does Fraunhofer EMFT Have to Offer?

Range of Offers

Range of Services Offered by Fraunhofer EMFT

- Do you need a customized sensor solution to solve a tricky problem in your firm?
- Would you like to know if your existing product can be flatter, more flexible and better integrated?
- Do you have a groundbreaking new product idea that you're looking to develop a prototype for?
- The electronics in your product keep failing and you want to know why?
- The electronic components for your product have to be particularly low-noise?



For answers to these questions and lots of other ideas on how you can benefit from Fraunhofer EMFT's expertise, see our website at www.emft.fraunhofer.de/services.

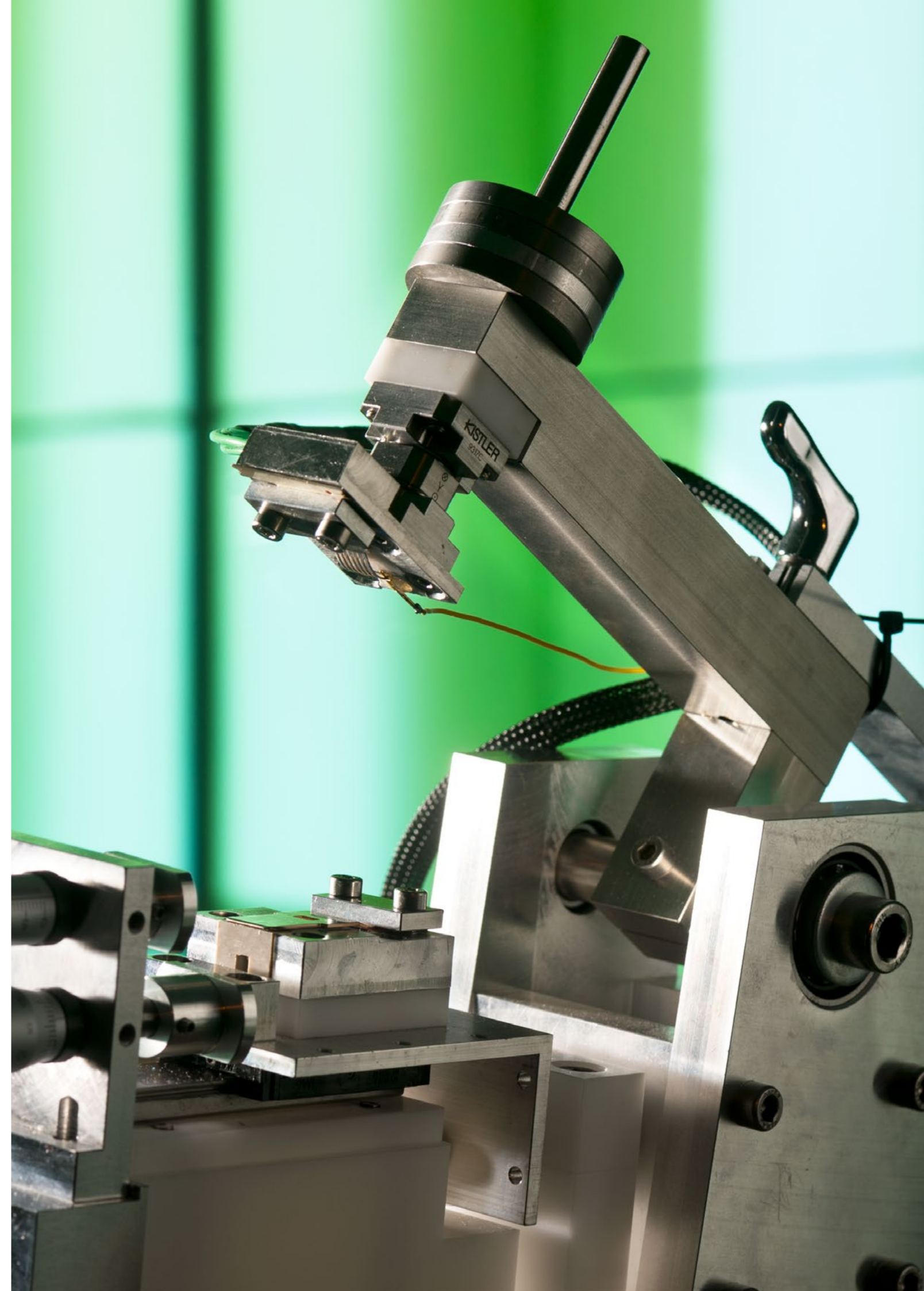
Technologies and Resources at Fraunhofer EMFT

