Fraunhofer
EMFT

Fraunhofer EMFT

Sensors and Actuators for People and the Environment

Fraunhofer EMFT

Tailored Solutions for Customers and Cooperation Partners

Our portfolio of offerings reflects 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,

Maintaining a clear objective is the best basis for tackling upcoming challenges, while at the same time consistently looking for the best solutions and building on your own strengths. We are particularly pleased to have achieved one of our key objectives by the end of 2022: the Fraunhofer Research Institution for Microsystems and Solid State Technologies EMFT is now the Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT!

The positive decision on the part of the Fraunhofer Executive Board shows that we have done a lot of things right in recent years, underpinning our firm belief that continuous strategy work is essential in terms of our competitiveness and future viability. Last year we again kept on track in terms of strategy, analyzing our know-how and portfolio of offerings and fine-tuning them regarding to our strategic research topics (⟶ see page 10). We presented the results to external experts in an audit in November and received a good deal of praise along with valuable suggestions.

One key requirement of successful strategy work as far as we're concerned is to align it with the needs of our customers. What could make more sense than to get together to identify promising topics and plan long-term collaborative ventures on a concrete basis so as to be able to maintain and build our competitive capacity? In future we would like to do more to take the initiative here and invite you to engage with us in close dialog on a joint strategy! After the past two years of the pandemic, we are very much looking forward to being able to communicate in person once again.

"Stronger together" also applies to our strategic research topics, which we drive forward through powerful networks. Whether Green ICT, Munich Quantum Valley or the Fraunhofer Center for Biogenic Value Creation and Smart Farming – behind all of these initiatives there is clustered expertise from a variety of fields focused on solutions to the key challenges of our times: we are making the production of microelectronics more resource-efficient and ecofriendly by means of optimized processes and new materials. Our quantum technologies are contributing to building a competitive quantum computer in Bavaria which is to be available for use by industry. Meanwhile, developments in the field of smart farming seek to promote environmental protection, while at the same time ensuring the supply of food to our society is sustainable and resilient. Generous funding support from Bavaria and at the federal level has given these activities additional tailwind. ⟶ Further details from page 58

We now invite you to browse through the pages that follow and find out about what we did in 2022 – and we wish you an intriguing read!

Best regards,

Prof. Dr.-Ing. Amelie Hagelauer

Prof. Dr. rer. nat. Christoph Kutter

Content

200-mm wafer with Al Josephson junction test structures for superconducting qubits

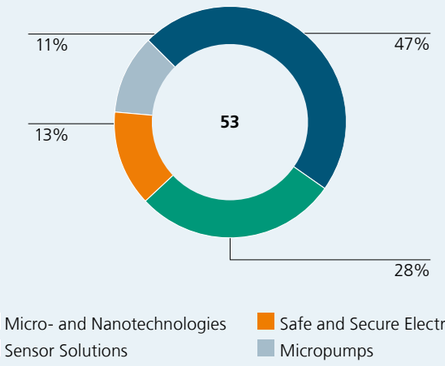
People, Facts and Figures

53
Projects

The Fraunhofer EMFT team was able to make its contribution to tackling the current challenges facing society in 2022 with a total of 53 projects. Almost half of these – 47% to be precise – can be attributed to the area of expertise Micro- and Nanotechnologies. This in turn forms the basis for the competences Sensor Solutions, Micropumps, and Safe and Secure Electronics. It is precisely the interdisciplinary interaction between these areas that helps us produce forward-looking solutions for people and the environment.

(⟶ More about our competences and projects from page 12)

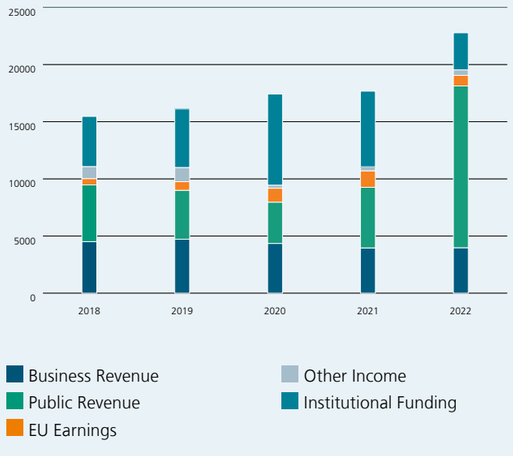
Share of Research Projects by Competence



22.8 M€
Total Budget

The total budget of Fraunhofer EMFT in 2022 was around 22.8 million euros. Industrial orders generated a total volume of around 4.0 million euros, or 22.10% of the operating budget.

Financial Budget



155+
Employees

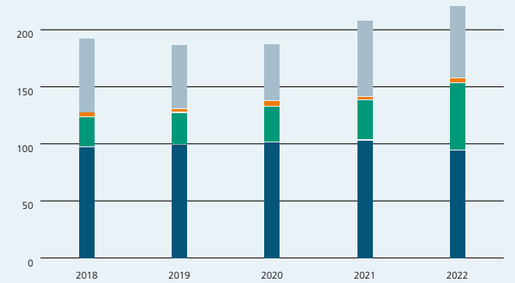
In order to achieve this, you need a strong team: compared to the previous year, the number of permanent staff at the institute increased by four in 2022, with a total of workforce of 155 as of the end of the year. Of these, 94 people are employed in the scientific area and 58 in support areas. The latter are made up of marketing, IT, administration, technology, quality management, organization and services. In addition, the Fraunhofer EMFT team has been supplemented with three trainees.

Another 62 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 23 different countries. Together, we drive forward research and development of sensor systems and actuators to the benefit of human beings and the environment. Our multicultural background is a key advantage, enabling us to look at scientific issues from a diverse range of perspectives. We make the most of this opportunity to inspire each other in our mindsets and our problem-solving strategies.

⟶ For details of individuals to contact, see page 70 ff.

Team Size



* marketing, IT, administration, technology, quality management, organization & services

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 future-oriented 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 to establish underlying principles, through to tried-and-tested *ready-to-market solutions* where we are involved in adding the finishing touches. Thanks to this broad spectrum, we help to shape new solutions from start to finish and at the same time building 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 our society is facing.

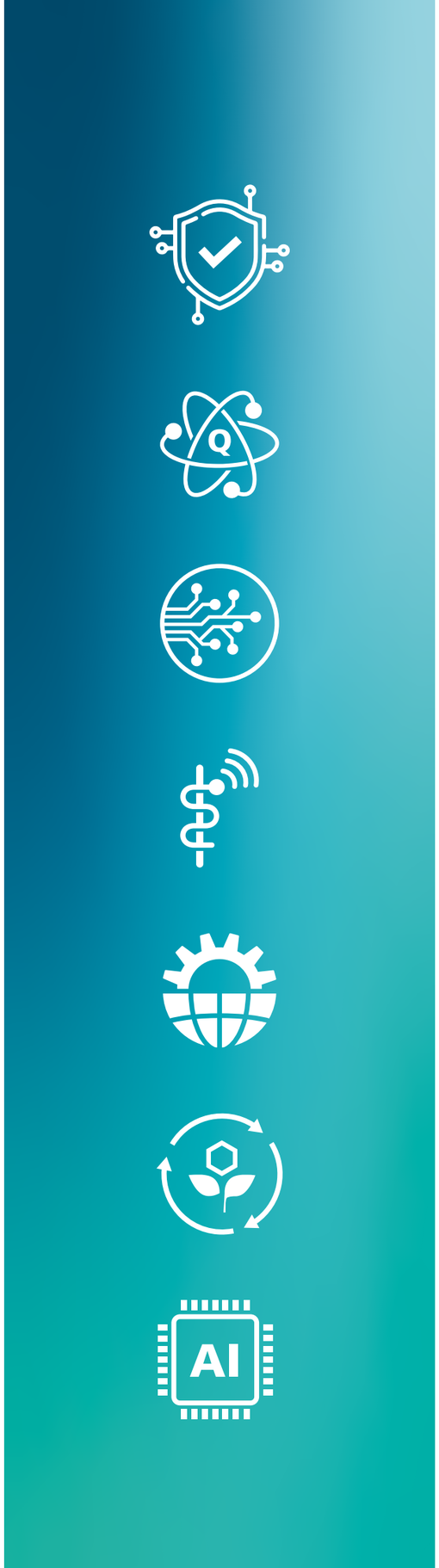
But what does this mean in concrete terms? Starting from issues of current and future relevance to society, Fraunhofer EMFT identifies precisely those topics where its expertise really can generate added value. In short: the strategic research topics pursued by Fraunhofer EMFT – and by the Fraunhofer-Gesellschaft 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 not static at all: 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 dialog 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's competences in the field of **Safe and Secure Electronics** enable 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 achieve 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 applies its expertise in **Micro- and Nanoelectronics** to investigate neurologically inspired computer architectures with memristors based on new 2D nanomaterials, for example. In the area of circuit design, these are used 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. Numerous R&D activities at Fraunhofer EMFT are concerned with solutions in the area of smart medicine. **Micropumps** have a key role to play here and are used in a wide variety of medical applications. In the field of **Sensor Solutions**, novel methods and systems are developed for improved diagnostics.

Resource Efficiency in Microelectronics

Resource conservation, energy efficiency and a significant reduction of the CO_2 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 ecofriendly 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. Smart farming is a promising and pragmatic approach to applying information and communication technologies in farming to combine economic and environmental goals in food production. Fraunhofer EMFT's expertise in sensor and actuator technology can be put to use in a variety of ways here: in the areas of **Sensor Solutions** and **Micropumps** this is currently happening in connection with plant phenotyping, emission analysis in livestock and supply chain monitoring in the food industry, to name a few examples.

Artificial Intelligence (AI) for Sensor Technology

Sensors are already indispensable as suppliers of data 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 items such as smart sensor nodes for environmental monitoring, medical wearables and production process monitoring.

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, for both people and the environment.

For an overview of **scientific findings** published by Fraunhofer EMFT **in 2022**, please see page 38 "Scientific Activities".

More Info

www.emft.fraunhofer.de**/competences**

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 institute's research activities. ⟶ Further details + projects from page 15

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 21

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, module preparation for safety analyses and hardware-based tamper protection technologies. ⟶ Further details + projects from page 27

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 33

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, such as:

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 and prototyping of CMOS components: Prototyping of CMOS-based silicon devices is a long-standing competence at Fraunhofer EMFT. Novel diode, detector, sensor and actuator concepts are the main focus, in both service and in R&D. Epitaxy, MEMS development, 3D integration and wafer thinning are used in addition to classic CMOS technologies.

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 institute. For customers, this development expertise is an essential part of the Fraunhofer EMFT service portfolio.

Detailed view of a foil system to measure temperature during processing

More Info

www.emft.fraunhofer.de/
micro-nano-technologies

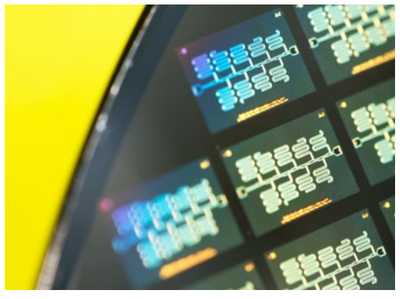
Projects

Micro- and Nanotechnologies

On the path to quantum computing: higher scalability of qubits

Quantum computers are to easily solve tasks that even today's data centers fail to tackle. But there are still some challenges to overcome before these computing geniuses can actually be used in widespread applications. As part of the Munich Quantum Valley (⟶ see page 59), Fraunhofer EMFT researchers work to promote the transfer of quantum technologies to industry. One focus of their activities is to optimize the scalability and stability of superconducting qubits. These are the basic units of a quantum computer and consist of a Josephson junction – a high-precision set superconductor-noncon-ductor-superconductor junction in the qubit circuits – and a resonator.

They are able to superpose for a certain period of time – the so-called coherence time, assuming all possible states simultaneously. This allows the quantum computer to compute all possible solution paths simultaneously, which dramatically increases computational speed. A quantum computer can only compute within this time span, however. In order to improve the coherence time and keep it stable over as long a period as possible, the researchers are focusing on achieving the greatest possible homogeneity in production. The more finely tuned the individual components are to each other, the longer the coherence time that can be achieved. Improved coherence time of superconducting quantum circuits is considered a critical requirement for the successful industrial operation of quantum computers.



