Microelectronics News

June 2021 **82**

PEOPLE. MAKE. MICROELECTRONICS.

Forschungsfabrik Mikroelektronik Deutschland

Dear readers,

Welcome to the summer edition of *Microelectronics News*. This is the first time that our Group magazine has looked beyond the boundaries of the Fraunhofer Group for Microelectronics to include the collaboration known as the Research Fab Microelectronics Germany (FMD), with all of its partners from the Fraunhofer-Gesellschaft and the Leibniz Association.

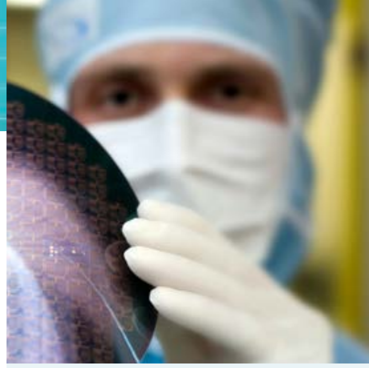
When *Microelectronics News* was first published in October 2000, it ran to just four pages. Since then, it has published regular news from the Group and its institutes – and just as the number of member institutes has grown over time, so too has the variety of topics and therefore also the size of our magazine.

Just before Christmas last year, we released an anniversary edition commemorating technological achievements and highlights from 20 years of Fraunhofer microelectronics research. In the current edition, experts within FMD and the Group offer an insight into their work under the slogan "People. Make. Microelectronics.": We speak to researchers and employees from all cooperation partners within FMD about pioneering technologies and gain a better understanding of their everyday work. These are people who, despite all of the adversity of the COVID-19 pandemic, are helping to shape our future with not only a high level of motivation but also impressive creativity and scientific expertise!

In total, some 3,500 researchers within FMD seek answers to key scientific and societal questions on a daily basis: What technologies and innovative electronic systems can we use to tackle the challenges of our time? Artificial intelligence (AI), Industry 4.0, smart living, or driverless cars – all of these digital developments require new methods, processes, and business models for the transmission, storage, and processing of data. Where and how can microelectronics be used as an enabling technology to provide powerful, trustworthy, and resource-efficient support?

The member institutes of the Fraunhofer Group for Microelectronics have already taken an important strategic step in order to bolster the use of microelectronics in collaboration with the Leibniz Institutes FBH and IHP. The Research Fab Microelectronics Germany, which emerged from this collaboration with support from the Federal Ministry of Education and Research in 2017, is now well on the way to establishing itself as a model for Germany's future research community in order to tackle major challenges on a global level.

So, without further ado, we invite you to join us on a journey of discovery through our institutes. We hope you enjoy reading this edition of *Microelectronics News*!



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You can gain further insights into ongoing work at FMD on our YouTube channel:

Dr. Stephan Guttowski.
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Dr. Stephan Guttowski studied electrical engineering at TU Berlin and subsequently earned a doctorate in the field of electromagnetic compatibility. This was followed by a postdoctoral position at Massachusetts Institute of Technology (MIT) in Cambridge, USA. After his return, he initially worked in the Electric Drives Research Laboratory of DaimlerChrysler AG before moving to the Fraunhofer Institute for Reliability and Microintegration IZM in 2001. At IZM, he was initially head of the Advanced System Development Group before taking over at the System Design & Integration department. From June 2017 to December 2020, he was Technology Park Manager for Heterointegration at the Research Fab Microelectronics Germany (FMD). Since January 2021, he has led the joint office of the Fraunhofer Group for Microelectronics and FMD.

"We're ready for current and future challenges in electronics research"

Dr. Stephan Guttowski is the new managing director of the joint office of the Fraunhofer Group for Microelectronics and the Research Fab Microelectronics Germany (FMD). A long-standing Fraunhofer employee, Guttowski took over as managing director on January 1, 2021. Prior to this appointment, he was committed to cross-institutional collaboration within FMD as Technology Park Manager for Heterointegration.

Dr. Guttowski, congratulations on your new position. How does it feel to be the director of the joint office?

Thank you! It feels great, and despite all the challenges of the coronavirus pandemic, I'm optimistic about the future. First of all, I'm following in some very big footsteps: Over the last three years, Jörg Amelung and Michael Galetzka have successfully steered FMD through its setup phase, and Patrick Bressler led the office of the Fraunhofer Group for Microelectronics during these turbulent times, having taken over from Joachim Pelka. Secondly, the joint office faces the challenge of continuing this success story while also exploiting synergies for the Fraunhofer and Leibniz Institutes within FMD, whose representation we organize here, within sustainable standard operating procedures for the benefit of all parties.

Where would you like to focus your energies as the new director of the office?

In my view, there are three main areas of action in which we want to achieve visibility for the office. The first of these is active business development based on the complementary expertise of our institutes, which calls for effective collaboration in the areas identified as being at the cutting edge. This, in turn, is where I think the second role of the office lies – in getting the experts around a table and developing a joint technological portfolio. In my view, the third area of our work relates to communication and the visibility of the services we offer. I'm often surprised how little people know about groundbreaking findings from the world of research. This is something we need to work on in order to safeguard the future of subsequent generations.

Last but not least, where do you get your motivation?

I'm driven by both very big and very small issues. I think that, in a country like Germany, the future and prosperity of subsequent generations depends to a large extent on our ability not only to understand technological progress but also to help shape it. It also relies on companies – whether they are large international groups or small, recently founded startups – receiving the best possible access to new concepts and solutions from research. I also find it hugely motivational to discuss ideas with the researchers and to see the excellent work going on at our institutes, as well as the enthusiasm with which ideas are pursued and new approaches are tested.

With his colleagues Dr. Dirk Nüßler (Fraunhofer FHR), Dr. Andreas Grimm, and Dr. Patrick Bressler (f.l.t.r.) during the last FMD Innovation Days at Leibniz IHP.
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“The only way to meet the expectations placed on modern microelectronics is through networking and cooperation”

Prof. Albert Heuberger.
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Professor Heuberger has been executive director of the Fraunhofer Institute for Integrated Circuits IIS since 2011. Among other memberships, Professor Heuberger is a member of the Scientific and Technical Council of the Fraunhofer-Gesellschaft, a member of the board of the Medical Valley Europäische Metropolregion Nürnberg (EMN) e.V., of the university council of Nuremberg Tech Georg Simon Ohm and of Coburg University of Applied Sciences and Arts as well as of the Communication and Navigation program committee of the German Space Agency DLR. In 2017, he was appointed as a member of acatech, the German National Academy of Science and Engineering. In 2019, he was awarded the Fraunhofer Medal for his services to the Fraunhofer-Gesellschaft. Professor Heuberger has been chair of FMD and spokesperson for the Fraunhofer Group for Microelectronics since 2020.

Microelectronics are a fundamental driver of innovative potential in numerous sectors. The Research Fab Microelectronics Germany (FMD) was created in 2017 to strengthen the position of Europe’s semiconductor and electronics industry on the global playing field. We spoke to the chair of FMD and spokesman of the Fraunhofer Group for Microelectronics, Professor Albert Heuberger, about FMD’s accomplishments so far and the expectations associated with modern microelectronics.

Professor Heuberger, the process of setting up FMD is largely completed. What has been achieved, and what’s next?

We’ve managed to complete the considerable investments in infrastructure in the member institutes, with the exception of a few delays caused by the COVID-19 pandemic. We are now in the process of implementing and establishing the Research Fab Microelectronics model. A first step has been taken with the reorganization of the administrative office. Already, FMD is regarded as a paradigm for the deployment of diverse expertise from different institutions united by a common strategy, offering complementary products and services to industry.