Its extensive infrastructure and wide range of **technologies for microelectronics and microsystems technology** make Fraunhofer EMFT an attractive partner both for SMEs and larger industrial companies. Since 2007 Fraunhofer EMFT has also hired out its excellent facilities (cleanrooms, laboratories and equipment) to high-tech companies. See our website for a summary of the technologies and equipment available for microelectronics and microsystems engineering: www.emft.fraunhofer.de/technologies



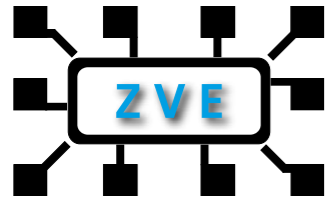
Training Courses for Electrical Connection Technology

Fraunhofer EMFT's own **Center for Interconnection Technologies (ZVE)** has offered training courses and certification in the areas of soldering, manual soldering, packaging technology and crimping since 1994. The ZVE has established itself as a key center for consulting and further training in the field of electronics packaging technology in the Munich area: for example, the ZVE offers training as a soldering technology specialist within the AVLE association's modular training system. In addition, the ZVE is accredited as an initial training and instruction center for high-reliability soldering and crimping by both the European Space Agency (ESA) and the Association Connecting Electronics Industries (IPC). —> further details from page 52



ZVE

Center for Interconnection Technologies



At Fraunhofer EMFT's Center for Interconnection Technologies (ZVE) in Oberpfaffenhofen, experts have taught essential know-how relating to electrical connection technology for more than 40 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 continue to be 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 center for training and professional development.

Derating measurements and reliability testing of the electrical connections of signal and power networking in mechatronic systems

The modern training concept used by the team in Oberpfaffenhofen is based on the fact that it is virtually impossible to separate

learning from practice 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 production technologies and information on installation and production through to retouching, 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, test rigs for assessing fretting corrosion, 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. Together with external partners, a forward-looking process was also developed at the High Performance Center "Secure Intelligent Systems" to make

further training even more practically based using holo-lenses and augmented reality (AR). This significantly improved participants' learning success.

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.



ZVE soldering mobile for virtual practical training

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 "ESA-APPROVED SKILLS TRAINING SCHOOLS") 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.



More Info

www.zve-kurse.de



Network

Everyone talks about how incredibly important “networking” is – after all, you have to have the right contacts to be successful and move your project forward.

Whether or not you’re a natural networker, Fraunhofer EMFT is not just a competent partner when it comes to microsystems and sensor technology, it is able to **open doors for you to a highly relevant network**, too.

- Firstly there is the **Fraunhofer-Gesellschaft**, itself a Germany-wide and international network for applied research covering a huge range of topics.
- In addition, as a member of **Research Fab Microelectronics Germany (FMD)** – the largest cross-location R&D alliance for microelectronics in Europe – Fraunhofer EMFT has access to a unique range of expertise and infrastructure in the field of microelectronics and nanoelectronics.
- Meanwhile, the **High Performance Center “Secure Intelligent Systems” (LZSiS)** clusters interdisciplinary expertise and versatile know-how on the topic “safe and secure from sensor to cloud” and makes this knowledge available specifically to companies.
- Fraunhofer EMFT’s strong links with **universities and other higher education institutions** secure the foundation for research and development, in turn providing the prerequisite for innovation – namely basic research and early-career talent. This combination often produces ideas that either originate from basic research or can be validated by it.