Resonators for material analysis for superconducting qubits on 200-mm wafers with Nb coating

Another challenge is to minimize the noise that occurs in existing quantum computers. This is necessary because otherwise it can lead to a high error rate in the calculations, which significantly reduces performance capacity. The problem is that the individual qubits are extremely susceptible to interference, as they are subject to thermal, electromagnetic and even cosmic interference and phenomena that result in noise and therefore computational errors. In order to compensate for these fluctuations, as many qubits as possible must be interconnected as closely as possible to one another on a chip while still not influencing each other. At the moment, the limit here is nine qubits. The research team is pursuing the approach of being able to interconnect significantly more qubits than before based on space-saving design by means of through-silicon vias (TSV) through the 200-mm silicon wafer.

Munich Quantum Valley is funded by the State of Bavaria.

Neuromorphic computing © Fraunhofer IGD

1.25-m copper conductor tracks with a width and spacing of up to 20 µm were produced on polyimide foil by means of digital photolithography and wet chemical etching of the copper. Copper lines of any length can be created by lithographically stitching together successive images of 10-cm line segments.

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

Today's von Neumann-based computer architectures require enormous amounts of energy, so a massive expansion of computing to the edge would not make sense.

The project will combine hardware components developed on a common platform and the algorithms for federated learning so as to enable efficient implementation of inference and training. The neuromorphic accelerators that are to be developed have far lower levels of power consumption and can be optimized for AI algorithms. This makes it possible to shift data processing to edge devices.

The results of development will be demonstrated in two use cases. The first scenario focuses on material and defect detection in industrial applications. In the second use case, the scalability of architecture and methods for applications with higher data rates will be demonstrated in a virtual prototype.

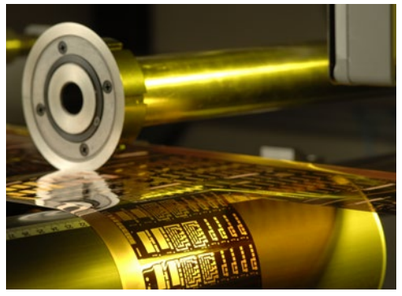
Here, the machine learning is to take place in the distributed systems without the basic data having to be passed on to the central cloud.

In this way, sensitive data can remain in the local systems, thereby ensuring data protection. The development of the core IPs is to be carried out internally at Fraunhofer to enable broad use in subsequent exploitation. Several Fraunhofer patents already exist in the field of neuromorphic devices (memristors). In terms of the algorithms and software, the main goal is to develop usable building blocks and platforms.

The work is being funded internally as a Fraunhofer lead project.

Sustainable medical devices off the roll

European countries are facing rising healthcare costs in the face of an aging population. At the same time, there is an increasing demand for medical devices to perform screening and monitoring functions. In recent years in particular, the focus has increasingly shifted to the aspect of sustainability: medical devices and tools are to be as resource-efficient and ecofriendly as possible throughout the entire value chain and leave a small ecological footprint.



Continuous roll-to-roll processing of electronic films

The aim of the EU project SusFE (Sustainable Flexible Electronics) is to develop a sustainable design and production platform for a new generation of sustainable yet cost-efficient medical wearables and diagnostic devices. Nine European partners in research and industry are pooling their expertise to this end, including Fraunhofer EMFT.

The consortium, led by Medtronic Ibérica, is pursuing a combination of sustainable materials and processes such as novel flexible integrated circuits (FlexIC), printed sensors, compostable paper-based energy sources, and a roll-to-roll (R2R) manufacturing platform for devices used in wound healing monitoring, autologous blood collection, and point-of-care devices.

Among other things, the partners in this project are looking to develop a smart sensor patch for monitoring patients' health status. It consists of FlexICs, a bioenzymatic fuel cell, and an atmospheric plasma coating of bioreceptors and is to be fabricated by means of a roll-to-roll process. In addition, the team is working to investigate materials and define processes for producing biodegradable, printed, textile-integrated multi-electrode arrays.

Fraunhofer EMFT scientists are focusing on contributing their longstanding expertise in the manufacture of flexible electronics using the R2R process. Their tasks include the production of copper wiring systems on foil substrates and the modular integration of electronic modules, sensor patches and batteries.

The project is funded under the EU Horizon RIA program, reference 101070477 – SusFE.

Resource-efficient and ecofriendly microelectronics production

In many areas, digitalization can make a significant contribution to saving energy and therefore reducing CO_2 emissions. The other side of the coin is that the manufacture and operation of electronic devices themselves involve the use of large amounts of resources and energy. Fraunhofer EMFT works on optimization approaches and innovative technologies in the area of information and communication technology that are designed to be ecofriendly and resource-efficient.

As part of the research project Green ICT, Fraunhofer EMFT researchers are optimizing lithography and etching processes with the aim of reducing chemical and energy consumption. New materials are also being tested to replace critical or environmentally harmful chemicals such as solvents or cleaning gases. In addition, Fraunhofer EMFT's abatement system demonstrates how to significantly reduce harmful emissions from the cleanroom into the environment, e.g. from harmful gases and toxic or corrosive substances from the installed equipment.

In another work package, Fraunhofer EMFT researchers are investigating the sustainability level of processes and materials used in common electronic products based on LCA (life cycle assessment). Criteria such as service life, modularity, recyclability and reuse are taken into account, as are the future availability and criticality of materials.

The competence center Green ICT is a cross-site research project run by the Fraunhofer and Leibnitz institutes cooperating as part of the Research Fab Microelectronics Germany FMD and is funded by the German Federal Ministry of Education and Research BMBF under reference 16ME0492.

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.

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

Fraunhofer EMFT has designed a portfolio of silicon, stainless steel and titanium micropumps for various areas of use. One main focus of R&D activities in the area of silicon micropumps is further miniaturization. The aim here is to significantly reduce production costs, thereby facilitating access to the mass markets. The smallest silicon membrane pump currently available in the world, sized 3.5 x 3.5 x 0.6 mm^3, was developed at Fraunhofer EMFT. A key focus just now in the area of metal micropumps is designing the pumps and valves. Here Fraunhofer EMFT cooperates closely with industry partners: the aim is for the latter to 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 to enable smooth interplay of all components in a microdosing system.

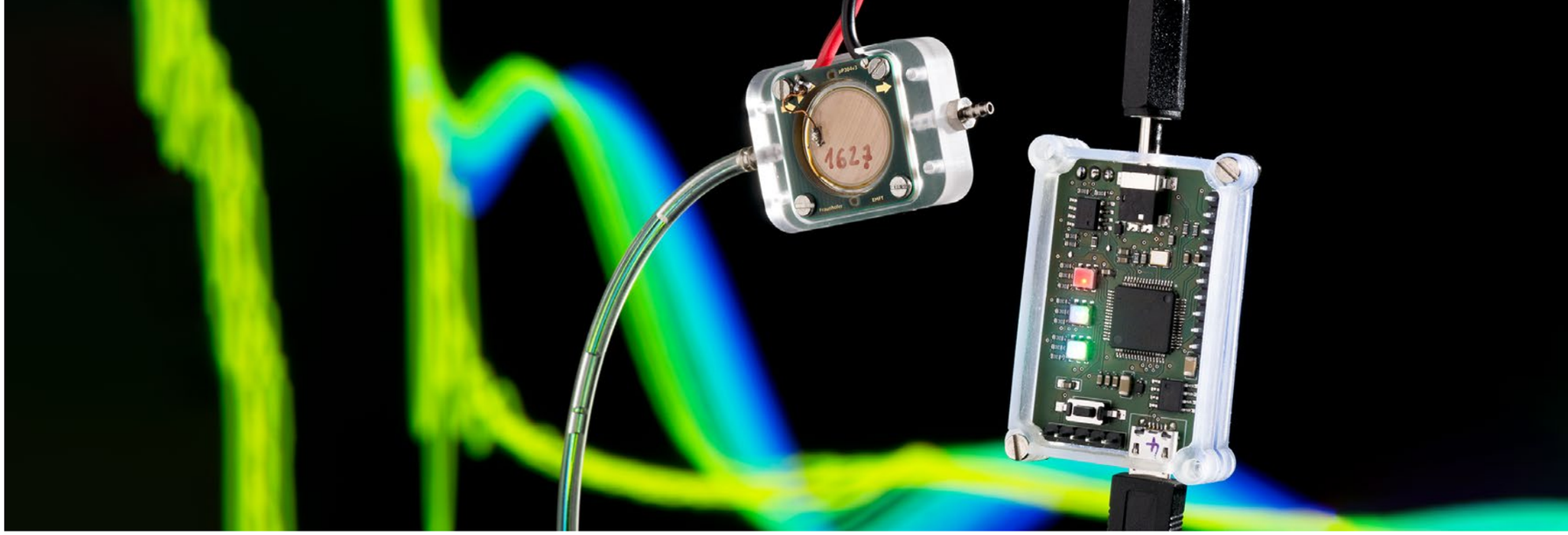
Multilayer connections of the stainless steel micropump

More Info

www.emft.fraunhofer.de/
micropumps

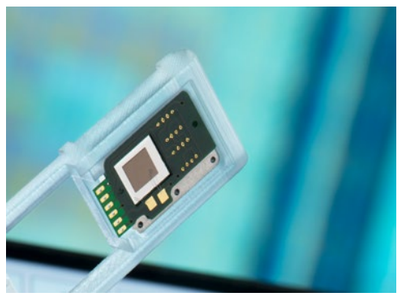
Projects

Micropumps



Research platform for optimized drug dosage using micropumps

In patient surveys on insulin dosing, patch pumps do significantly better than conventional insulin syringes in terms of convenience and user-friendliness. They are easy to use, comfortable to wear, and do not need to be removed – even during sports or when taking a shower, etc.



Tiny silicon micropumps offer enormous potential for medical dispensing applications

In terms of miniaturization, metering accuracy, backpressure capability and bubble tolerance, the micropumps developed at Fraunhofer EMFT are ideally suited for use in such patch pumps. However, another aspect is crucial in terms of the actual application in the product, too: the interactions between the pump and the medium to be dosed. This is because different media place very specific demands on the pump.

Researchers at Fraunhofer EMFT have launched the internal R&D platform "Smartpump" to investigate in more detail the interaction between micropumps and media that are relevant to medical technology. Insulin causes higher dosage fluctuations than water, for example, because more stable bubbles form due to the higher surface tension. This is confirmed by experience of existing insulin patch pumps: some diabetes patients report problems adjusting their blood glucose when they reattach a pump, for example. This indicates that there is some sort of running-in process and that the dosing rate initially has to stabilize in the first few hours.

So the research team's goal was to test their micropump without running it in to demonstrate that high accuracy can be achieved right from the start. For this purpose, the insulin doses in individual "volume packages" were examined. The devices can also be set to handle very small quantities of liquid, as the micropump's small dimensions allow very fine graduation of the desired volume. By switching the electrical control of the pump on and off, the dosing time can be adjusted and therefore the package size, too. The team tested repeatability using Fraunhofer EMFT micropumps with water and insulin respectively, and using three different package sizes. Even with the smallest amount of only 0.5 mg, they were able to dose the insulin extremely accurately using this method – the variation was less than 4%. Such precise dosing accuracy is the basic prerequisite for using higher-concentration insulin in the pumps in the future. The advantages: the smaller volume would further reduce the reservoir size or the size of the overall patch pump system, thereby further increasing patient comfort.

Sensor wristband with micropump for autonomous blood pressure measurement

Wearables such as smartwatches can already measure heart rhythm, pulse and oxygen saturation in the blood or record "simple" ECGs. But lifestyle trackers of this kind are not medical devices. Firstly, they would have to be able to draw on a properly prepared medical database, which would require scientific studies involving a statistically relevant number of patients with differing symptoms.

Together with industry partners, hospitals and outpatient surgeries, Fraunhofer EMFT is working on wearables with integrated sensor technology that meet these requirements. Relevant data sets on disease patterns are collected in cooperation with medical partners. These can be used as a basis for a mobile medical prophylaxis and diagnosis platform.

Self-monitoring of a piezoelectric micropump: detection of bubbles by monitoring of the drive signal

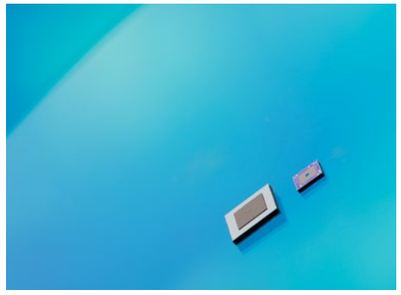
Portable blood pressure measurement using Fraunhofer EMFT micropumps

At the same time, Fraunhofer EMFT is developing the relevant wearables – including a sensor wristband for autonomous, continuous blood pressure measurement. At the heart of the device is a micropump that pumps air into an integrated flexible reservoir, which then presses on the arteries at the wrist. The systolic and diastolic blood pressure levels are recorded by means of specialized analysis methodology and displayed on the medical professional's tablet. To this end, the scientists are working on machine learning methods that draw on the database compiled from clinical studies and using this to identify indicators of specific diseases in the measurements.