Furthermore, we must continue to systematically combine and strategically develop the expertise of our member institutes so as to maintain the technological sovereignty and the appeal of Germany and Europe for top-level research. It is important that we work purposefully and together on key future issues so as to be more agile than our competitors in the USA and Asia.

Many sectors are facing seismic changes as a result of digitalization. What challenges will the field of microelectronics have to overcome?

Artificial intelligence (AI), Industry 4.0, driverless cars – all of these digital developments require new methods, processes, and business models for the transmission, storage, and processing of large amounts of data. Existing computer technology can barely keep up with evolving demands in terms of energy consumption, data processing, and transfer speeds. As we become more dependent on digital networks and data, our security needs also become more sophisticated. A particularly crucial aspect in this regard is technological sovereignty, i.e., self-determination and control over systems and data in Germany and Europe. Until now, the market clout of primarily US-based IT corporations such as Microsoft and Google has led to virtually unavoidable dependencies. The same is true of chip manufacturing, which is primarily based in Asia.

Trusted electronics and data security are at the heart of all digital networked systems – especially the Internet of Things, but also AI. Particularly in fields involving the processing of personal or security-critical data, such as medical technology, driverless cars or critical infrastructure, it is vital for owners to have full control over their ICT systems and for users to receive information about the characteristics of the systems they are using. And this concerns the entire data flow – from the end customer to the actual hardware processing the data.

In order to use electronic devices securely and reliably, it is important to know how they operate and how they are constructed.
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Example of an energy-saving, self-learning system of the future: the "smart screw connection."
© Fraunhofer IIS

Can you give us any examples of how the FMD helps industry in this regard?

We design comprehensive, innovative electronic systems for new research fields requiring this kind of wide-ranging expertise. I would like to name three examples. In the TRAICT (TrustedResourceAware ICT) project, eight FMD institutes collaborate with ten other Fraunhofer institutes to create the necessary framework conditions for trusted and data protection compliant information and communication technology that can be used in a self-determined and secure manner. The key issue here is how to validate and safeguard the reliability of critical electronic components and systems

Microelectronics will play a key role in the achievement of German and European climate protection goals. © Shutterstock

in globally interconnected supply and value chains. Nowadays, many of the critical components in digital technologies are manufactured outside of Europe, and in many parts of the digital supply chain suppliers in other countries hold quasi-monopolies. The result is a high level of dependency that could become detrimental to Germany. In March, we launched the "Velektronik" platform for trusted electronics, the goal of which is to examine the entire value chain and devise coherent concepts. In all, 12 partners are involved in the project: 11 Fraunhofer and Leibniz institutes belonging to the FMD, and the edacentrum. They will develop and apply appropriate standards, norms, and processes on the basis of a national and European chip security architecture.

Despite intensive efforts to design increasingly energy-efficient electronic components, primarily with the aim of increasing mobility supported by electronic devices, overall energy consumption by information and communication technology has continued to rise. This problem is exacerbated by recent developments in the field of self-learning systems and their expected propagation into all areas of life and work. The upshot is that large data centers will no longer be solely responsible for the bulk of energy consumption, as increasingly prevalent IoT devices and systems account for an ever greater share. More and more of the energy consumed will be due to the massive increase in data transmission. To address these challenges, the FMD is planning a competence center for resource-efficient information and communication technology, or "Kompentenzzentrum Green ICT".

We're curious: You have been chair of FMD and spokesperson of the Group for Microelectronics for a little over a year. What has changed from your perspective?

The past year has been filled with difficult challenges for all of us. The frequency of online meetings and the lack of personal contact with FMD colleagues has significantly affected my own working practices and culture. I am thankful that technology enables us to keep on working and stay in touch. My role as spokesperson involves some interesting duties, for instance in the executive board of the Fraunhofer-Gesellschaft or in European bodies. I find it motivating that the significance of microelectronics for future issues like quantum technology or technological sovereignty is being acknowledged, and that I can personally play a part in shaping the changes underway in Germany's research community.

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High-frequency electronics for the 6G world

Dr. Hady Yacoub.
© FBH / Petra Immerz

Hady Yacoub studied electrical engineering at the German University of Cairo and microelectronics and communications engineering at the University of Ulm. After completing his master's degree in 2011, he received his PhD from RWTH Aachen University in 2017, focusing on III-V semiconductor-based devices for high power and high frequency applications. Hady Yacoub joined the Ferdinand-Braun-Institut in Berlin as a postdoctoral researcher in 2018 and has been leading the InP Devices Lab there since 2019. He is author and co-author of more than 20 papers in the field of III-V semiconductors.

Whether privately or professionally, our world is becoming increasingly digital – fuelled not least by the current restrictions on life in times of pandemics. The new communications standards such as 5G and 6G promise higher data speeds, greater network capacity and faster response times. For this to succeed, the hardware components needed to support it will require enormous technological advancements. Dr. Hady Yacoub from Leibniz FBH is addressing precisely this issue and is researching possibilities for using new frequency bands in the mm-wave range.

The Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) is part of the Research Fab Microelectronics Germany (FMD) and contributes its expertise in the development of energy-efficient semiconductor components. Conducted research revolves around novel materials and development of necessary components for applications such as electromobility, Industry 4.0 or the mobile communication of the future.

Dr. Yacoub, you conduct research in the field of III/V electronics and are head of the InP Devices Lab at FBH. What do you expect from indium phosphide?

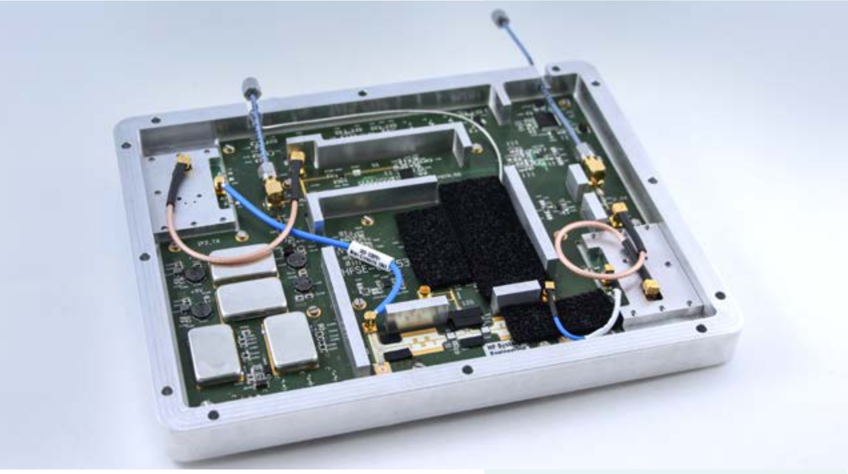
The future communications standard 6G targets frequencies above 100 GHz. This places new demands on hardware as well as high-frequency electronics, which has consequences for the choice of semiconductors. Hetero-bipolar transistors (HBT) based on the semiconductor indium phosphide (InP) are compact thanks to their high integration capability and deliver excellent power densities, high operating voltage and thus, compared to silicon-based technologies, high output power. Together with multiple thin-film routing layers, complex monolithic integrated circuits can be realized on a small area. However, such circuits are very challenging in terms of technology and process since they must be extremely scaled. In other words, they have to offer more power on a smaller area – while maintaining the same yield.

How can you solve this challenge?

Clearly with high-performance fabrication infrastructure. In order to master the technological requirements, FBH has upgraded its facilities in the clean room accordingly as part of the Research Fab Microelectronics Germany. With state-of-the-art e-beam lithography, structure sizes as small as 30 nm are possible. Additionally, fully automated high-tech equipment for etching or electroplating not only increases the yield and homogeneity of the circuits, but also the wafer throughput.