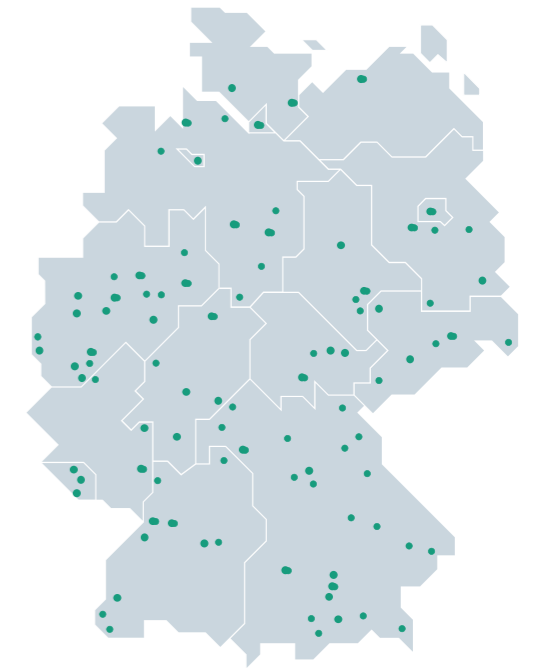


More Info

www.emft.fraunhofer.de/network

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft based in Germany is the world’s leading applied research organization. Prioritizing key future-relevant technologies and commercializing its findings in business and industry, it plays a major role in the innovation process. A trailblazer and trendsetter in innovative developments and research excellence, it is helping shape our society and our future. Founded in 1949, the Fraunhofer-Gesellschaft currently operates 76 institutes and research units throughout Germany. Over 30,000 employees, predominantly scientists and engineers, work with an annual research budget of €2.9 billion. Fraunhofer generates €2.5 billion of this from contract research.



More Info

www.fraunhofer.de/en/institutes



Research Fab Microelectronics Germany

A Key Partner to Business and Science, Policymakers and Society

Since 2017 Fraunhofer EMFT together with another ten institutes of the Fraunhofer Group for Microelectronics and the two institutes FBH and IHP of the Leibniz Association, has formed the cross-site Research Fab Microelectronics Germany, or FMD for short.

For the first time, 13 institutes from the two research organizations, Fraunhofer and Leibniz, are combining their expertise under one virtual umbrella, thus creating a new quality to the research and development of micro- and nanosystems. With more than 2,000 scientists, the FMD is one the world's largest R&D network of its kind. With its unique diversity of expertise and infrastructure at the institutes, it is helping Germany and Europe to further expand their leading position in research and development.

Transition to regular operation

Until the end of 2020, the FMD was in its start-up phase. The extensive investments of the Federal Ministry of Education and Research (BMBF) in the modernization of the institute's infrastructure could be completed by the end of 2020 / beginning of 2021, with the exception of a few minor delays caused by the Covid19 pandemic.

At the beginning of 2021, FMD started steady operations with the merger of the two offices of the Fraunhofer Group for Microelectronics and Forschungsfabrik Mikroelektronik Deutschland and the new head of the joint office, Dr. Stephan Guttowski. This transition was marked by the digital conference "Impulsgeber FMD: Angebot & Potenzial – Köpfe & Know-how" on April 22, 2021. This model of interdisciplinary and interorganizational cooperation in the German research landscape is already bearing its first fruits and it may serve as a role model at the European level in the future.

Networking and cooperation for technological sovereignty

In the meantime, the FMD is considered a role model when it comes to setting up the competencies of different R&D institutions with a joint strategy and a bundled offer to industry. With its cross-location, cross-technology and cross-competence collaboration, FMD ensures that technological sovereignty is maintained and expanded along the entire value chain.

The Berlin office represents the FMD institutes and acts as a central point of contact for all issues related to micro- and nanoelectronic research and development in Germany and Europe.

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 and education. These are aimed directly at cooperative processing of research questions, such as collaborative work in joint projects and the operation of joint laboratories. A major opportunity for cooperation lies the testing of special concepts and solutions from basic research on the facilities of the FMD institutes to gain a better understanding of their suitability in more application-oriented environments.