In the future, this is to provide a diagnostic platform for more complex diseases such as sepsis, cardiac arrhythmia, stroke and pressure wounds.

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.



Dosage chip, silicon micropump and flow sensor

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.

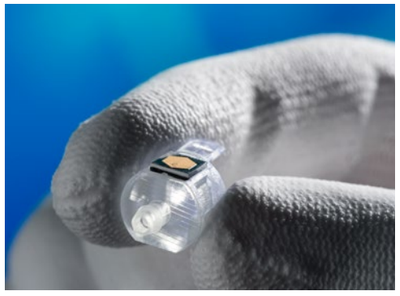
The project is being funded under the ECSEL JU program in collaboration with the Horizon 2020 framework program run by the EU and national authorities under reference H2020-ECSEL-2019-IA-876190.

Ammonia gas sensor module for use in livestock facilities

The agricultural sector is of significant economic importance in Bavaria, with sales of some 121 billion euros per year. However, conflicts arise repeatedly between the farmers' economic objectives and the sustainable goals of environmental and animal welfare initiatives due to the different interests involved. In particular, the emission of ammonia gases is a controversial issue in society at large.

Constant monitoring of emissions could help make the debate more objective. The measuring systems that are currently available on the market are inexpensive, but purely passive: as a rule, these are measuring boxes with sensors that are distributed throughout the system and analyzed at regular intervals. For higher-quality active alternatives, farmers currently have to invest in very expensive optical measurement systems.

Researchers at Fraunhofer EMFT are working with the Bavarian start-up EC Sense, TU Danzig and the Polish KmU issrfid on the project i-MAGS to produce a solution for inexpensive, active, decentralized and instantaneous measurement of ammonia gases harmful to the environment and animals in livestock facilities using a miniaturized ammonia gas sensor module.



Highly integrated gas sensor module: micropump module

In order to significantly improve the response time of the sensor, a micropump was integrated in the ammonia gas sensor module which actively feeds the air from the environment to the sensor. This combination makes it possible to measure absolute gas concentrations in the ppb range very cost-effectively within a few seconds. The sensor module with integrated micropump was developed previously by Fraunhofer EMFT and EC Sense in the previous MIAGS project. In the current project, the Polish cooperation partners are now working on integrating these sensor modules in an IOT network for monitoring ammonia concentrations in large-scale pigpens.

The project is funded by the German Federal Ministry of Education and Research (BMBF; contract no. 01DS22002A) and the National Center for Research and Development (NCBR; contract no. WPN/4/66/i-MAGS/2022) under the 4th Polish-German call for proposals in the field of digital green technology.

More Projects

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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 failsafe operation – in sensitive areas such as medical technology, the automotive industry and aerospace technology. In its R&D activities, Fraunhofer EMFT pursues the goal of enabling so-called zero-defect systems. Focus areas here include failure analyses and characterization of electronic modules and systems, development of novel ESD test and protection concepts and the monitoring of electrical connections using 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 Internet of Things applications will 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

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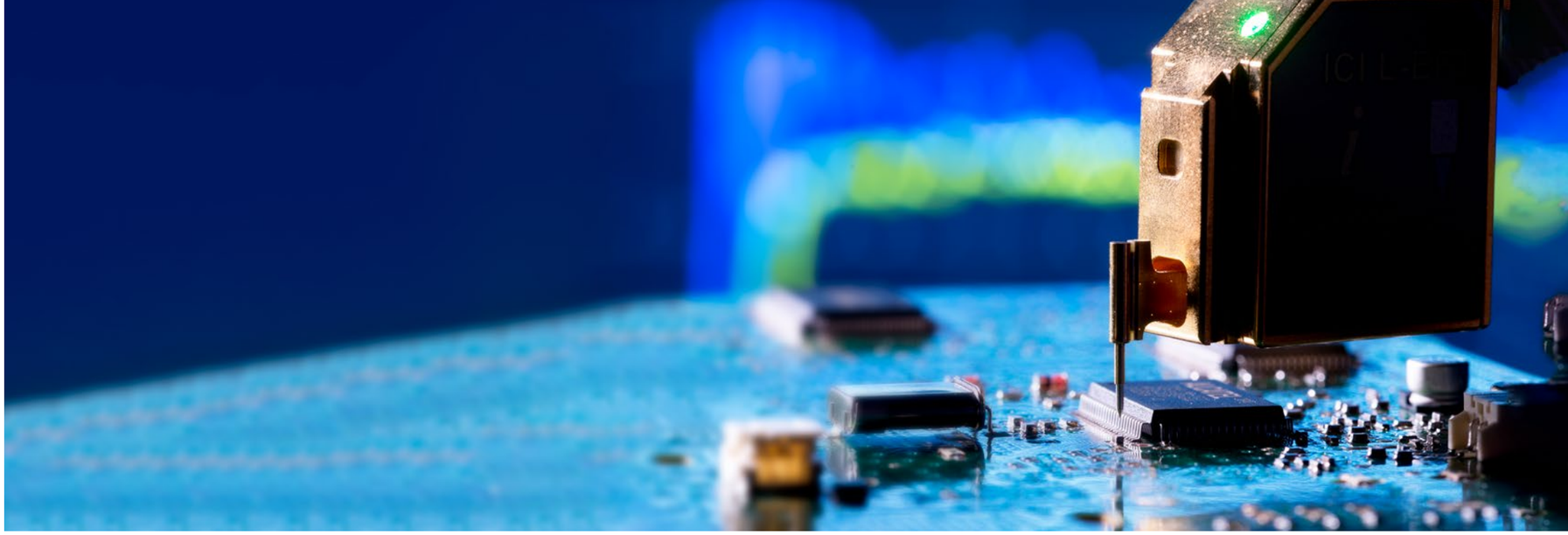
safe-secure-electronics

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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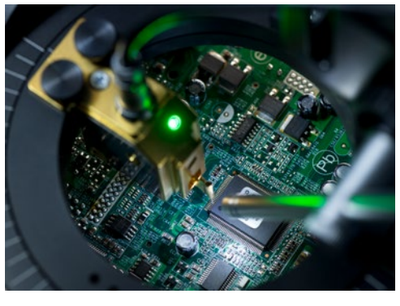
Researchers at Fraunhofer EMFT primarily focus on the hardware level here:

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 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 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 the use of high-performance semiconductor components from the cost-sensitive consumer area for highly reliable Industry 4.0 applications without having to undertake a costly, comprehensive redesign.

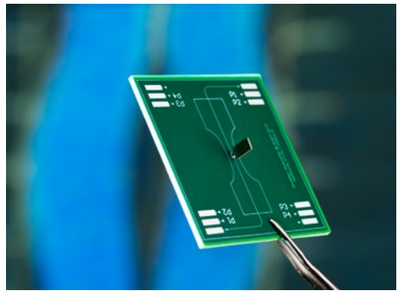
Probe for the injection of stress pulses

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).

Scrutinizing the quality of press-fit contacts

Electromobility is seen as an important component in making individual transportation more climate-friendly and resource-efficient. Not only costs and drive comfort are essential for acceptance, but in particular the safety aspect, too: data and power transmission in the vehicle must function absolutely reliably. Contact degradation poses a challenge for vehicle power transmission connection systems as it is especially difficult to control.



Investigation and simulation of the damage response in press-fit connections as a result of mechanical and thermal loads

Press-fit technology is an innovative joining method that is particularly suitable for use in safety-relevant connection points due to its high degree of reliability and robustness. Another advantage: this method is much more ecofriendly than the soldering technique that is currently most commonly used.

In the ProPin project, Fraunhofer EMFT scientists are developing an innovative measurement methodology to determine the quality of press-fit contacts under mechanical and thermal stress. A predictive model is to be used to determine the link between readily available material/process data and connection reliability. This project is intended to enable SMEs and start-ups to enter new fields of application by significantly reducing development and qualification efforts.

This makes Fraunhofer EMFT the only provider of a comprehensive method for predicting and validating the quality of press-fit connections. After completion of the project, the novel technology will be made available to SMEs as a research service.

The project is internally funded by the Fraunhofer-Gesellschaft.

Industrial robot with radar-based collision protection

The principle is already state of the art in modern passenger cars: radar sensors that sound the alarm when the vehicle approaches an obstacle. Such collision protection will also be indispensable in industrial production in the future – smart factories where intelligent industrial robots are expected to act completely autonomously in an increasing number of work stages – so as to ensure safe collaboration between humans and machines.

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In the project RoboMove, Fraunhofer EMFT is working with robotics manufacturer KUKA and the company InnoSenT GmbH to develop an intelligent 3D distance measurement and obstacle detection system for robot arms in motion. This will result in a highly integrated radar system with intelligent 3D environmental perception and close-range detection that will enable reliable detection even in dynamic operational environments. The challenge is to ensure safe, automated execution of the machine's operations while the robot arm is moving in the event of sudden changes in the environment. Impending collisions with workers or obstacles by the robot must be correctly detected by the system in good time so as to enable a reaction such as swerving or an emergency stop.

The latest technologies and machine learning methods will be used to implement environment characterization for controlling and safeguarding industrial robots. As part of this project, Fraunhofer EMFT is to investigate and optimize object recognition based on the target list returned by the radar so that not only the distance to an obstacle is identified but also which object it is. In order to be able to attach the radar modules to robot arms to optimum effect, the complete radar sensor technology is also to be integrated on flexible and stretchable foils. This is where Fraunhofer EMFT is able to make its extensive expertise in the field of flexible electronics available.

The project is funded by the Bavarian State Ministry of Economic Affairs, Regional Development and Energy under the funding line "Digitalization – Electronic Systems" under reference DIE 0130.

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

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

R&D focus areas at Fraunhofer EMFT:

- Energy-efficient sensors
- Sensors on flexible substrates
- Chemical sensorics/gas sensorics
- Biosensorics
- Cell-based sensor technology
- Characterization and validation
- Combined sensor systems
- Sensor systems with machine learning support

Sensor materials for combined in-line measurements

More Info

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sensor-solutions

Projects

Sensor Solutions

Artificial Intelligence (AI) for Sensor Technology

Nowadays, the analysis of sensor data usually takes place in the cloud. But as digitalization continues, the amount of sensor data being collected and analyzed is growing rapidly. Even modern mobile networks and wired communication networks will be overwhelmed by the transmission of such immense amounts of data in the foreseeable future. At the same time, the requirements for data security and protection are increasing. Storing raw data at the edge is a promising way of both reducing data volumes and increasing data security.

So in the project KIS, researchers at Fraunhofer EMFT are working on equipping sensors and actuators with AI. The goal is to be able to perform intelligent (pre-)processing and aggregation of data in the edge. To this end, various methods will first be investigated that allow machine learning (ML) models to be trained in such a way that they can be executed in an intelligent sensor node. Furthermore, the research team will conceptualize and develop an intelligent environmental monitoring station. This is to be installed on the Fraunhofer EMFT roof, for example, where it will monitor the environmental impact of traffic and industrial facilities in the Munich urban area. In the context of the project, the measuring station serves firstly as a supplier of measurement data, where data is collected appropriately so it can be used for training ML models, and secondly as a vehicle for the investigation and testing of ML models integrated in the sensor node.

AI in the sensor node: embedded tiny machine learning platform

A second transfer demonstrator for AI-controlled micro-dispensing will be developed to evaluate the transferability of the lessons learned. In addition, further transfer demonstrators will be defined together with industry to demonstrate the developed methods.

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

On-plant sensors: on the pulse of the plant

An optimum supply of nutrients and water is the key to vital and high-yielding crops. Accordingly, constantly updated knowledge of the nutrient and water content of the soil and crops, as well as any potential pest infestation, is of great importance to farmers as it forms the basis for irrigation and fertilization of the fields in line with requirements. Although soil fertility can be measured well with the methods currently in use, this is not the same as the vitality of the plant, since it is primarily the interactions between soil and crop that are the key factor here.

Sensors based on organic semiconductors for the monitoring of plant vitality and as indicators of parasitic infestation

As part of their research activities in the field of smart farming, researchers at Fraunhofer EMFT are pursuing a completely new approach in cooperation with Tel Aviv University (TAU) in order to better understand the “inner workings” of crops: using a special printing process, they apply sensors directly to the plants to record their vital data.