What opportunities does this create for your research area?

The new, high-performance infrastructure will be used in various national and European projects. One of these is the ULTRAWAVE project, in which a consortium is developing a novel wireless system architecture for communications with improved network coverage and unprecedented data rates.



Module with monolithic integrated InP DHBT circuits for D-band wireless communications.
© FBH / Nicole Vlach

FBH is supplying the monolithic integrated circuits required for this purpose, which are based on the in-house InP DHBT process. Thanks to a point-to-multipoint infrastructure in the D-band at 140 GHz, the system architecture offers 100 Gbps within a radius of one square kilometer. This will be achieved for the first time in a test trial in Valencia – point-to-point systems in the same frequency band have already been demonstrated by other groups in initial trials. The ULTRAWAVE system uses standard modem access and enables wireless data transmission of up to one kilometer.

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Dr. Johann Heyszl.
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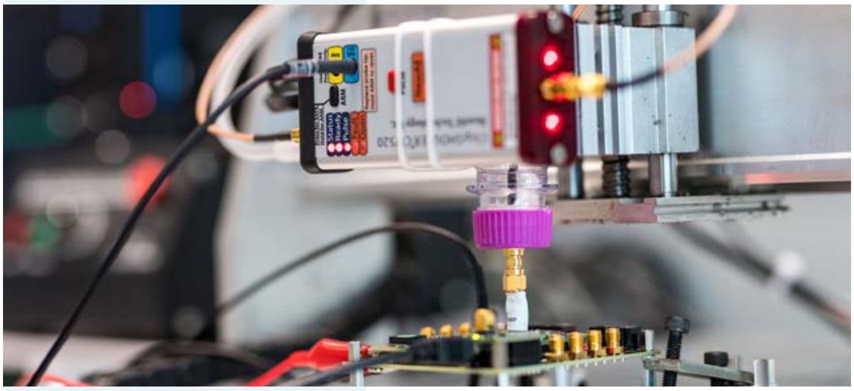
Johann Heyszl earned his doctorate at TU Munich in the field of applied cryptography and its protection against highly sophisticated side-channel attacks. At Fraunhofer AISEC in Garching near Munich, he is head of the Hardware Security department and deputy director of the institute. His work focuses on the security and trustworthiness of embedded electronic systems and networked devices for the Internet of Things.

Platform for trusted electronics for networking and solutions

In order to engineer and use embedded electronic devices securely and reliably, it is important to know that the underlying electronics are trustworthy, do not contain any weaknesses and are of high quality. Although there are already technical solutions and research projects covering individual aspects of trusted electronics, consistent end-to-end concepts and solutions for internationally distributed value chains are still missing. This is where the "Trusted Electronics" platform comes in.

Funded by the Federal Ministry of Education and Research (BMBF) as part of research projects for the "Trusted Electronics" (ZEUS) funding guideline, this platform is known in short as Velektronik (from the German "Vertrauenswürdige Elektronik") and began operating in March 2021. Dr. Johann Heyszl from the Fraunhofer Institute for Applied and Integrated Security AISEC played a key role in developing the concept. He also serves as the technical director of the research project, which involves a total of 12 partners from the Research Fab Microelectronics Germany (FMD) and the Fraunhofer Group for Microelectronics, as well as the edacentrum.



The security and trustworthiness of electronic components can be investigated by way of attacks on embedded systems.
© Fraunhofer AISEC

Dr. Heyszl, are all electronics not automatically trustworthy?

Extensive internationalization in the development of electronics means that the issue of trustworthiness actually poses a serious challenge. Electronics are trustworthy if they meet all our expectations in terms of functionality and specifications while also leaving no back doors or vulnerabilities open to attackers – as this could lead to tampering, attacks, or the failure of entire systems.

What exactly is the aim of the project?

The vision for this project is to create a networking platform for trusted electronics as an interface between research and companies. Work is therefore ongoing in all areas of electronics development, production, and analysis with a view to identifying solution concepts. These results can then be used within the platform, for further research projects, and above all in industry to allow the targeted development, production, analysis, and subsequent integration of trusted electronic components and assemblies. The aim is for the Velektronik platform to act as a tool for the entire value chain of trusted electronics and to support the expansion of technological sovereignty in this area for German industry and the public sector as they operate within the global marketplace.

What role does trusted electronics play in the context of "technological sovereignty"?

We are dependent on electronic components in all relevant application domains – whether in critical infrastructure, Industry 4.0, the automotive sector, or even in medical equipment. It is vital that we are able to rely on and trust these components so that they can ultimately serve as the basis for products, systems, and infrastructure. Technological sovereignty means that, against the backdrop of highly internationalized value creation, we retain sovereignty over the specific properties of technological components in our products. This will ensure the long-term innovative capacity and competitiveness of German companies – and especially small and medium-sized enterprises.

The more we design, develop, manufacture, and safeguard the security of our own advanced electronics in Germany and Europe, the better we will understand what third-party electronics does or doesn't do. That, in turn, will enable us to cooperate globally on an equal footing and to impose requirements on the electronic systems that we use or operate.

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New system architecture for THz frequency-domain spectroscopy

Dr. Lars Liebermeister.
© Fraunhofer HHI

Dr. Lars Liebermeister has been a project leader and deputy group leader in the Terahertz Sensors and Systems group at Fraunhofer HHI since 2017. His current research interests include integrated terahertz photonics, terahertz optoelectronic systems, and terahertz quantum optics. Lars Liebermeister studied physics at Georg-August-Universität Göttingen and received his PhD in quantum and nanophotonics from Ludwig-Maximilians-Universität München in 2016.

Terahertz sensor technology offers great application potential for industrial quality monitoring. Here, the complexity of current measurement systems and the associated high system price is a major challenge. The THz frequency-domain spectroscopy is a very attractive alternative to established time-domain spectroscopy, as it is easier to implement and more robust.

Dr. Liebermeister, quality monitoring at a low price sounds very promising. How did your team come up with the idea for this project?

There are many useful applications for THz sensor technology in quality monitoring. The current technology solves many measurement tasks that could not be fulfilled by any other method so far. However, the high price has prevented many more advanced projects. Against this background, Fraunhofer HHI is pursuing two different concepts: The widely used THz time-domain spectroscopy (TDS) and the more niche THz frequency-domain spectroscopy (FDS). TDS commonly serves as a workhorse, but its setup is complex and therefore expensive. FDS is characterized by a lower measurement speed. So far, this technology has been used in niches such as gas analysis. It has the advantage of being more robust and simpler to set up. In the future it will even be possible to realize it on a single photonic-integrated chip. I have worked intensively on FDS and have been able to develop an alternative, simplifying system architecture. The result is a new FDS system that is two orders of magnitude faster than previous FDS systems, making it competitive with TDS for many applications. In addition, material and setup costs could be further reduced. I have successfully demonstrated my new approach in the laboratory.

And how can a layman imagine how the technology works?

From two optical waves (lasers), an electromagnetic wave with the difference frequency of the two optical waves is generated in a special non-linear component, a so-called photomixer. In this way, frequencies can be generated at which none of the lasers themselves can operate. This THz wave is then reflected by a specimen and the reflection is passed on to a second photomixer. If the second photomixer is also fed with the same two optical waves, a measurement signal can be tapped. This signal provides information about how the sample has changed the THz wave – both in its amplitude and in its phase position. By continuously changing the frequency of one of the optical waves, the THz wave itself can in turn be tuned in its frequency and thus a broad reflection spectrum of a sample can be recorded.

What are the benefits?