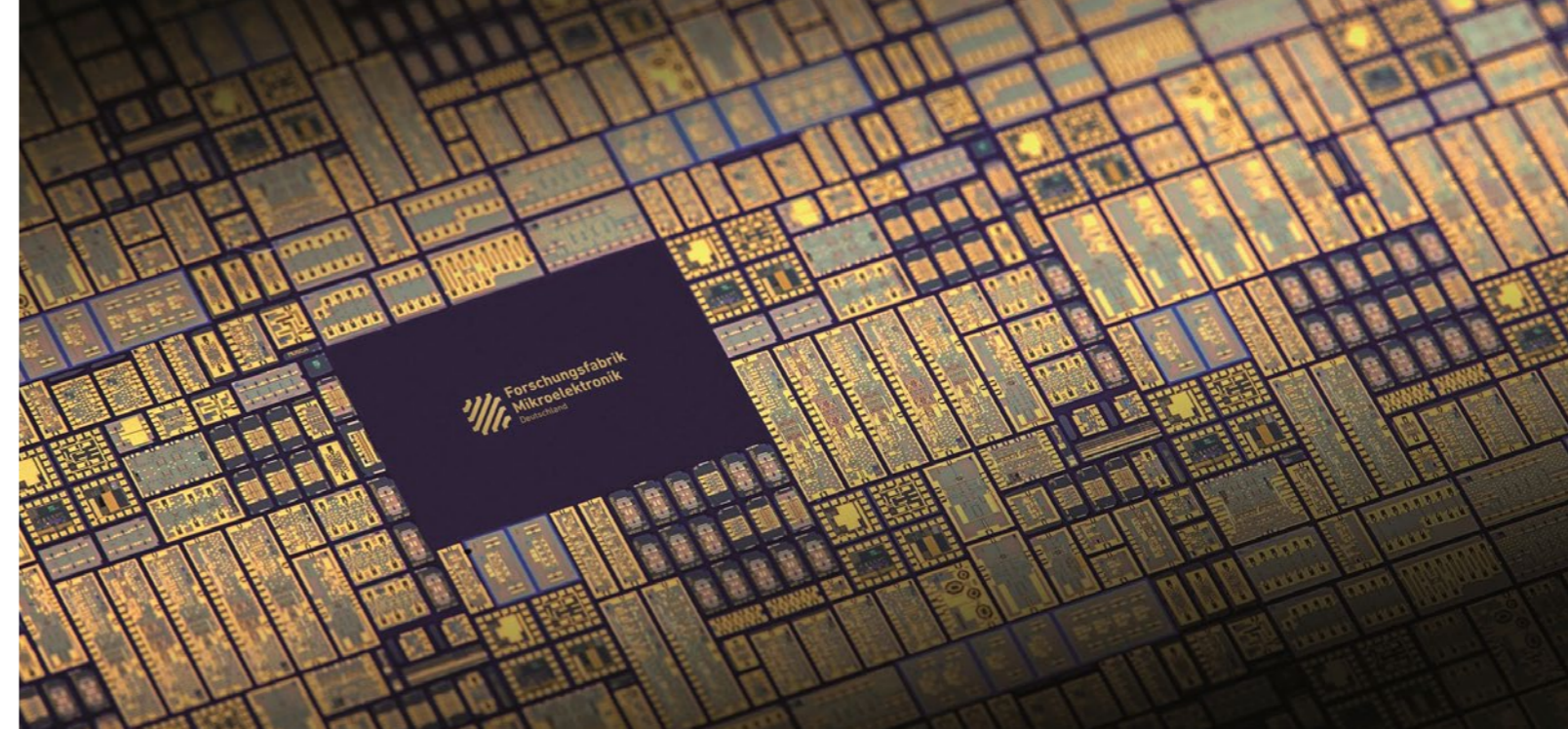
Trustworthy and sustainable microelectronics systems for innovative strength

A future-oriented society depends on electronic components in all relevant technical application domains – whether in critical infrastructures, in Industry 4.0, in the automotive sector or even in medical devices. People must be able to rely on these in order to build trustworthy products, systems and infrastructure with them.