With a sensor attached to the underside of a leaf, it is possible to monitor metabolic processes at the stomata – the openings on the plant’s epidermis. Gases emitted in small amounts through the stomata may then be measurable. The team can draw on previous research conducted at TAU in order to determine and measure the molecules in the leaves.

In future, the method is to enable early detection of pest infestations in addition to the detection of nutrients and water content. In addition, the scientists plan to investigate in more detail the relationship between the measured soil and plant data in order to develop an efficient prediction model based on easily accessible data.

The project is funded by the German Federal Ministry of Education and Research and the Bavarian Ministry of Economic Affairs as part of the Fraunhofer Center for Biogenic Value Creation and Smart Farming BWSF.

Machine learning methods for quality assessment and predictive replacement of lubricating oils

AI-based predictive maintenance for manufacturing equipment

The goal of predictive maintenance is to maintain operating equipment in a proactive and anticipatory manner. The aim is to reduce downtimes and maintenance work to a minimum. Researchers at Fraunhofer EMFT are testing new concepts for using machine learning methods to efficiently process even extremely heterogeneous data and make accurate maintenance predictions for manufacturing equipment.

Development of a machine-learning-based predictive maintenance solution for manufacturing equipment

Fundamental technologies for predictive maintenance are networked sensor nodes and a central data repository, which is why this topic is closely linked to the technology trends of the Internet of Things (IoT) and Industry 4.0. A model that has been trained by machine learning with the centrally stored data can later also be used at the decentralized nodes for the purpose of data analysis.

In the project KIWA, a Fraunhofer EMFT research team combines sensor data from a manufacturing plant with other external sensors to generate additional relevant characteristic values such as the vibration of a drive. Critical plant components are then monitored during operation and correlated to the process flow. An application example is provided by plant systems run by project partner Mühlbauer: additional external sensors such as vibration sensors or sensor systems for the precise measurement of other parameters are installed for an exact recording of the time sequences in order to predict maintenance or the replacement of drive systems and components. The data collected is to be used to draw conclusions about the current operating condition and make predictions about further service life or necessary maintenance requirements.

While conventional questions of condition monitoring and predictive maintenance usually draw on unimodal data, often even one-dimensional data of constant clock frequency, the challenge in this project lies in the selection and processing of extremely heterogeneous data from a wide variety of sources with clock rates in the range of a few hertz to about 50 kHz using machine learning methods. The anticipated results could in future lead to currently prevailing preventive maintenance being replaced by predictive maintenance management.

In addition to Fraunhofer EMFT and the Mühlbauer Group, Procon IT and Munich University of Applied Sciences are also involved in the project. The project is funded by the Bavarian State Ministry of Economic Affairs, Regional Development and Energy under reference DIE0147.

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.

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The resulting IoT devices are expected to combine outstanding energy efficiency with robust neuromorphic computing capabilities. Drawing on efficient 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 to the creation of 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.

More Projects

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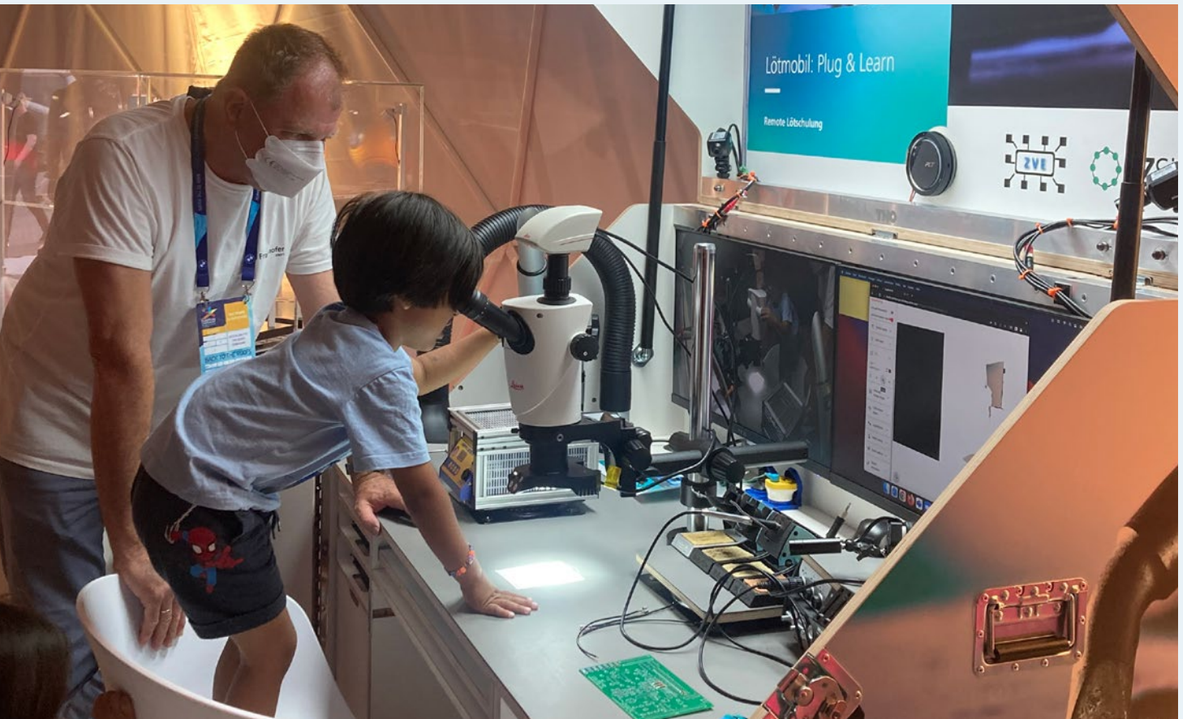
Highlights and Scientific Activities

Since we are an institute dedicated to 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 2022:

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

But first of all we'd like to give you a sneak peek at our highlights from last year!

Young researcher takes a close look at the mobile learning hub



Highlights

The Roofs Festival 2022

A festival? Cool! In summer? Even better! In Munich? We'll be there! The pandemic resulted in a seemingly never-ending run of canceled events. So we were instantly fired up when the idea arose of doing our very own Fraunhofer Technology Roof in the Olympic Park in Munich during the European Championships. In the glorious August sunshine and amid thousands of cheerful visitors, the time finally came: together with the Fraunhofer-Gesellschaft, the High Performance Center "Secure Intelligent Systems" (LZSiS) and numerous other Fraunhofer institutes, we filled the Technology Roof with research and science. Frank Ansorge and his team from Oberpfaffenhofen represented Fraunhofer EMFT on site: they presented their remote training courses with the mobile learning hub.

How does it work? With a dash of augmented reality (AR). This enables a virtual learning environment and also interaction – so it is of enormous benefit, and not only in times of crisis. The idea for the whole thing originated with the need for a suitable alternative to in-person training at the ZVE – the Center for Interconnection Technologies in Oberpfaffenhofen. It was achieved by means of a soldering station on four wheels: this mobile learning hub can be put into operation directly on the customer's premises by means of plug & play. Permanently installed cameras enable ideal interaction between ZVE training staff and learners. Festival visitors were able to experience this at first hand, too: at our stand, young and old alike got to perform their very own handiwork in electrical connection technology, i.e. soldering and crimping via AR. And the team even made provisions for the little ones: AR glasses were available with fun 3D games – because as we all know, you can't start the recruitment process early enough!

Our personal icing on the cake at the end: a survey carried out in the Technology Roof showed that our booth was best received by visitors. So the Roofs Festival was a resounding success! Or as you might say in Bavarian dialect: ***da war ma dabei, das war priiima ...*** we were in on the action and had a blast!

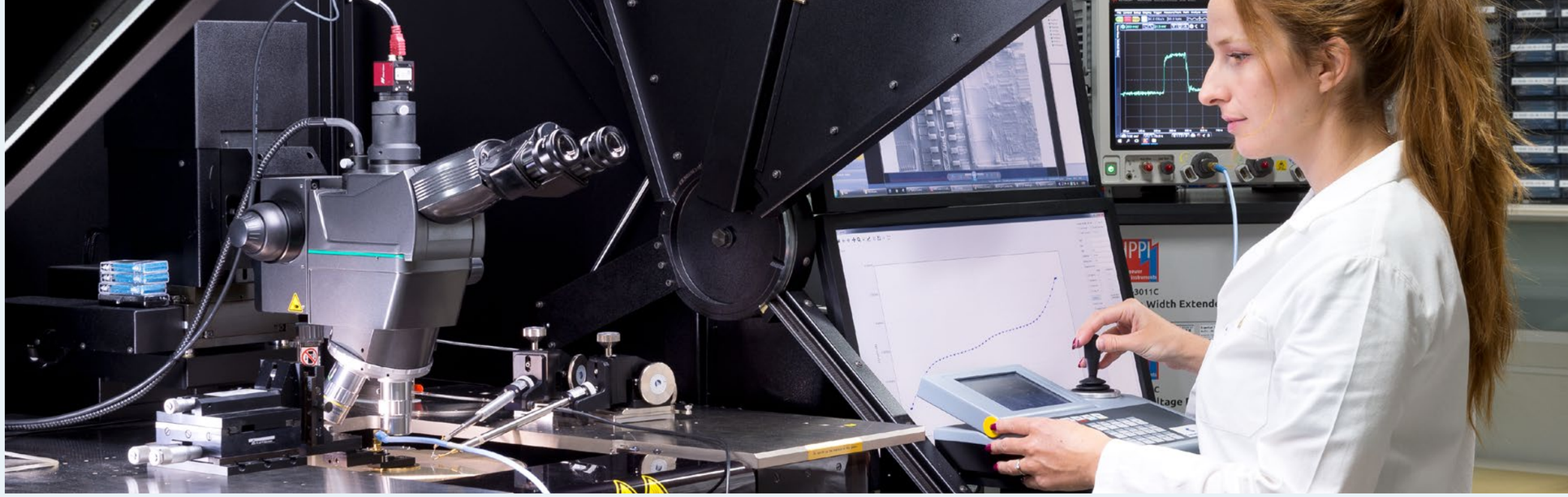
⟶ More about the ZVE training center and the soldering mobile from page 48

Mission DressMAN

Superman? Batman? The LZSiS has its very own superhero: DressMAN! And he was sent out on tour in his hometown in December. His mission: to check the air quality at various locations in Munich. His route included the Munich urban development project Werksviertel as well as an ALDI SÜD outlet. But what sounds like a superhero is actually a project being run by the Fraunhofer Institute for Building Physics, or IBP for short, to carry out research into thermal comfort. Analyzing various physical signals in different situations with up to 60 sensors, DressMAN can be used in a variety of ways. He ensures our well-being – whether at home, at work or on the road. He can analyze our day-to-day routine or take on extreme situations on our behalf so as to make our lives safer and more pleasant – in other words, he really is a superhero. As part of the campaign week – organized by the High Performance Center "Secure Intelligent Systems" (LZSiS), Fraunhofer EMFT, Fraunhofer IBP and Fraunhofer IVV – it was possible to marvel at him in full action mode, while researchers were there on the spot to answer any questions asked by Munich residents on the subject of sensor technology. DressMAN, a superhero you can touch ... ⟶ More about the LZSiS and DressMAN from page 54

The Fraunhofer-Gesellschaft's Technology Roof

DressMAN goes shopping for bread rolls at ALDI Süd; © LZSiS / Burke Agentur



CC-TLP: original probe for capacitively coupled CDM-like TLP stress testing at wafer level

Strategy audit and in-house exhibition

Thinking about tomorrow today! In these fast-moving times, when everything and everyone is networked, the famous crystal ball can sometimes fail when we look into the future. Perhaps that is precisely why this year was the perfect time for the entire Fraunhofer EMFT to take a closer look at where we stand today, where we want to go, and how we can get there together. So under the leadership of our institute directors Amelie Hagelauer and Christoph Kutter, we sketched out our common path into the future. Measurable strategic goals were defined and the first measures were designed to achieve these objectives under various different framework conditions and scenarios. The result was then reviewed by external auditors from business and science at the end of November. In the course of two intense days, a fascinating exchange of ideas took place in a constructive atmosphere about current and future challenges and potential solutions in the areas of business, research, personnel and society. Research findings from all areas of Fraunhofer EMFT were presented at an in-house exhibition so as to demonstrate the implementation of our guiding principle: "Fraunhofer EMFT – Sensors and Actuators for People and the Environment". After all, even though there might well be several dead ends and detours in store for us along the path to the future we have sketched out for ourselves – or precisely because of this – Jack Welsh's quote is especially true in applied research: "In reality strategy is actually very straightforward. You pick a general direction and implement like hell."