THz frequencies are harmless and offer a unique compromise between penetration depth and spatial resolution for many materials (such as plastics or ceramics). This allows non-contact measurement of wall coating thicknesses, where multiple layers can be resolved individually. A simple example is the determination of the thickness of a plastic film. This can have a thickness of several 10 µm. With our system, we can measure the THz reflectance properties in a broadband manner within a few milliseconds. From amplitude changes at certain frequencies, it is then possible to draw clear conclusions about the film thickness. The same principle applies to multilayer samples, such as the paint stack on a car body.

THz spectroscopy offers a unique compromise between penetration depth and spatial resolution.
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Dr. Fabian Thome wrote his PhD thesis at Fraunhofer IAF on the topic "Wireless Low-Power Data Transmission Systems with High Data Rate". Currently, he is conducting research in the field of ultra-low noise amplifiers and leads the cooperation project "SEQUENCE" on the part of IAF. © Fraunhofer IAF

Felix Heinz is doing his doctorate at Fraunhofer IAF in the field of microsystems technology on ultra-low noise amplifiers and is researching the characterization and modeling of cryogenic nanoelectronics in the project "SEQUENCE". © Fraunhofer IAF

Low-noise high-frequency electronics for quantum computers

Dr. Fabian Thome and Felix Heinz from Fraunhofer IAF are developing cryogenic high-frequency electronics for existing quantum computer concepts in the EU-funded joint project "SEQUENCE". The motivation is to scale up established quantum computer architectures, which is only possible by means of compact and extremely low-noise electronics.

Neither of you are (quantum) physicists, how did you get involved in this project?

Thome: Quantum computing has long since ceased to be an exclusive research field for quantum physicists and has become an interdisciplinary one. Ultimately, the current goal of scaling quantum computers (QCs), which have been proven to work today, relies heavily on electrotechnical components – and this is where we, as high-frequency engineers, come into play.

Heinz: We both have our scientific background in the research of cryogenic and ultra-low-noise amplifiers. Until a few years ago, this was truly a niche topic, typically applied in radio astronomy. However, since the first functional QCs emerged, there has been a whole new interest in this research area. Cryogenic and low-noise electronics are needed for reading out and controlling qubits.

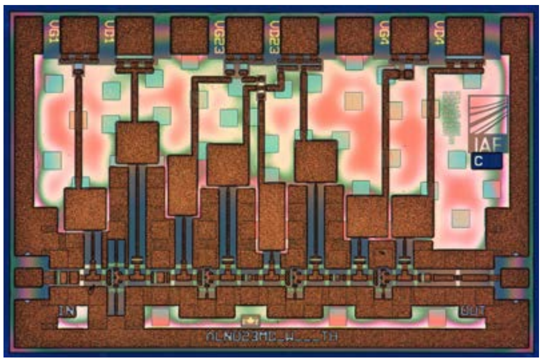
What is your role in the project?

Thome: In this project, we at Fraunhofer IAF are researching high-frequency technologies with which we have already gained a lot of experience, such as mHEMTs and MOSHEMTs. We want to optimize these with regard to their use in QCs. To do this, we need to further reduce the noise of the established technologies and make the components more compact so that the electronics can work closer to the sensitive and cooled qubits. As IAF's project manager of "SEQUENCE", I'm mainly focusing my research on low-noise amplifiers.

Heinz: I am primarily responsible for cryogenic measurements and noise modeling. I research different technologies at extremely low temperatures and describe their behaviors with electrical models for CAD systems. Based on this, I design ultra-low noise circuits optimized for cryogenic operations.

What research questions would you like to pursue next?

Thome: An exciting topic that has not yet been exhaustively studied is the frequency scaling of QCs. Today, QCs use low-noise amplifiers in the frequency range of about 5 GHz as central components in their readout circuits. However, it is theoretically possible to increase this frequency. On the one hand, this could improve the performance of the systems, and on the other hand, it would allow us to exploit more synergies that go beyond quantum computing. One example are future satellite systems, in which low-noise amplifiers could be used at an operating temperature of about -220 °C.



A low-noise amplifier (70 – 116 GHz) with an average noise temperature of 30 K, manufactured with Fraunhofer IAF's 35-nm HEMT technology. © Fraunhofer IAF

Heinz: The chase for increasingly low-noise high-frequency electronics will remain an exciting question even after "SEQUENCE". In this project, we will certainly take a big step in that regard, but it will not be the end. Furthermore, I am interested in novel integration concepts and multifunctional electronics for scalable QCs.

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New capabilities in processing for the next generation of MEMS and MOEMS

Fritz Herrmann. © Fraunhofer IPMS

In his interview, Fritz Herrmann, Technical Sales Manager at Fraunhofer IPMS, reports on the institute's new capability to manufacture "intelligent BSOI wafers". This allows MEMS and MOEMS with sophisticated properties to be realized that are hardly possible with conventional manufacturing approaches and technology concepts.

Mr. Herrmann, what does "intelligent BSOI" mean?

BSOI stands for "bonded silicon on insulator" and refers to a special wafer structure that is used as a starting material for modern MEMS technologies (MEMS = micro-electro-mechanical systems), among others. The structure of a BSOI wafer basically consists of a handle wafer on which an oxide layer is deposited. The top, final layer, the so-called device layer, is an adapted layer which is used in various technologies, also beyond the MEMS area.

What is it useful for?

The demand for BSOI wafers is increasing every year, particularly in the MEMS area, because sophisticated sensors require these wafers as a basis. Currently, device layers are typically offered with different thicknesses, materials or dopings. With its many years of experience in wafer processing, the Fraunhofer Institute for Photonic Microsystems IPMS now wants to add features such as buried conductive paths or cavities to the device layers to address customer requirements even more individually and go one step further with their development. In addition, this is intended to expand the market offering of standardized BSOI wafers.

How can the Research Fab Microelectronics Germany support this?

Thanks to the support of FMD, we were able to procure a grinder which is used for wafer thinning in order to set the target thicknesses of the device layers. In addition, EFRE provided us with a 5-zone CMP that planarizes surfaces and thus prepares wafers first for bonding and then also for productive substrate processing. We are very proud that we received these two systems as part of the Research Fab Microelectronics Germany, which now enable us to manufacture intelligent BSOI wafers.

Fritz Hermann studied industrial engineering in Dresden. After an internship at BMW, he was drawn to the Fraunhofer-Gesellschaft. He started as a research assistant at Fraunhofer IWS. The joy of working with semiconductors and the contact to industrial customers drew him to Fraunhofer IPMS, where he has now been working as Technical Sales Manager for two and a half years. Here he is responsible for acquisition and project planning. At the same time, he manages his own projects, represents the institute at trade shows, gives technical presentations, and at the same time always looks forward to every day he can spend in the clean room.

In addition to his work as Technical Sales Manager, Fritz Herrmann also regularly gives technical presentations for Fraunhofer IPMS. © Fraunhofer IPMS

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Frank Vanselow. © Fraunhofer EMFT

Frank Vanselow studied electrical engineering at the Ruhr University in Bochum. After graduating in 1991, he worked at Grundig E.M.V. developing RF receive and transmit modules for the then new digital transmission formats for radio and television. In 1997, he moved to Texas Instruments, where he supported the development of RFICs and DC-DC converters in various functions. There he led the international development team for Low Power DC-DC converters. Since 2016, he has been working on smart sensor systems, neuromorphic hardware and frequency synthesis as group leader for integrated circuit technology at Fraunhofer EMFT in Munich.