The cross-technology competencies needed to meet these challenges are being developed by the institutes of Forschungsfabrik

Mikroelektronik Deutschland in large-scale projects such as "TRAICT" or "Velektronik". In the TRAICT (TrustedResourceAware ICT) project, for example, eight FMD institutes worked together with another ten Fraunhofer institutes until the end of 2021 to develop framework conditions to ensure that information and communication technology is trustworthy and compliant with data protection requirements, and can be used in a self-determined and secure manner.

In order to shed light on the entire value chain and create end-to-end concepts for trustworthy electronics in Germany and Europe, a platform for trustworthy electronics – "Velektronik" for short – was launched in March 2021. A total of 12 partners are involved – 11 institutes of the FMD as well as the edacentrum. Within the project, corresponding standards, norms and processes based on a national and European chip security architecture are to be developed and brought into application.



Chip collage

More Info

www.forschungsfabrik-mikroelektronik.de/en





Safe autonomous driving in any weather conditions?
ROADAR: Early warning system for detecting aquaplaning and black ice

High Performance Center “Secure Intelligent Systems”

Clustered competencies 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), TU Munich, the University of the Federal Armed Forces and Munich University of Applied Sciences, LZSiS brings together university and non-university research in the relevant subject areas so as to make digitalization available to customers in 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 digitalization 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 digitalization 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, smart 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, cleanroom environment etc.) is available to 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 digitalization issues.

Turning ideas that seem impossible into reality together with the LZSiS – an example of a project:

Have you ever felt the road disappear from under the wheels of your car? Anyone who has ever experienced aquaplaning is sure to have vivid memories of that moment of shock.

A fast and appropriate response is absolutely essential in extreme road conditions. And of course this applies to autonomous vehicles, too: after all, they're supposed to get us to our destination on their own – and above all, safely.

The idea is to ensure safe autonomous driving in all weather conditions.

The problem with phenomena such as aquaplaning and black ice is that the electronic systems currently in use in vehicles are not able to reliably detect slippery surfaces such as water or ice on the road – and this can have fatal consequences. So optimized solutions are required, particularly when it comes to autonomous driving.

The team: Fraunhofer EMFT, LZSiS, Uedelhoven Studios

The solution: ROADAR – a new type of assistance system presented for the first time at the IAA 2021. Visitors were able to watch live as the ROADAR-upgraded vehicle was put into action on a test track prepared with water.

How does it work?

- Unambiguous detection and localization of weather-related hazards on road surfaces is enabled based on data from near-infrared (NIR) and polarization sensor technology together with AI-assisted analysis.
- The system works in all light and weather conditions.
- The data generated can be instantly processed to enable the autonomous driving system to respond.

The competence portfolio of the research platform covers the following:

- Conception, development and assembly of networked sensor nodes for data logging to serve customer-specific applications
- Networking of embedded systems such as sensor nodes and control units by means of wireless and wired communication systems
- Establishment of secure cloud-based data and control solutions
- Conception and establishment of real-time communication systems in an industrial setting
- 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



More info about LZSiS

www.lz-sis.de/en



Dr. Sabine Jarothé, Assistant Secretary of State at the Bavarian State Ministry of Economic Affairs, Regional Development and Energy, visiting the IAA test track



More info about ROADAR

www.emft.fraunhofer.de/roadar

Universities



Technical University of Munich

- Prof. Amelie Hagelauer is not only Director of Fraunhofer EMFT, she also holds the Chair for **Micro- and Nanosystems Technology** at TUM. Her research and teaching have been concerned with integrated and discrete circuit technology for the realization of microelectronic systems in communications, radar technology, automotive engineering, medical technology and sensor technology.
- Prof. Marc Tornow, co-head of the Department of Silicon Technologies and Devices, is also head of the Chair of **Molecular Electronics** and conducts research on nanoscale devices in biomolecular, neuromorphic and quantum electronics.
- In addition, Fraunhofer EMFT has a longstanding collaboration with Prof. Gabriele Schrag, the acting head of the Chair of **Physics of Electrotechnology**. The research focus here is on physically based modeling, numerical simulation and the characterization and diagnosis of production processes and operating response of microstructured components.