⟶ For further information about our strategic research topics, see page 10

In-house exhibition with virtual training provided by ZVE

Ceremonial opening of the research platform FIP-SENS@TAU

On June 22, 2022, Tel Aviv University (TAU) together with Fraunhofer EMFT and guests from public institutions, industry, academia and politics inaugurated FIP-SENS@TAU – the Fraunhofer Innovation Platform for Sensors and Applied Systems at Tel Aviv University.

The new research collaboration led by Managing Director Dr. Sabine Trupp focuses on multidisciplinary and interdisciplinary research and development in the field of sensors and will work with partners from industry in Israel, Germany and other countries. The goal is to become a globally recognized solution provider for intelligent sensor systems.

The opening event was held at the TAU Museum of Nature with about 60 distinguished guests. FIP-SENS@TAU had the pleasure to welcome such personalities as the German Ambassador to Israel, Dr. Susanne Wasum-Rainer and the Israeli Ambassador to Germany, Ron Prosor. The ceremonial signing of the framework agreement by Prof. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft, and Prof. Dan Peer, Vice President for Research and Development at TAU, was accompanied by a fascinating program of presentations on ways to commercialize outstanding research.

⟶ For more information on FIP-SENS@TAU, see page 56

At the ceremonial opening of FIP-SENS@TAU
© Chen Galili

Post-doctoral lecturing qualification in chemo- and biosensorics

The Faculty of Electrical Engineering and Information Technology at the University of the Federal Armed Forces in Munich has awarded Sabine Trupp a post-doctoral lecturing qualification in the field of chemo- and biosensorics. Considered one of the leading experts in her field, the researcher's accomplishments in the course of obtaining this qualification were outstanding. In her postdoctoral thesis she presented new findings on the development of sensors for the analysis of biological and chemical substances. With the award of this qualification, the faculty not only recognizes her excellent scientific work but also her ability to communicate complex topics in a comprehensible manner. We congratulate Sabine Trupp on this notable achievement and wish her ongoing success in research and teaching in the future.

After successfully delivering her post-doctoral qualification lecture a beaming Dr. rer. nat. habil. Sabine Trupp with the team

Bachelor's Degree Theses

Knopp, P. (2022). **Lithography of Polyionic Liquids.**
Supervision: Yakushenko, A.
Hochschule München University of Applied Sciences

Master's Degree Theses

Ali, S. F. (2022). **Characterization of Humidity-Sensors based on Polymer Sensing Layer.**
Supervision: Boudaden, J. & Ramm, P.
Hochschule München University of Applied Sciences

Bajt, A. (2022). **Design of a Receiving Front-End Time-Gain-Compensation Amplifier with Automatic Gain Control in 0.18 µm SOI Process for an Optimized pMUT Device.**
Supervision: Poongodan, P. K.
Technische Universität München

Calderaro Rodrigues, P. (2022). **Numerical simulations of fluid-structure interaction for investigating microvalve's functioning using ANSYS.**
Supervision: Leistner, H. & Wackerle, M.
Leibniz Universität Hannover

Canbey, O. (2022). **Physical Aspects of PUF Generation Parameters for Anti-Temper Security Foils.**
Supervision: Yakushenko, A.
Technische Universität München

Debera, P. (2022). **Prüfstand zur Charakterisierung der Gas-Leckrate von Silizium-Mikroventilen.**
Supervision: Anheuer, D.
Universität Stuttgart

Duong, B. T. (2022). **Characterization and Validation of PEDOT:PSS and its application on the surface of leaves for condition monitoring.**
Supervision: Ansorge F., Meltzer E.
Hochschule München University of Applied Sciences

Gadwala, V. (2022). **Modelling of valve behavior for MEMS Micropumps.**
Supervision: Grünerbel, L.
Ernst-Abbe-Hochschule Jena

Heigel, M. (2022). **Technologieentwicklung für Silizium-Avalanche-Photodioden mit lateralem elektrischem Feld zur Erhöhung der Rot-Empfindlichkeit.**
Supervision: Neumeier, K.
Hochschule für Angewandte Wissenschaften München

Hoffmann, S. (2022). **Automatisierte fluidische Integration von piezoelektrischen Mikromembranpumpen in eine elektronische Pille zur Medikamentenverabreichung im Gastrointestinaltrakt.**
Supervision: Bußmann, A.
Universität der Bundeswehr München

Mothukuri, A. G. (2022). **Design and Implementation of a Hardware-Aware SNN Simulator.**
Supervision: Pscheidl, F.
Universität Siegen

Schumann, M. (2022). **Entwicklung eines Embedded System für die Auswertung von Vitalparametern zur automatisierten Vorsichtung.**
Supervision: Bußmann, A.
Hochschule für Angewandte Wissenschaften München

Schwarz, J. (2022). **CFD-Simulation von Leckraten an MEMS-Klappenventilen.**
Supervision: Axelsson, K.
Technische Universität Bergakademie Freiberg

Siebers, Z. (2022). **Poly-ionische Flüssigkeiten basierte elektrochemische Gasmessung.**
Supervision: Yakushenko, A.
Technische Universität München

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Supervision: Durasiewicz, C. P.
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Scientific Publications

www.emft.fraunhofer.de/publications

Range of Offers

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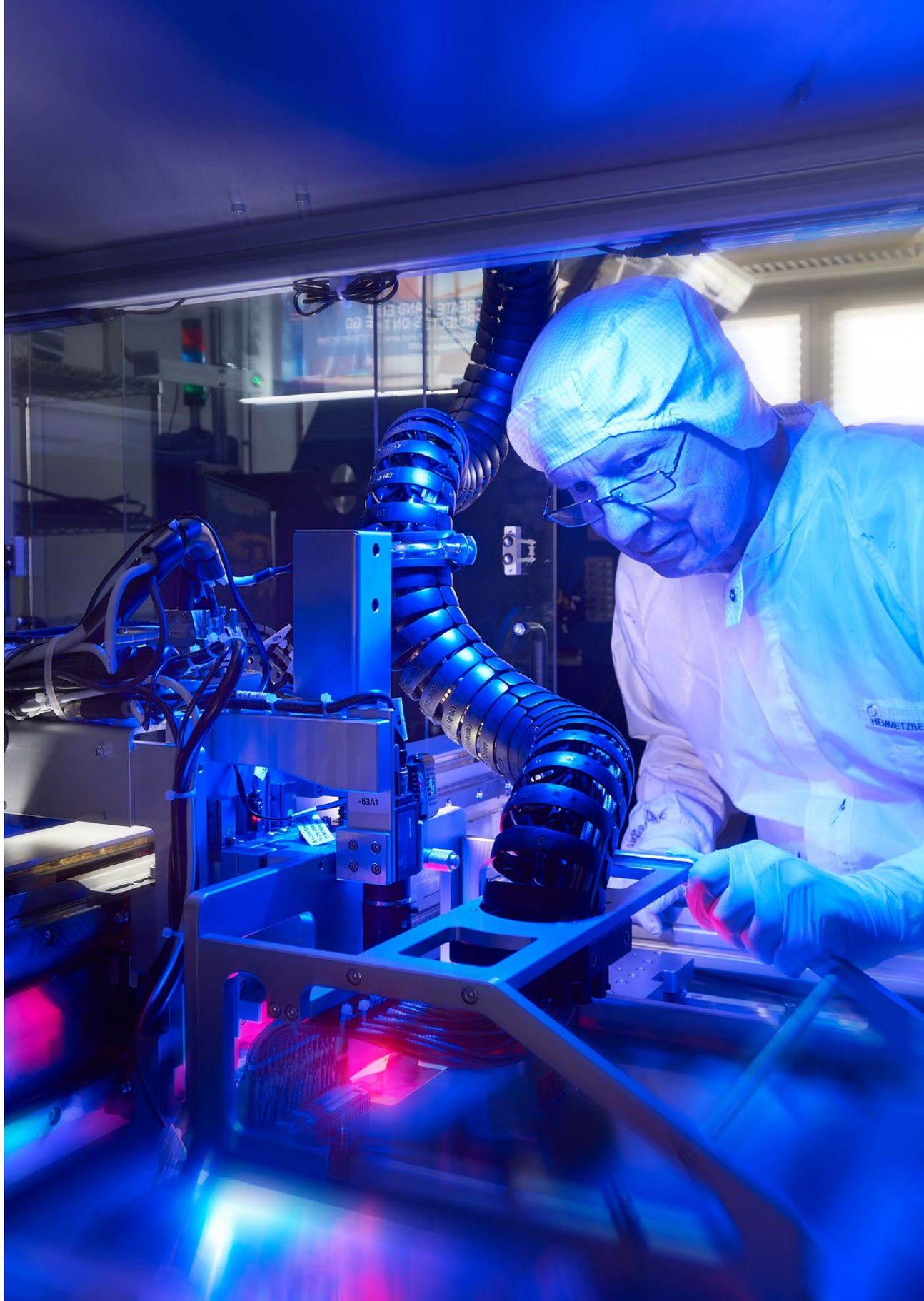
Technologies and Resources at Fraunhofer EMFT

Its extensive infrastructure and wide range of **technologies in the field of microelectronics and microsystems engineering** make Fraunhofer EMFT an attractive partner for both 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 48



Inside view of the reel-to-reel electrical measuring system by db matik

Range of Offers

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, skilled 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 40 years of experience, the ZVE has become well established as a center for training and professional development.

ZVE soldering mobile for virtual training in practice

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 dedicated to 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 mobile learning hub, it was even possible to conduct remotely monitored practical training: The fully equipped mobile learning hub is put into operation at the customer's premises via a standard 220V socket. 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.

Continuing education and training 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 its 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

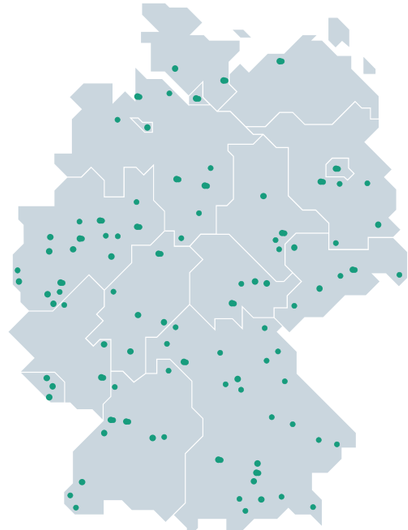
Everyone talks about how incredibly important "networking" is – it's the right contacts that help move projects forward successfully.

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.

- First of all, the **Fraunhofer-Gesellschaft** itself deserves to be mentioned: a Germany-wide but also international network of applied research covering a truly enormous variety of fields.
- 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 "secure from the sensor to the cloud" and makes this knowledge available specifically to companies.
- At the **Trusted Electronics Center Bavaria**, Bavaria-based Fraunhofer institutes work together to enable or simplify access to trusted technologies in the form of secure and protected hardware and software components for industrial companies.
- At the **Fraunhofer Center for Biogenic Value Creation and Smart Farming**, five Fraunhofer institutes, among them Fraunhofer EMFT, are jointly developing innovative technologies for the agriculture of the future. The focus is on the goal of making agriculture more sustainable while at the same time ensuring the future viability and resilience of the food supply.
- As a research and development platform for renowned Bavarian research organizations and universities, **Munich Quantum Valley e.V.** promotes quantum science and quantum technologies and their transfer to industrial applications. One key objective is to develop and operate a competitive quantum computer in Bavaria.
- At the research unit **FIP-Sens@TAU**, scientists from Fraunhofer EMFT and Tel Aviv University are working on interdisciplinary developments in the field of sensor technology. The focus is on applied solutions in the fields of agriculture, security applications and environmental monitoring where there are very good marketing opportunities.
- 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.

The Fraunhofer-Gesellschaft

The Fraunhofer-Gesellschaft, based in Germany, is the world's leading organization for applied research. 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 euros. Fraunhofer generates 2.5 billion euros of this from contract research.