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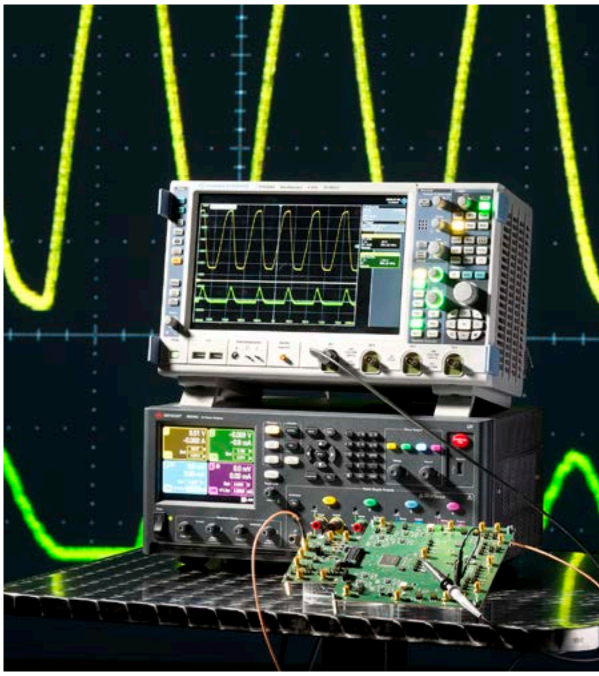
Innovative chip integration in human-machine interaction systems

In areas such as Industry 4.0, Smart Health, Smart Security and Automotive, intelligent systems for human-machine interaction are increasingly being used. Sensor systems for the non-verbal exchange of information in the near-distance and contact range are essential for both functionality and safety.

However, the growing requirements in terms of energy-efficient 3D acquisition and faster signal utilization cannot be satisfied with the solutions currently available. Fraunhofer's researchers from four institutes are developing new approaches within the "ProtaktilUS" project. The results are to be incorporated into a modular MEMS technology and sensor platform.



Measurement setup for an eight-channel ultrasound transceiver chip. © Fraunhofer EMFT

Mr. Vanselow, what is your task in the project?

Together with colleagues from the Fraunhofer institutes IPMS, IKTS and IFF, we are working on the first chip integration of high-resolution capacitive and ultrasound generating elements on a CMOS-compatible platform. Specifically, we want to demonstrate the performance of our approach using the example of reactive gripping in robotics for handling and identifying diverse objects. Our part here at Fraunhofer EMFT is the miniaturization of the multi-channel high-voltage electronics required to drive the microelectromechanical ultrasonic transducers.

Which tricky challenges have you already solved in the project?

Key challenges included the synthesis of possible solutions for reducing the number of external components, high-voltage driving of the MEMS structures, and converting them into a fully integrated solution. For example, we can now use our approach to drive the ultrasonic CMUT elements without external DC blocking elements and still use low-voltage transistors in the low-noise preamplifier. In the future, this solution will allow us to take the next steps for integrating drive electronics and MEMS elements in either a system-in-package or monolithic approach.

The project work is intended to pave the way for a new Fraunhofer business area. What are the associated expectations?

With the modular platforms, developed in the project for MEMS, electronics and signal processing, we want to open up access to further application fields in industrial, medical, consumer-oriented and safety-related sectors in the future.

What do you find particularly interesting about the development of new types of circuit technology?

For many years, I have been fascinated by the new tasks that are emerging in the design of integrated circuits and especially in the design of analog circuits. We will continue to need solutions for these new tasks in the future: For example, how can we reduce the internet's hunger for energy through neuromorphic or quantum computers, or how can we help protect the environment by using smart sensor solutions? This makes this topic so fascinating for me.

New 3D printers for high-frequency components at Fraunhofer FHR

Wave guide filter printed from aluminum for use in the frequency range of 100 GHz. The thickness of the fine lamellae inside the waveguide is about 200 µm. © Fraunhofer FHR

At the end of 2020, Fraunhofer FHR expanded its Villip site with new equipment. The new fused deposition modeling 5 axis machine and the laser powder bed fusion printer for metal and plastic were procured as part of the Research Fab Microelectronics Germany. Alex Shoykhetbrod is one of the researchers working on the three machines. Today he tells us about the advantages of additive manufacturing processes.

Mr. Shoykhetbrod, how would you explain your work to your grandmother?

I work at the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR in the Integrated Circuits and Sensor Systems department and would start the explanation with a quote from Charles Darwin: “It is not the strongest species that survives, nor the most intelligent, but rather the one most willing to change”. This is exactly the aspect we are trying to address in our research group. Every project in the millimeter-wave range is unique and brings with it various challenges: complex geometries, low weight requirements, use of material composites.

Alex Shoykhetbrod. © Fraunhofer FHR

What are the new 3D printers useful for?

The new manufacturing capabilities in combination with the traditional processes enable us at the institute to react quickly and agilely to the requirements of our customers. With the help of the new machines, we are able to manufacture advanced antenna concepts, waveguide components, filter structures and meta-materials. Due to the high mechanical complexity, these existed until now only conceptually in a simulation environment. The expanded additive manufacturing park in Villip is thus certainly a “game changer”.

What other areas do the results of your work feed into?

There are a variety of application areas for which our work results are relevant. One example is thermal management, because radar systems with high output power in particular need to be cooled efficiently. Additive manufacturing processes can be used to significantly expand the surface area of a heat sink, which leads to an increase in efficiency. At the same time, this heat sink can also serve other purposes and, for example, function as part of a waveguide system. Compared to traditional manufacturing processes, the results of the new 3D printers also allow a higher degree of freedom in the design of high-frequency components. Flexible control over the geometry of the components allows much lighter components to be produced while maintaining functionality. This allows highly integrated radar systems to be flown using airborne systems.

Alex Shoykhetbrod was born in 1983 in Odessa, Ukraine. He graduated from Koblenz University of Applied Sciences in 2009 with a degree in Telecommunications Engineering. In 2012, he received his M.Eng. at Koblenz University of Applied Sciences in Systems Engineering. Since November 2012, he has been working at Fraunhofer FHR in Wachtberg as a research associate. His main research area includes interdisciplinary research on integrated millimeter wave systems. Recently, this has also included the use of additive manufacturing technologies.

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Fraunhofer ENAS Chemnitz
Fraunhofer FHR Wachtberg
Fraunhofer HHI Berlin
Fraunhofer IAF Freiburg
Fraunhofer IIS Erlangen
Fraunhofer IISB Erlangen
Fraunhofer IMS Duisburg
Fraunhofer IPMS Dresden
Fraunhofer ISIT Itzehoe
Fraunhofer IZM Berlin
Leibniz FBH Berlin
Leibniz IHP Frankfurt (Oder)

Guest members of the Fraunhofer Group for Microelectronics

Fraunhofer AISEC Garching
Fraunhofer FOKUS Berlin
Fraunhofer IKS Munich
Fraunhofer IMWS Halle/Saale
Fraunhofer IZFP Saarbruecken

A cooperation of

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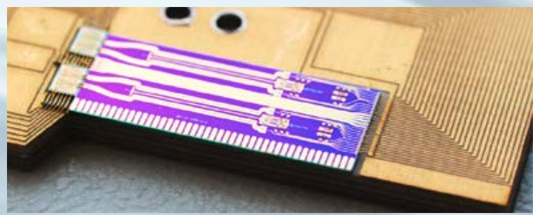
Our technology offer

As a research network for micro- and nanoelectronics applications and systems, we are able to offer customized technology and system solutions from a single source. Based on the broad technology portfolio of the cooperation partners in FMD, we have established six technology platforms. These bundle the necessary individual competencies – from system design to testing and reliability assessment – to cover customer needs.

Sensor Systems

Sensor design, manufacturing, integration, characterization and test of sensors, also in systems.