University of the Federal Armed Forces in Munich

- There are close links between the Faculty of **Electrical Engineering and Information Technology** at Universität der Bundeswehr München and Fraunhofer EMFT, not least as a result of staffing connections: since 2012, Fraunhofer EMFT Director Prof. Christoph Kutter (Chair of Polytronics) has been joined at the university by the head of the Circuits & Systems department, Prof. Linus Maurer (Professorship for Electronic Devices and Integrated Circuits).
- In addition, Dr. Sabine Trupp, head of the High Performance Center "Secure Intelligent Systems", is completing her post-doctoral lecturing qualification in the field of gas sensor technology at the Faculty of Electrical Engineering and Information Technology at the Institute of Physics.
- Fraunhofer EMFT and Bundeswehr University Munich complement each other ideally due to the nature of their respective cleanroom facilities.



Hochschule München University of Applied Sciences

- Fraunhofer EMFT business developer Dr. Karin Bauer is also a lecturer and assistant professor at the Department of **Applied Sciences and Mechatronics**. Here she teaches a course in Microfluidics and Applications for both the master's degree program in Micro- and Nanotechnology and the international Micro- and Nanotechnology program. The course gives students the opportunity to look at applied micro-nanotechnology and systems.



University of Regensburg

- Fraunhofer EMFT has a longstanding collaboration with the Institute for **Analytical Chemistry, Chemo- and Biosensors** at the University of Regensburg. Since January 1, 2017, Prof. Joachim Wegener has been in charge of the Fraunhofer EMFT group Cell-Based Sensors (ZBS) in Regensburg. Joachim Wegener is Professor of Bioanalytics and Biosensors: 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 combination with Fraunhofer EMFT's microelectronics and polymer electronics expertise is expected to open up new fields of application in bioanalytics and biotechnology.



Landshut University of Applied Sciences

- As a lecturer at the Faculty of **Electrical and Industrial Engineering**, Dr. Frank Ansorge, Head of the Center for Interconnection Technologies (ZVE), acts as the interface for cooperation between Fraunhofer EMFT and Landshut University of Applied Sciences. The master's degree program in wiring system development was launched at this university in 2016. The course Electrical Connection Methods offered as part of this program focuses on the fundamentals of contact physics, contact materials, and contacting methods. Other topics include failure analysis techniques and analysis methods of wiring system components.