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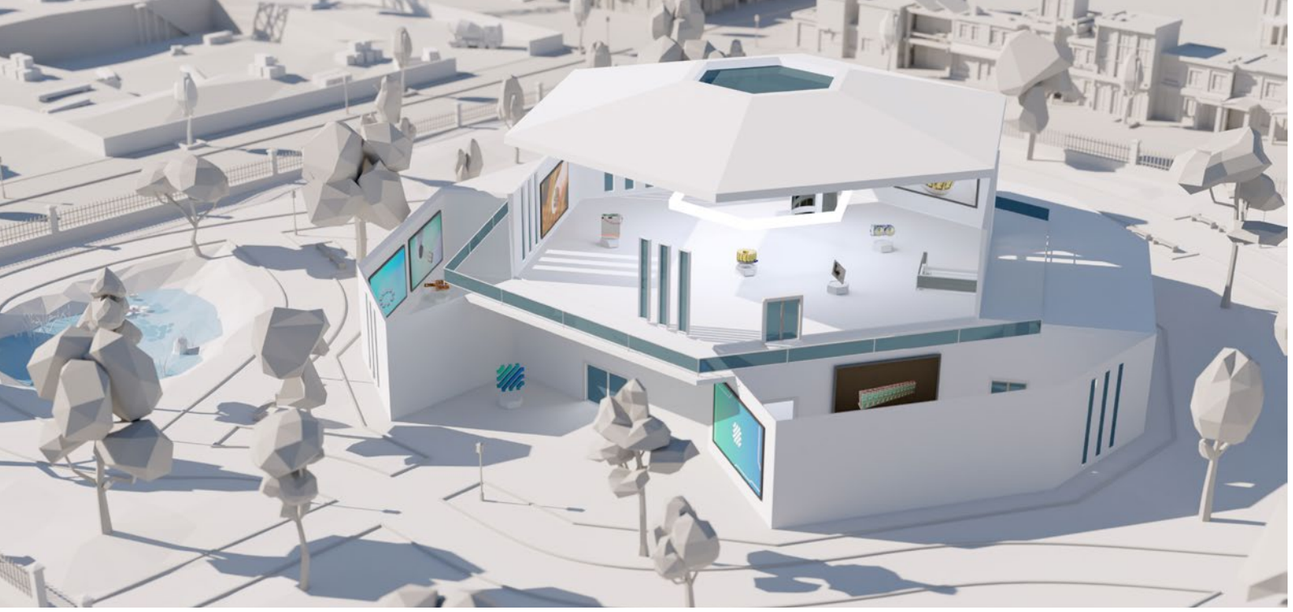

Virtual 3D showroom

Research Fab Microelectronics Germany

Fraunhofer EMFT has been part of the Research Fab Microelectronics Germany (FMD) since 2017. As a cooperation of the Fraunhofer Group for Microelectronics and the Leibniz Institutes FBH and IHP, the FMD is the central contact for all questions concerning micro- and nanoelectronics in Germany and Europe. As a pioneer for cross-location and cross-technology cooperation, the FMD is actively addressing the current and future challenges of electronics research, providing key impulses for the development of elementary innovations for the world of tomorrow.

In 2022, the FMD has further grown. Currently, more than 4,500 employees contribute their expertise to the research and development of micro and nanosystems. The FMD is thus one of the largest R&D associations of its kind in the world.

Major projects launched for sustainable electronics and new computing technologies

Building on the competences, structures and services created within the framework of the FMD, two new major projects – the "Green ICT @ FMD" and the "FMD-QNC" – were launched in 2022.

As part of the Green ICT @ FMD project, the Fraunhofer and Leibniz Institutes cooperating in the Research Fab Microelectronics Germany, together with the Fraunhofer ISI, are setting up a cross-location competence center for resource-conscious information and communication technology (ICT). Within this framework, Green ICT-specific issues can be addressed in a bundled manner and cross-technology ICT solutions up to a high level of technical maturity can be provided to partners in industry and research – all from a single source. This project, launched in August 2022, is funded by the German Federal Ministry of Education and Research (BMBF) under the Green ICT Initiative, which in turn is part of the Federal Government's Climate Action Program 2030.

More about the Green ICT @ FMD: www.forschungsfabrik-mikroelektronik.de/press-GreenICT

Furthermore, to bring together and expand the existing microelectronic research and the developments related to quantum and neuromorphic computing carried out in Germany, the FMD together with four further Fraunhofer institutes, the Research Center Jülich and AMO GmbH launched a joint project in December 2022: The Research Fab Microelectronics Germany - Module Quantum and Neuromorphic Computing (FMD-QNC). FMD-QNC is a nationwide collaboration aimed at supporting researchers and companies in developing customized microelectronics and scalable manufacturing and integration processes for new computing technologies. The equipment and structural setup required for this is being funded by the BMBF.

More about the FMD-QNC: www.forschungsfabrik-mikroelektronik.de/press-QNC

Setting up a Microelectronics Academy

As part of the Green ICT @ FMD and the FMD-QNC projects, a Germany-wide microelectronics academy will be established over the next three years. In December 2022, the kick-off of the conceptualization phase took place and with it, the establishing of the Academy and the enabling of modern training opportunities in the field of micro and nanoelectronics. Regarding its thematic foundation, the Academy is structured in three thematic pillars. The first two pillars, Resource-conscious ICT and Practice-oriented semiconductor engineering and technology (both derived from the Green ICT @ FMD and FMD-QNC projects), are further complemented by the third pillar focusing on design of microelectronic circuits and systems. In the process of setting up the Microelectronics Academy, the FMD is not only assuming the organizational management, but also taking responsibility for the three thematic pillars. The overarching goal is to improve the quality of the training for skilled workers in the field of microelectronics as well as, in the long term, to actively impact and drive forward areas such as climate protection and sustainability, new computing technologies and trustworthiness in the semiconductor and chip sector.

More about the Microelectronics Academy: www.forschungsfabrik-mikroelektronik.de/press-MEA

Increasing the innovative strength of microelectronics in Europe

To ensure that Germany and Europe remain key players in the global value chain, the FMD undertook crucial preparatory work for the technological foundation of the "European Chips Act" in 2022. For instance, the FMD-QNC is being complemented at the European level by the PREVAIL project (Partnership for Realization and Validation of AI hardware Leadership). This project brings together four European research organizations, CEA-Leti, Fraunhofer, imec and VTT, to create a networked 300-mm technology platform for manufacturing chip prototypes used in advanced artificial intelligence and neuromorphic computing applications. The national part of PREVAIL constituted by four Fraunhofer institutes EMFT, IIS, IPMS and IZM, which as part of FMD are broadening their 300-mm fabrication, design and test facilities to complement the 300-mm technology of their European research partners.

For more information about the FMD, visit www.forschungsfabrik-mikroelektronik.de/en.html. Check out also our 3D virtual showroom at https://fmd-insight.de/showroom.

More about the FMD

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DressMAN at the checkout in Aldi SÜD © LZSiS / Burke Agentur

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.

Sensors for pleasant and safe interior spaces: on a fact-finding tour with DressMAN

We spend the majority of our lives indoors: whether at home or at work, or on the road in a bus, train or car – in our free time, too. It goes without saying that we would like the conditions in those spaces to be pleasant and safe. But how can we even assess the indoor climate in the first place? What do sensors for this look like? These are the questions that DressMAN sought to answer on his exploratory tour.

DressMAN at Werksviertel and in the coworking space there © LZSiS / Burke Agentur

At Fraunhofer IBP, DressMAN was set up as a sensor platform to support automotive manufacturers with new developments and the optimization of parameters for climate control, for example in electric cars. For this purpose, DressMAN is equipped with sensors for measuring temperature, solar radiation and air speed.

But he is capable of much more than this, of course! Fraunhofer LZSiS has expanded his capabilities to include the analysis of air quality and acoustics parameters.

During the week of December 12-16, 2022, DressMAN was on the road in the Munich urban development project Werksviertel and at Aldi SÜD in Dülferstraße 69, Feldmoching, on his mission to get citizens more closely engaged with the whole notion of sensors. For example, he showed that sensors for well-being and safety in indoor spaces can be harmoniously integrated in the environment while at the same time protecting privacy and even transparently communicating knowledgeable insights into the latest technological developments.

More about the DressMAN tour

www.lz-sis.de/dressman-on-tour

The Roofs Festival 2022

During the European Championships, colleagues from Fraunhofer EMFT and LZSiS provided fascinating insights into the world of AR glasses and the mobile learning hub at the Technology Roof!

The soldering station on wheels can be put into operation directly on the customer’s premises via plug & play. Permanently installed cameras enable ideal interaction between ZVE training staff and learners. Together with the Dutch research organization TNO, ZVE is also working on XR solutions that will enable an even more realistic learning experience in the future.

The Roofs Festival: remote soldering training using the mobile learning hub

The mobile learning hub corresponds to a fully equipped workstation at the ZVE training center in Oberpfaffenhofen. Any additional equipment required is provided in accordance with the training course in question. It is easy to transport, like a mobile exhibition stand. The station only needs to be connected to the mains and can then be put into operation according to the plug & play principle.

Whether **Plug & Learn** or **Graffiti 3D**, everyone was very enthusiastic about the technology and what it is now capable of doing. And the AR **games** saw many an adult rediscover their childhood self!

More about Plug & Learn

www.zve-kurse.de/plug-and-learn

Fraunhofer Innovation Platform for Sensors and Applied Systems at Tel Aviv University

Fraunhofer EMFT and Tel Aviv University (TAU) opened the new Fraunhofer Innovation Platform for Sensors and Applied Systems at Tel Aviv University (FIP-SENS@TAU) in Tel Aviv at the end of June 2022. This Fraunhofer-like research unit conducts top-level multi- and interdisciplinary research and development in the field of sensor technology. The aim is to advance the technology transfer for hardware, software, data processing algorithms and networking through to human-machine interfaces for sensor systems so as to become established as a globally recognized solution provider for customers in the private sector and industry as well as for academic and public research institutions.

Prof. Dr.-Ing. Reimund Neugebauer, President of the Fraunhofer-Gesellschaft, and Dr. Sabine Trupp, Head of the High Performance Center Secure Intelligent Systems and Managing Director of FIP-SENS@TAU for Fraunhofer EMFT, at the opening of the Fraunhofer Innovation Platform for Sensors and Applied Systems at Tel Aviv University; © Chen Galili

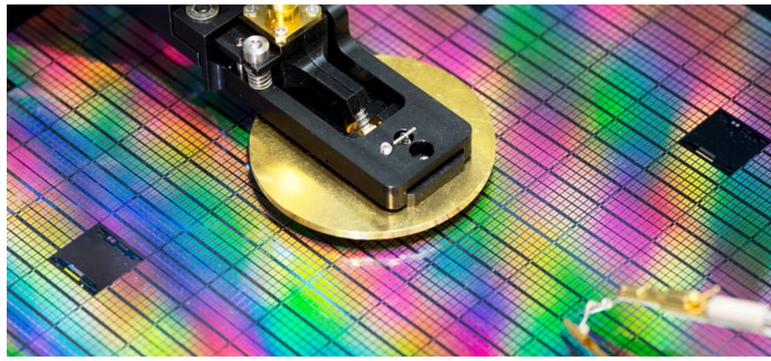
FIP-SENS@TAU will focus on solutions for real-world applications that offer opportunities for commercialization. The aim is to ensure that transfer to industrial production is incorporated in the early stages of conception and development. The cooperation partners are looking to use the well-established transfer channels of the Fraunhofer-Gesellschaft to achieve swift implementation on the market.

In their research activities, the scientists will initially concentrate on the areas of agriculture, safety applications and environmental monitoring. "Our focus is on low-energy systems that are mobile and can be operated without the need for complex infrastructure," says Dr. Sabine Trupp, Managing Director of FIP-SENS@TAU for Fraunhofer EMFT.

FIP-SENS@TAU is led by Prof. Yossi Rosenwaks (FIP Managing Director, TAU), Dr. Sabine Trupp (FIP Managing Director, Fraunhofer EMFT), Prof. Slava Krylov (FIP Technical Director, TAU) and Christian Wald (FIP Technical Director, Fraunhofer EMFT).

Trusted Electronics Center Bavaria

In the wake of increasing digitalization, trusted information systems are needed in Germany and Europe in all application domains, e.g. critical infrastructure, Industry 4.0, automotive, Internet of Things (IoT), aerospace, defense and healthcare. In the implementation of products and solutions that use artificial intelligence (AI) and machine learning (ML) in particular, trusted electronics is becoming a key component in IT security, product safety, anti-piracy and anti-counterfeiting. These capabilities will be crucial for companies in the future in order to stay competitive on the international market based on powerful unique selling points for their products.



CC-TLP: original probe for capacitively coupled CDM-like TLP stress testing at wafer level

Trust and integrity in networked systems can only be achieved if the electronic hardware provides a trustworthy basis, too (processors, memory, security components, sensors). Only in this way is it possible to design the software components (firmware, operating systems and application software) that build on them in a secure manner, while also excluding backdoors, Trojans and other malicious mechanisms, for example.