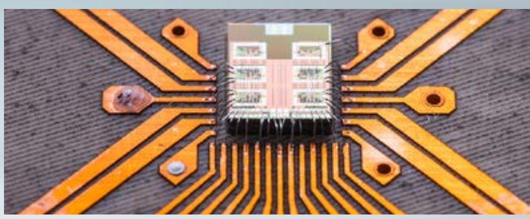


Optoelectronic Systems

Fully integrated optoelectronic systems for image generation and processing, and communication at Tbit/s speed.

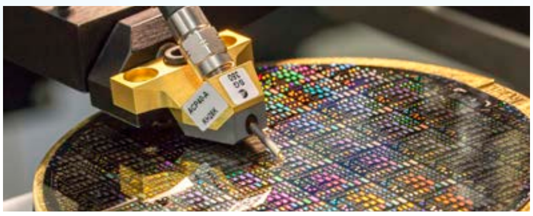
Extended CMOS

Design, manufacturing and system integration of CMOS circuits.



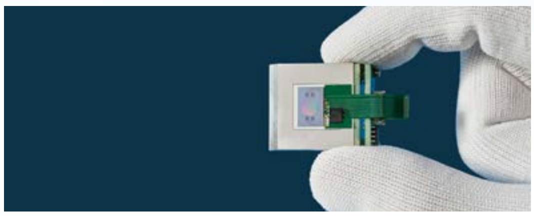
Microwave & Terahertz

Cutting-edge devices and circuits for frequencies up to the THz range.



Power Electronics

Design and manufacturing of power devices, and their integration into modules and systems.



MEMS Actuators

Design and manufacturing as well as characterization, testing and system integration.

Dr. Marie Christin Wolff.
© Fraunhofer ISIT

Dr. Marie Christin Wolff studied chemistry at the University of Oldenburg and subsequently completed her doctorate in inorganic chemistry at the University of Hamburg in AK Heck. In 2018, she moved to the Fraunhofer Institute for Silicon Technology ISIT, where she first worked in the area of electroplating and then also in the area of wet chemistry. In January 2020, she became team leader of the fabrication for wet chemistry, electroplating and chemical-mechanical polishing. Since summer 2020, Dr. Wolff has represented Fraunhofer ISIT on the Scientific and Technical Council of the Fraunhofer-Gesellschaft.

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Etching expert at Fraunhofer ISIT

Oxidizing, etching, structuring, polishing and depositing are part of Dr. Marie Christin Wolff's everyday work. At Fraunhofer ISIT, she and her team are dealing with single process development in the fields of wet chemistry, electroplating and chemical mechanical polishing (CMP).

Dr. Wolff, what are you and your team working on right now?

We manufacture microsystems. My team and I develop the individual processes for planned components and take care of process stability and the associated equipment. We work on pretty much all processes that have something to do with (corrosive) liquids – that is more or less the common denominator of the team. This includes electrochemical deposition processes in electroplating, but also chemical-mechanical polishing of wafer surfaces. In between, there are all the etching and cleaning processes in wet chemistry. Within the Research Fab Microelectronics Germany and the Fraunhofer Group for Microelectronics, we are currently involved in expert groups to strengthen the shared experience of those responsible for devices. This results in good networks and exchange platforms. We can show customers from this pool a second supplier for processes, offer completely different processes or stimulate expert discussions on process control.

What is your work useful for?

The results of our work are a central component for the production of MEMS components and MEMS devices. In Fraunhofer ISIT's 1000 m² clean room, wet chemistry, electroplating and CMP make an important contribution to the process chain to realize sensors, actuators and post-CMOS integration. For example, we etch electrode structures and membranes, deposit conductive tracks and pads, and polish glass and metal surfaces.

What is the share of microelectronics in your research area?

If you look at the chain of creating components, we are part of the manufacturing. In our daily work, we apply our processes to different materials and stacks. One of our main tasks is to integrate and evaluate materials that are new to us into our existing equipment, such as aluminum scandium nitride, parylene or gallium nitride. But also the testing of other etching media, grinding materials or electrolytes is part of it. The

Dr. Wolff at work on the spray etching system for processing GaN surfaces in the MEMS clean room at Fraunhofer ISIT.
© Fraunhofer ISIT

balancing act is to make the processes as comparable and reproducible as possible despite the different substrates. At the same time, the different requirements of a feasibility study have to be combined with pilot production and, in some cases, production on the same equipment.

What do you find particularly exciting about your work?

I like the combination of practical relevance and the freedom that comes with a research environment best. In addition, I haven't been in the cosmos of microelectronics and silicon technology for that long, so every new project is exciting for me.

High-temperature protective coatings for space application

At operating temperatures of more than 1700 °C, researchers face major challenges in developing components for aerospace applications. Dr. Christian Reimann and Kevin Schuck from Fraunhofer IISB found a way to provide such components with cost-effective ultra-high temperature resistant protective coatings. With their idea, the young scientists won the 3rd place in the DLR Challenge of the "INNOspace Masters" 2020.

Such high heat generation is particularly problematic in engines, drives and thermal protection structures for aerospace. In common carbon fiber composite components active oxidation and inevitable destruction of the materials by particle ablation and spalling occurs. As a result, current use is limited to lower temperature applications and engines and propulsion systems do not reach their potential.

Mr. Reimann, Mr. Schuck, please tell us more about your approach.

At the heart of our approach is the spray coating technology developed at Fraunhofer IISB, which helps to provide components for aerospace applications with ultra-high temperature resistant protective coatings. Through the symbiosis of our idea and the spray coating technology developed at the institute, it is now possible to provide the affected carbon fiber composite components with the temperature-resistant oxidation protection coating. This results in engines and drives being able to operate at higher temperatures and achieve better efficiency.

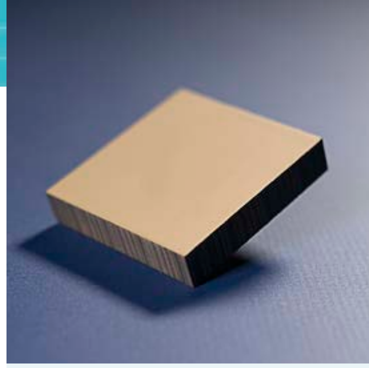
What changed for you after the award?

The "INNOspace Masters" competition initiated by the German Aerospace Center (DLR) annually honors innovative ideas and concepts for the transfer of technologies, services and applications from space to other industries and vice versa. The award gave us, as researchers, access to global science networks. We also received funding to carry out our two-year "HOSSA" research project. This involves bringing our idea for high-temperature protective coatings into practical application together with companies from the aerospace industry.

From theory to practice. How far along are you with your research project?

After the project documents have been reviewed by DLR, we intend to start our project at the beginning of June 2021. By directly involving an industrial advisory board of suppliers and users from the aerospace industry, we are very confident that there will be further follow-up projects and technology exploitation. Another key point is to generate as many application scenarios as possible for the novel technology. Our expertise in semiconductor material production and processing helped to already succeed in getting companies from this sector interested in our approach and in conducting the first licensing negotiations.

Dr. Christian Reimann and Kevin Schuck handing over the certificates during the "INNOspace Masters" 2020. © Fraunhofer IISB / Anja Grabinger



Graphite plate covered with a high-temperature protective layer. © Fraunhofer IISB / Anja Grabinger

Christian Reimann studied Mineralogy at Johannes Gutenberg University Mainz and at the University of Cologne. He has been a research associate at Fraunhofer IISB since 2005 and received his PhD from Friedrich-Alexander-University Erlangen-Nuremberg 2010. In the same year, he became group leader and deputy head of the Materials department at Fraunhofer IISB in 2016.