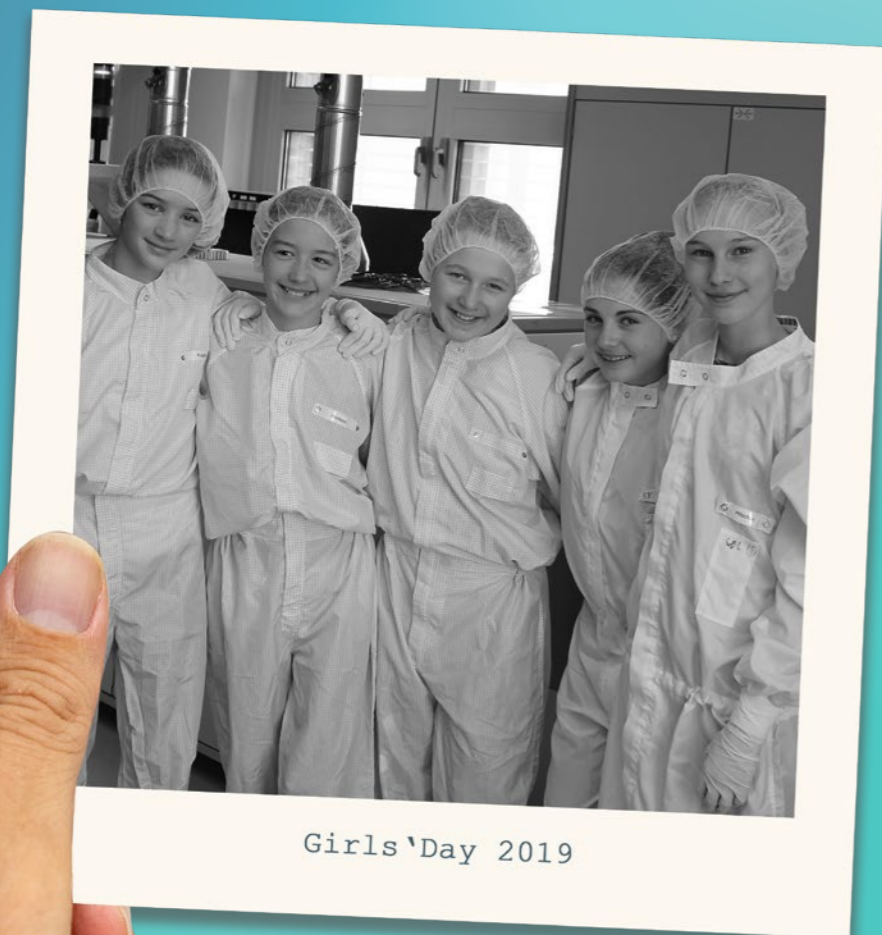
University of Kassel

- Dr. Erkan Isa's lectureship at the Department of **Electrical Engineering and Computer Science** at the University of Kassel forms the basis for the cooperation between Fraunhofer EMFT and the University of Kassel.

The postdoctoral researcher's lecture program focuses on integrated RF sensor systems and highlights the interrelationships between technological and economic challenges in the value chain of such systems.

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Well-qualified early-career investigators are vital in ensuring Germany retains its research expertise [and] innovation capability [...] in the long term."

BMBF,
Federal Ministry of Education and Research



New Generations – New Knowledge

Youth Development

We seek to introduce children and young people to the various facets of science in order to arouse interest in research among the future generation of scientists early on. By opening our laboratory doors to them, we are also giving them a glimpse of the often mysterious and seemingly unapproachable world of science. Even that first peek behind the scenes can make research seem more accessible, thereby broadening youngsters' horizons in terms of their interests and potential later career choices. With our various formats, such as Girls' Day, internships for school and university students, trainee positions and jobs for students, we provide opportunities for both initial exposure and more in-depth contact.

Virtual Girls' Day 2021

April saw an extra dose of girl power at Fraunhofer EMFT! The aim: to get nine girls excited about the world of microelectronics. To be on the safe side and make sure that the girls really did engage with the subject on virtual Girls' Day, our female scientists put together small, individual packages and sent them out to the students' homes. The girls were allowed to take a peek in advance ... but what on earth was that weird stuff inside the package?! On Girls' Day, the time finally came: the mystery of the curious objects was revealed. Together, we figured out step by step what a silicon wafer has to do with a bank card or a health insurance card, and why one wafer shimmers purple and the other shines green.

Afterwards, our trainee Saskia Heinze took the girls on a virtual behind-the-scenes look at what it's like to train to be a microtechnologist. We also asked ourselves the following questions, and then embarked on an interactive journey to answer them: Where do the materials used to make a smartphone come from? Why can even a broken smartphone be very valuable – and why else is it a good idea to have it repaired?

Training as a microtechnologist

During her training as a microtechnologist, Saskia Heinze is learning how the various processes work, which materials 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 course 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 to support 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."

School student placement

The sustainable production of large-area printed circuit boards for the solar industry involves three basic stages. A ninth-grade girl from the secondary school Staffelsee Gymnasium in Murnau did an internship to find out more about this process. First, there were sessions in facilities such as the cleanroom, and our scientist explained to her the various manufacturing techniques for creating conductor paths on foil substrates on our premises. Subsequently, working under supervision, she got to carry out laser structuring, electroplating and wet chemical etching herself to create her very own conductor paths for the first time. → for more information about the sustainable production of large-area printed circuit boards for the solar industry, see page 19

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Event Management



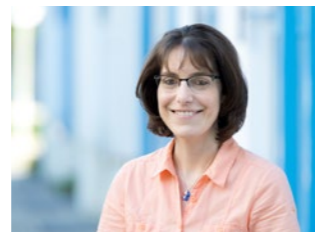
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Cover

Intelligent dosing system for nuclear medicine applications
using contact-free capacitive flow sensing

Image on the Patent Page (S. 48 f.)

Computed tomography (μ -CT) of an IC

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