In the Trusted Electronics Center Bavaria, Fraunhofer AISEC, Fraunhofer EMFT and Fraunhofer IIS work closely together to create an internationally visible center of excellence for research and development in the area of secure electronic systems. The Center serves as a focal point for Bavarian industrial companies and SMEs in particular, offering low-threshold access to trusted secure technologies, integrated analog and digital circuits, system protection solutions and excellently equipped analysis laboratories.

"In times of AI and digitalization, the quality of electronic products is no longer purely about functional safety, but increasingly also about information security and trustworthiness of the processed data. In view of this, technological sovereignty in the field of cybersecurity cannot be valued highly enough," explains Prof. Christoph Kutter, Director of Fraunhofer EMFT.

The Trusted Electronics Center Bavaria is funded by the State of Bavaria.

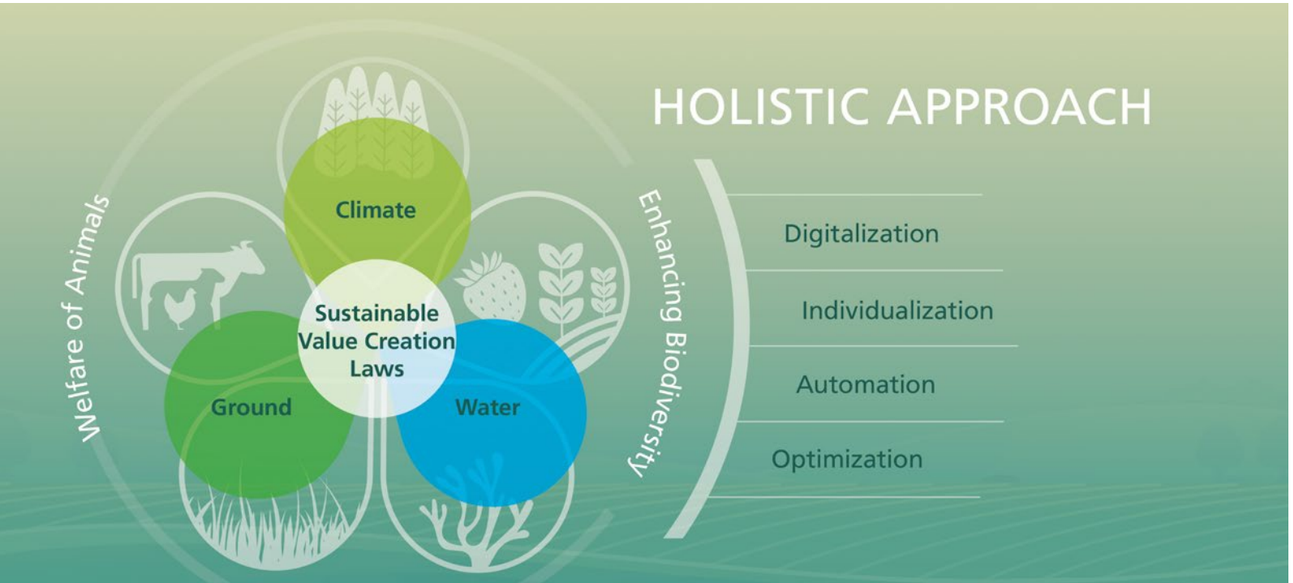
Fraunhofer Center for Biogenic Value Creation and Smart Farming

At the Fraunhofer Center for Biogenic Value Creation and Smart Farming, five Fraunhofer institutes – among them Fraunhofer EMFT – are jointly developing innovative technologies for the agriculture of the future. The focus is on the goal of making agriculture more sustainable while at the same time ensuring the future viability and resilience of the food supply. The partners involved are looking at the entire value chain in the food sector so as to help farms and companies in the food industry to reposition themselves in terms of sustainability.

The Center is divided into two subsidiary initiatives organized at a number of different locations in Bavaria and Mecklenburg-Western Pomerania. Suitable infrastructures are being set up on site for this purpose. In terms of the project work, the researchers draw on shared methodology and technology building blocks from the fields of robotics and automation, sensors, analytics and actuators, AI and Big Data, as well as design, production and process engineering. In this way, the respective core competences of the individual institutes can be effectively clustered, enabling complex system solutions to be implemented across locations in different fields of application – also involving regional and nationwide cooperation partners.

Fraunhofer EMFT contributes its expertise in sensor solutions, system integration and microactuators to the Center in order to develop innovative technologies and systems for measuring various environmental parameters in plant breeding and animal husbandry, for example (⟶ see On-plant sensors on page 35). The researchers' expertise in machine learning for sensor systems is applied to analysis and further processing of the sensor data. Fraunhofer EMFT draws on its extensive expertise in the field of safe electronics in order to ensure safe and robust functionality of the systems under harsh environmental conditions.

Holistic approach – the motivation behind the Fraunhofer Center; © Fraunhofer IGD

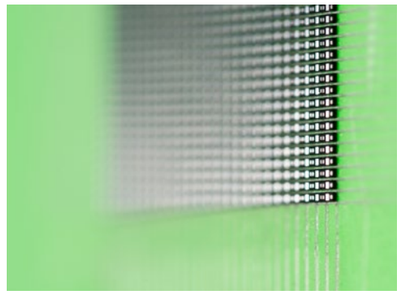


Munich Quantum Valley

Munich Quantum Valley e.V. (MQV) is a joint research platform run by the Bavarian Academy of Sciences and Humanities (BAdW), the German Aerospace Center (DLR), the Fraunhofer-Gesellschaft (FhG), the University of Erlangen-Nuremberg (FAU), the University of Munich (LMU), the Max Planck Society (MPG) and the Technical University of Munich (TUM).

The aim of Munich Quantum Valley e.V. is to act as a hub between research, industry and the public at large in promoting quantum technology and quantum science in Bavaria. The platform is dedicated to the development and deployment of competitive quantum computers (QC) in Bavaria. The focus is on the three most promising technology platforms: superconducting, neutral atom and trapped ion qubit systems. Adopting a unique holistic approach, researchers are simultaneously driving technology development at all the levels ("QC stack") that are necessary to build and successfully operate a QC. These range from hardware, qubit technology, quantum control and quantum software to quantum algorithms and their applications.

⟶ Further information about the research project "On the path to quantum computing: higher scalability of qubits" on page 16



Low-noise varicaps in QFN package for LTE, 5G and 6G applications

A network with international outreach is to be established in order to ensure the efficient transfer of knowledge from research to industry. At the same time, the MQV offers tailored initial training and professional development opportunities in quantum science and technology.

Another task of the platform is target-group-oriented science communication to promote public understanding of quantum technologies and the benefits they offer society.

Munich Quantum Valley is a registered association and is funded by the State of Bavaria.

Universities

Technische Universität München

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 TU Munich**. 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.

der Bundeswehr Universität München

University of the Federal Armed Forces in Munich

- There are close links between the **Faculty of Electrical Engineering and Information Technology** at the University of the Federal Armed Forces in Munich 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", completed 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 the University of the Federal Armed Forces in Munich complement each other ideally due to the nature of their respective cleanroom facilities.

HM

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 entitled "Microfluidics and Applications" as part of both the master's degree program and the international degree program in micro- and nanotechnology. The course gives students the opportunity to get to grips with applied micro-nanotechnology and systems.

UR

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.

HOCHSCHULE LANDSHUT

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 the 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.

UNIKASSEL VERSITÄT

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.

  His lecture course focuses on integrated RF sensor systems, highlighting the links between technological and economic challenges in the value chain of such systems. The content of the course is supported by ongoing European funding projects and reflects research expertise acquired at Fraunhofer EMFT.

Youth Development

As a research institute, Fraunhofer EMFT is particularly concerned to ensure that it has well-trained junior staff. After all, there is no doubt that our employees are the key to our success. It is absolutely vital to identify and promote individual potential. But what if the potential young talent of the future has had no contact with STEM subjects at all? In other words: the interest might be out there somewhere, but nobody knows about it. The science gene might actually be dormant in certain individuals – it's simply a matter of making it come alive. Arousing curiosity for science and research is another of the tasks pursued by Fraunhofer EMFT. Our aim is to catch school and college students in particular before they start out on their working lives and provide them with information: What career opportunities are available? What's it to like to work in a lab, a cleanroom or an office? What topics do our researchers deal with on a day-to-day basis? What are the benefits? In-person events are absolutely crucial here: if people have questions they want answered, this can often be taken care of much more quickly in a face-to-face situation. It was finally possible to organize events again in 2022, and we didn't need to be told twice: from the Fraunhofer Science Campus to school class visits and the Roofs Festival at the Olympic Park (⟶ page 39 and page 55) – making contact with people at first hand is just so much more fun!

⟶ For more information about careers at Fraunhofer EMFT, see page 66

Girls' Day 2022

From virtual cleanroom tours to the ecological luggage of a smartphone: the pandemic didn't stop us this year either, and we had another great Girls' Day featuring lots of fascinating topics. The program included a 360-degree tour during which our employee Sabine Scherbaum gave the 14 participants an insight into what it's like to work in a cleanroom: why does everything have to be so clean, what do you have to pay particular attention to, and how much effort is really involved in operating a cleanroom? The girls got on-the-spot answers to these and all kinds of other questions. To give them a source of inspiration for the future, Sabine then took the group on a journey through the life cycle of a smartphone. The girls' facial expressions began to turn more serious as Sabine pointed out the social and environmental impact of smartphone production. This is something that should get us all thinking, of course – not just our Girls' Day participants.


Virtual Lab Tour on Girls'Day

Visits by school classes and study groups

No distance was too far for school and university students to visit Fraunhofer EMFT this year. A 12th grade class from Herzog-Ernst-Gymnasium in Uelzen were the first: the students of a biology and mathematics course stopped off at Fraunhofer EMFT as part of their class trip. While our colleague Martin Richter gave the group an insight into the research area of microdispensing systems, our colleague Sabine Scherbaum introduced the students to the materials and processes involved in microelectronics. Afterwards they were given a tour of our institute.

Visit of a school class, 12th grade

In November we received a visit from a study group from the University of Belgrade: our institute director Amelie Hagelauer warmly welcomed the students of electrical engineering before giving them an introduction to Fraunhofer EMFT. In individual presentations by our researchers, the guests found out about our institute's research in the area of Circuit Design in the Analysis & Test and Flexible Systems group.

Fraunhofer Science Campus 2022

"Mission STEM" was the motto in Munich and Holzkirchen at the beginning of October: the Fraunhofer Science Campus 2022 was aimed specifically at women, who continue to be severely underrepresented in the subjects of science, technology, engineering and mathematics – something that we want to change, of course! And what better way to do so than to give female students first-hand insights into our work? In the course of the three-day event, research topics were presented not just by Fraunhofer EMFT but also by Fraunhofer IKS and Fraunhofer IBP. Specialist talks, workshops and guided tours were held in Munich and Holzkirchen to support career planning in science and research. At Fraunhofer EMFT, the students were able to immerse themselves in the world of pioneering solutions for semiconductor processes, MEMS technologies, 3D integration and foil electronics. Cleanroom work in particular met with great interest. The following day our institute hosted two management seminars: "Career paths in research and science" and "What does good research practice mean in the Fraunhofer-Gesellschaft?". In the afternoon there was a careers fair which provided an opportunity to talk about job offers and career paths in the Fraunhofer-Gesellschaft and at Fraunhofer EMFT, enabling the young women to pick up a few more tips. Our HR manager Katrin Menz was particularly in demand here: participants received first-hand answers to any questions they still had regarding the application process.


Fraunhofer Science Campus

School student placement

Printed circuit manufacturing using laser technology, microscopy and data acquisition were among the topics explored in a one-week internship taken by two students in February. Ramon Linke and Erwin Yacoub-George of the Analysis & Test and Thin Silicon teams respectively showed the students techniques used for wet chemical preparation in microelectronics. At the same time, the two students got to see the inside of the semiconductor cleanroom. And since it's not every day you get to see a cleanroom like this and there are all sorts of additional safety precautions too, it made the whole experience that much more exciting. At the end of their internship week, they got to do some soldering work themselves. The result: an electronic tea candle.

A young female student from the high school Kirchheim near Munich did an internship with Ramon Linke's Analysis & Test team in July. Since she loves programming in her free time, it didn't take long to find a focus area for the taster week. During her time with us she got to independently evaluate verification measurements on an automated basis using Python and then compare them to the standard for HBM measurements. The internship week was rounded off with a tour of the electronic measurement lab and a closer look at the cleanroom.