Kevin Schuck successfully completed his studies at Friedrich-Alexander-University Erlangen-Nuremberg in the field of Materials Science and Materials Engineering in 2019. After graduating his Master, he has been a research assistant at Fraunhofer IISB in the Materials department, working on protective coatings for high-temperature applications.

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Christian Dils. © private collection

Christian Dils studied microsystems technology at the University of Applied Sciences (HTW) Berlin and graduated in 2005 He worked for International Fashion Machines in Seattle, a pioneer company for electronic textiles, and at the TZI – Center for Data Processing and Communication Technologies in Bremen. In 2007 Christian Dils joined the research group "Systems on Flex" at Fraunhofer IZM as a research associate. His research interests include the development of stretchable and textile-integrated electronic systems, especially in the field of substrate processing, manufacturing technologies and interconnection techniques.

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Smart fashion comes with microelectronics

Can fashion do more than dress? In the "Re-FREAM" project, artists and researchers are working together to find synergies between textiles and technology to make clothing smart. Scientists like Christian Dils from Fraunhofer IZM are taking care of the integration technologies and electronic modules needed for this.

Mr. Dils, while watches have become smartwatches and wristbands have become fitness trackers, clothing has remained clothing. Has fashion already arrived in the digital age?

The first textile products are already available today that can record vital functions and fitness data and send them to a smartphone, warn of dangers at work, or quite simply, keep you warm. Compared to smartwatches or fitness trackers however, electronic textiles – so-called e-textiles – have not yet reached the mass market. At the Fraunhofer Institute for Reliability and Microintegration IZM, however, we are firmly convinced that e-textiles have great potential for innovation and growth.

What would be a fitting example from the Re-FREAM collaboration?

The "Connextyle" project around designer and product developer Jessica Smarsch. She and her team have developed garments that can optimize rehabilitation processes after a stroke. To do this, muscle activity is measured with textile-based electromyography sensors and sent to a textile-integrated electronic module by means of stretchable conductor paths data can then be transmitted to the responsible therapists via smartphone.

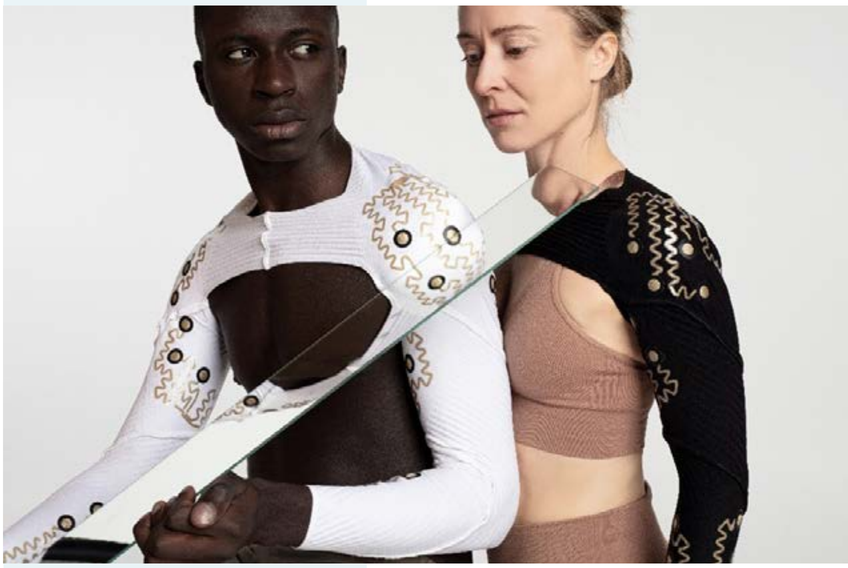
However, the application scenarios are unlimited and not limited to fashion. One subproject in Re-FREAM is "Alma," with which the Italian designer Giulia Tomasello wants to uncover taboos surrounding female health and realize monitoring of the vaginal flora. Another example is the sub-project "Lovewear", which develops underwear to help people with physical disabilities explore their own intimacy.

What technical challenges must be overcome in the process?

The contact points between electronics and textiles are particularly demanding, as these must be producible on an industrial scale and still function reliably when worn and after washing. This is made possible by the strong miniaturization of the electronic modules, special coating and encapsulation processes or contacting technologies suitable for textiles, such as bonding process specially developed at Fraunhofer IZM. Another challenge is the integrated conductor structures, which must be similarly soft, stretchable, bendable and foldable as textiles. The project is now in its second phase.

What can we expect in the coming months?

During the three Art-Tech projects in the first phase, innovative concepts for wearable and sustainable health applications were developed. In the second phase, we have again found three talented and motivated designers with whom we are looking at further implementation options for e-textiles Progress can be followed at any time on our project website. I would also like to invite anyone interested to connect via our Re-FREAM group on LinkedIn.



Style and functionality combined: here with clothing that measures muscle activity and thus optimizes rehabilitation processes.
© Jessica Smarsch

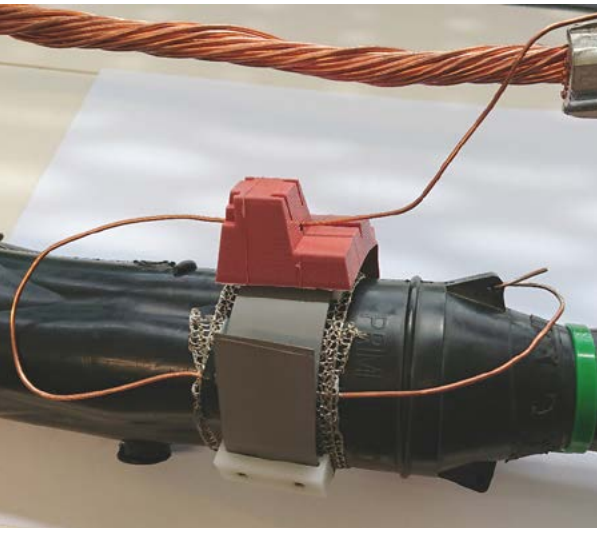
FMD equipment in use for cable monitoring

Dr. Alexander Weiß has taken over the management of the department Multi Device Integration at Fraunhofer ENAS in January 2021. In the current project "Cable Monitoring", in which Mr. Weiß is active, equipment is used, which was procured within the framework of the Research Fab Microelectronics Germany FMD.

Dr. Weiß, what is your main focus in your new role?

In the first step, I focused on organizational issues and reorganized some processes in the department. Currently, I'm focusing primarily on strategic issues. This also involves our role in FMD. Generally, the department Multi Device Integration (MDI) continues to be a development partner for new types of sensors and actuators as well as their integration into application-oriented systems. With our work in the FMD, we can make significant contributions in the FMD technology platforms "Sensor Systems" and "MEMS Actuators" as well as their broader application. It is also important for us to enhance the state of the art through our expertise in application-oriented research in the fields mentioned before. Furthermore we have to keep addressing future growth fields.

A prototype of the sensor attached to a connector.
© Fraunhofer ENAS



How does FMD support you in your work?

FMD offers our institute and department great added value. This starts with inter-institute cooperation in internal projects and continues with joint initiatives in joint projects and industry cooperation. Moreover, it continues top-down with the wonderful equipment, which was financed by the FMD. I want to mention two examples: our new "test station for MEMS functional testing at wafer level" and our "complex optical analytics cluster for the characterization of optoelectronics systems".

You work with this equipment in the cable monitoring project. What exactly is being implemented here?

The most fault-prone parts of a wired power system are cable connections and connectors. Gradual degradation of the cable insulation in combination with high voltage increasingly causes partial discharges. These errors usually result in extremely high short circuit currents, and finally destroy the cable connection. The aim of this project is to use novel sensors – in this project, for example, a partial discharge sensor – to develop self-sufficient multi-sensor systems that can reliably detect such faults at an early stage. The sensor nodes consist of a wireless communication module, a current transformer module and various sensors for detecting partial discharges, cable temperature and external influences such as vibrations or shocks. With the test station already mentioned, we are characterizing the MEMS vibration sensors used in the project.