And last but not least, we would like to introduce our current trainee Symeon Karousis, who joined Dieter Hemmetzberger's Polytronic Technologies team for an internship. During this time he learned quite a bit about electronic measurement technology and his interest was aroused more and more every day. He also gained an insight into the various laboratory activities that go on at Fraunhofer EMFT. At the end of the internship, it was instantly clear to both sides: this is definitely a good fit! It wasn't long before Mr. Karousis was offered an apprenticeship as a microtechnologist.

The example of Symeon Karousis shows once again how important internships are: they give young people the chance to find out in advance which topics interest them not just in theory but in practice, too, and also whether the employer is the right one for them. Our goal as a research institute is to provide young adults with more in-depth insights into the day-to-day work of researchers. In addition to this, we get a better impression of whether the individual is going to fit in the team: a classic win-win situation.

⟶ For further information about Symeon Klaus Karousis' apprenticeship, see page 66

Visit of a school class, 12th grade

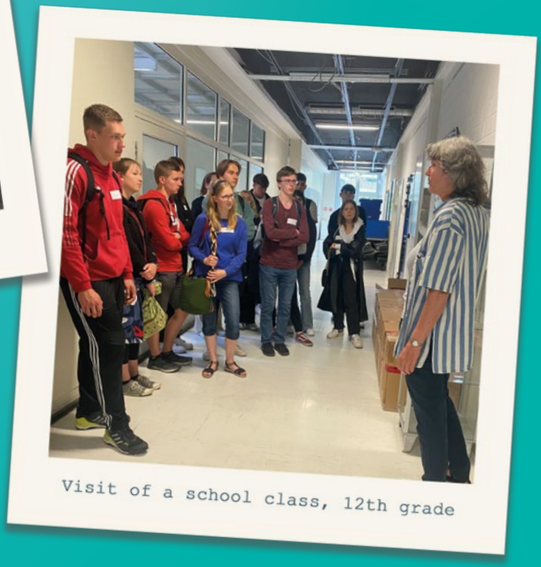
Fraunhofer Science Campus

Fraunhofer Science Campus

Challenges such as climate change, the energy transition, disease control and technological change are impossible to understand without STEM skills, and they can’t be tackled without STEM specialists. An education in mathematics, computer science, natural sciences and technology lays the foundations for a digital and sustainable society.”

BMBF,
Federal Ministry of Education and Research

Visit of a school class, 12th grade



Visit of a school class, 12th grade

Careers at Fraunhofer EMFT

Symeon Klaus Karousis, Trainee

Since 3 October 2022 I've been in the Flexible Systems department, where I'm training to become a microtechnologist. The focus here is on developing and manufacturing microsystems. I already knew my Polytronic Technologies group from the internship I did previously so I was familiar with the activities involved. Even during the internship I was fascinated with the work. I now come into contact with all kinds of different disciplines such as chemistry, physics, mathematics and electrical engineering. But my work also includes occupational health and safety, as well as documenting and optimizing production processes. Since I'm following a dual-track training program, things never get boring: I learn the theory at vocational college in Itzehoe and am taught the practical side of things at the institute. I particularly like the fact that I'm now being introduced to a lot that is new to me in terms of working with technology and I enjoy setting up and operating the systems and machines, too. I like working in my team because I'm continuously being shown new and interesting things. After completing my vocational training, I'm thinking of doing further training to become a technician.

Symeon Klaus Karousis,
Trainee

Anne Hüttenrauch, Student Trainee

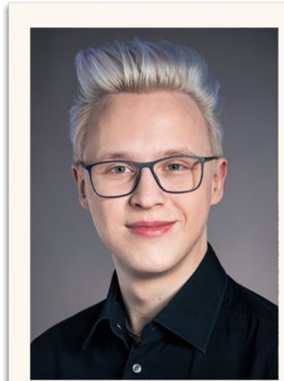
Anne Hüttenrauch,
Working Student

I'm still relatively new at Fraunhofer EMFT: I started working as a student trainee in the field of personnel/ HR on October 1, 2022. I help with preparing contracts, especially for student assistants, interns, bachelor's students and master's students. I also do onboarding for new student assistants, and I create job references and vacancy postings. In addition, I enter personnel master data and contract data in SAP and draw up analyses. Human resources management is a completely new area of work for me. So it's particularly good to have the opportunity to see how I like it here at the institute so I can develop personally and discover new things. I could actually imagine working in this field in the future, too. I'm at the institute two days a week and every time I come into the office, I really like it – so that says a lot. I appreciate the team spirit and the working atmosphere. Next up is my master's thesis, which I plan to complete at LMU in July 2023.

Bao Trung Duong, Research Associate

I started in December 2021 as a master's student in the Continuing Education and Technology Transfer ICS-WE department. My team and I have been doing research to come up with a way of monitoring the physical state of plants. We chose a method that allows direct printing of flexible and conductive structures on plant leaves. This can be used to determine the vital data of the plants quickly and easily at a later stage without physically damaging them. Over the course of time, I've been able to gain a good general idea of the different areas of activity at Fraunhofer EMFT. What I find most fascinating is the research being done into various bleeding edge technologies: unlike basic research, this has applications in industry and everyday life. Whenever I had questions or needed support, my colleagues were always there to help me. Thanks to their expertise, I was able to gain a lot of new experience that will be essential for my future career. I've now obtained my master's degree and am working as a research assistant. My next goal is to get a doctorate.

Bao Trung Duong,
Research Associate



Kamil M. Turewicz,
Trainee

Kamil M. Turewicz, Trainee

I started my training as an IT specialist in the IT Services department at Fraunhofer EMFT in September 2021. One of my main tasks is support, so I'm the first point of contact whenever employees have questions or need assistance. But recently I've been doing my own project, too: this involves monitoring our institute. In IT, the main purpose of monitoring is to detect failures and disruptive factors as quickly as possible and to identify the source of the problems early on before failures even occur. In order to ensure this can happen, I look at different monitoring tool providers, for example, then I compare them and arrange appointments for demonstrations. If I have any questions, I can always ask my training supervisor. Smaller-scale assignments like connecting a new server are within my field of activity, too. I particularly like the dynamic and the atmosphere in our team. Showing appreciation is a top priority here, and people are always very understanding and patient when I have to familiarize myself with new topics. I feel very much at home here so I can well imagine staying at Fraunhofer EMFT when I've completed my training.

Helena Goletz, Working Student

I started working as a student trainee in the marketing and communications department on March 1, 2022. My work is primarily focused in the area social media, i.e. I prepare posts for channels such as LinkedIn and Instagram and enliven them with images, videos and stories. My jobs also include editing and optimizing our institute website as well as writing copy for articles and information sheets. What I like best is working with my team – they're simply great, always supportive and lots of fun. Every day is different, too. Since we're involved in a lot of different operations in marketing, you get new insights into different areas every day. As such, the work is never boring. I also learn a lot by working with the researchers, especially in terms of expertise that I might not necessarily have come into contact with in my day-to-day life. All in all, the work is simply fun, varied and enriching. In terms of my career, I'd first like to complete my master's degree in journalism and corporate communications at THWS in Würzburg, and then I'll see what happens next.

Helena Goletz,
Working Student

Florian Rieger,
Research Associate

Florian Rieger, Research Associate

I've been with Fraunhofer EMFT since September 1, 2022 as a research assistant in the Circuits & Systems department. In the Machine Learning Enhanced Sensor Systems group – as the name suggests – I work on combining sensor signals with machine learning models to gain new insights. The focus is very much on predictive maintenance, and I use artificial intelligence to try to predict when certain machine parts will fail based on time series data. This additional information enables timely maintenance and prevents major damage. I have a lot of freedom in how I organize my work, both in terms of my working hours and working from home, and also in how I approach the projects I work on. My colleagues are really nice and helpful, and there's a good atmosphere in the office in general. I particularly appreciate the opportunity to work on different projects, and I get to find out about so many fascinating things, as well as meeting partners in industry and research. My goal for the future is to further extend my knowledge in the area of machine learning.

Evaluation board for the neuromorphic computing chip (TEMPO)

Contact

Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT

Hansastrasse 27d
80686 München

Tel.: +49 89 54759-0
Fax: +49 89 54759-100

www.emft.fraunhofer.de

Directors

Prof. Dr. Amelie Hagelauer
Tel.: +49 89 54759-300
Amelie.Hagelauer@
emft.fraunhofer.de

Prof. Dr. Christoph Kutter
Tel.: +49 89 54759-500
Christoph.Kutter@
emft.fraunhofer.de

Management

Andrea Keill
Tel.: +49 89 54759-507
Andrea.Keill@
emft.fraunhofer.de

Katrin Menz
Tel.: +49 89 54759-506
Katrin.Menz@
emft.fraunhofer.de

Business Development

Dr. Karin Bauer
Tel.: +49 89 54759-223
Karin.Bauer@
emft.fraunhofer.de

Strategic Projects

Dr. Peter Ramm
Tel.: +49 89 54759-539
Peter.Ramm@
emft.fraunhofer.de

Analytics & Technologies

Dominik Muß
Argelsrieder Feld 6
82234 Weßling
Tel. +49 89 54759-430
Dominik.Muss@
emft.fraunhofer.de

Circuits & Systems

Prof. Dr. Linus Maurer
Tel.: +49 89 54759-330
Linus.Maurer@
emft.fraunhofer.de

Flexible Systems

Christof Landesberger
Tel.: +49 89 54759-295
Christof.Landesberger@
emft.fraunhofer.de

Flexible Systems

Dr. Alexey Yakushenko
Tel.: +49 89 54759-211
Alexey.Yakushenko@
emft.fraunhofer.de

Micropumps

Dr. Martin Richter
Tel.: +49 89 54759-455
Martin.Richter@
emft.fraunhofer.de

Cell-Based Sensor Technologies

Prof. Dr. Joachim Wegener
Universitätsstr. 31
93053 Regensburg
Tel.: +49 941 943-4546
Joachim.Wegensser@
emft.fraunhofer.de

Silicon Technologies & Devices

Prof. Dr. Marc Tornow
Tel.: +49 89 54759-551
Marc.Tornow@
emft.fraunhofer.de

Silicon Technologies & Devices

Dr. Wilfried Lerch
Tel.: +49 89 54759-190
Wilfried.Lerch@
emft.fraunhofer.de

Head of High Performance Center LZSiS

Dr. Sabine Trupp
Tel.: +49 89 54759-561
Sabine.Trupp@
emft.fraunhofer.de

Marketing, Communications and Strategy

Pirjo Larima-Bellinghoven
Tel.: +49 89 54759-542
Pirjo.Larima-Bellinghoven@
emft.fraunhofer.de

Contact

Center for Interconnection Technologies ZVE

Oberpfaffenhofen
Argelsrieder Feld 6
82234 Weßling

Tel.: +49 89 54759-444
Fax: +49 89 54759-415

www.zve-kurse.de

Head of Further Training and Technology Transfer

Dr.-Ing. Frank Ansorge
Tel.: +49 89 54759-456
Frank.Ansorge@
emft.fraunhofer.de

Event Management

Monika Schmidt
Tel.: +49 89 54759-400
Anmeldung@
emft.fraunhofer.de

Trainer

Dirk Schröder
Tel.: +49 89 54759-417
Dirk.Schroeder@
emft.fraunhofer.de

Event Management

Silke Paul
Tel.: +49 89 54759-440
Anmeldung@
emft.fraunhofer.de

Trainer

Lucas Richter
Tel.: +49 89 54759-443
Lucas.Richter@
emft.fraunhofer.de

Trainer

Günter Paul
Tel.: +49 89 54759-418
Guenter.Paul@
emft.fraunhofer.de

Imprint

Publisher
Fraunhofer Institute for Electronic Microsystems and Solid State Technologies EMFT
Hansastrasse 27d
80686 München

Editors
Elisa Göbel
Helena Goletz
Pirjo Larima-Bellinghoven
Tina Möbius
Johanna Markl

Layout, Typesetting and Production
Johanna Markl

Print
Grafik + Druck digital K.P. GmbH
www.grafik-druck.de

Contact
Fraunhofer EMFT
Marketing, Communications and Strategy
Hansastrasse 27d
80686 München
contact@emft.fraunhofer.de

Cover
Resonators for material analysis for superconducting qubits on 200 mm wafer with Nb coating

Photographs
Chen Galili: p. 41 & 56
Elias Melzer: p. 35 & 48
Elisa Göbel: p. 38, 39, 40 & 55
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