What other project in the FMD universe would you like to be involved in?

We are currently hearing a lot about quantum computing and other advanced technologies. I could imagine us cooperating in the development of quantum optical sensors at FMD.

Dr. Alexander Weiß.
© Fraunhofer ENAS

As a child, I was very fascinated by large machines and what was possible with them. I almost wanted to study mechanical engineering after finishing my school education. But when I visited the Chemnitz University of Technology on Open House Day, I was fascinated by the scientific papers displayed on posters and the small microsystems exhibited. This work was done within the "Collaborative Research Center SFB 379 – Micromechanical Sensor and Actuator Arrays". I had not seen anything like that before and it was clear to me that this would shape the future. I am even more pleased today that our developments of small sensor systems are also used on large machines, for example for condition monitoring and predictive maintenance.

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Sebastian Schulze. © IHP GmbH

Sebastian Schulze was born in Burg in 1985, studied physical engineering at the Technical University of Wildau and graduated with an engineering diploma in 2009. He then worked at the IHP in the field of material characterization and dealt with various methods for surface analysis. After a stay abroad in 2011 in Vancouver, Canada, he returned to IHP in 2012 and his work focus shifted to process development. While working, he obtained his M.Sc. in nanotechnology from the University of Kaiserslautern in 2017. In addition to his scientific work at IHP, Sebastian Schulze is a passionate triathlete and is currently preparing for a race at the Ironman distance.

New bonding technologies for wafer-level packaging and 3D heterointegration

As part of the Research Fab Microelectronics Germany (FMD), Leibniz IHP modernized part of its research infrastructure over the past three years. Sebastian Schulze conducts research in the field of Al-Al bonding and works in Frankfurt (Oder) on one of the new high-tech devices – a high-vacuum bonder that helps, among other things, to reduce the high temperatures during bonding and thus protects the components.

Mr. Schulze, what are you working on right now?

I work at the Leibniz Institute for Innovative Microelectronics and I am currently involved in the optimization of physical and chemical vapor deposition processes for metal deposition and the solution of technology problems in the interconnect system. Due to FMD and the accompanying modernization of IHP's research infrastructure, my field of work has expanded to include aluminum to aluminum (Al-Al) wafer bonding. Since 2018, I have been working on Al-Al thermocompression bonding, preparation of the required wafers and post-processing. I am also pursuing a PhD on this topic. Currently, I spend a lot of time in the lab and I am busy with process development on a new wafer bonder.

What does "wafer bonding" mean and what is it used for?

Wafer bonding is about permanently connecting two wafers and ensuring low contact resistance at the Al-Al interface. Until now, oxide formation on the Al surfaces was one of the main limitations to realize reliable electrical connections with low contact resistance. Successful bonding was only possible at a very high temperature (> 400 °C). The high vacuum bonder I am currently working on circumvents exactly this problem.

How do these new technological opportunities help you in your field of research?

A novel surface treatment based on plasma cleaning combined with processing of the wafers under ultra-high vacuum enables oxide-free Al-Al wafer bonding. As a result, the temperatures during bonding can be reduced enormously to approx. 150 °C. This protects the components and reduces thermomechanical stresses during bonding. Another special feature: optical alignment with a very high accuracy of less than 1 µm enables the production of electrically conductive Al interconnects with ultra-fine dimensions between the substrates. With the help of this new bonding technology, future-oriented possibilities arise in the area of wafer-level packaging and 3D heterointegration, in which different semiconductor technologies can be combined to obtain higher functionality and performance.

Sebastian Schulze with colleagues Patrick Krüger and Thomas Voß (f.l.t.r.) in front of the high-vacuum bonder in the IHP Nanolab. © IHP GmbH

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Effective AI training with LIDAR data

Artificial intelligence (AI) can only operate as powerfully as the quality of the trained data allows. In particular, this applies to deep learning, which uses neural networks inspired by the human brain. Tools for labeling camera images are already established on the market, but corresponding tools for labeling laser scanner data are not yet available.

Bernd Schäufele. © private collection

Mr. Schäufele, how can the labeling tool FLLT.AI pave the way to autonomous mobility?

In many self-driving vehicles, LIDAR sensors, laser scanners, are part of the sensor technology that is used for environment detection. To ensure that the vehicles can make any use of the data, the AI in the vehicle must be trained. For LIDAR data, however, there are only a few data sets available so far. With our labeling tool FLLT.AI, one can easily create datasets for LIDAR and simultaneously use recorded video data to automatically pre-label the LIDAR data. Furthermore it is easy to manually post-process the LIDAR data. In addition, tracking labels are used to continue from one LIDAR scan to the next. Thus, on average, only 10 % of the time is needed to generate high-quality learning data.

How do humans drive AI and will this work (almost) without them in the future?

Today, it is often the case that the AI needs to get specifications in a so-called "supervised learning" environment. Here, the data used for training must be processed by humans beforehand, labeling various objects in the data. In the future "unsupervised learning" may work without humans. In this case, the AI tries to determine differences in the data during the training and thus will be able to determine classes itself. However, checking whether these classes are correct and the determination of the parameters during trainings still has to be executed by a human.

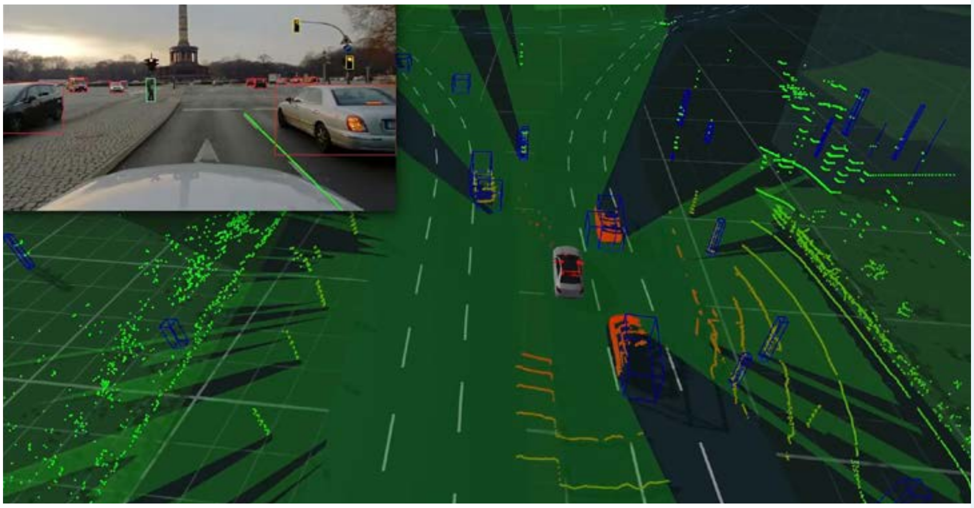
How do microelectronics interact with your tool?

Through various interfaces offered by the FLLT.AI tool, data recorded with LIDAR sensors and cameras can be directly integrated into the FLLT.AI tool. We are also working on integrating other sensors, such as RADAR. For the data labeling, we use our own very powerful AI server farm to run the neural networks. At the same time, we are also working on the AI-Flex project to develop an ASIC specifically for running neural networks.

What is still missing for the autonomous vehicle that can be put on the road without worries?

Research into self-driving vehicles is already very advanced in terms of environment recognition. This means that traffic areas with relatively low complexity, such as highways, can already be mastered well. A major challenge is the decision-making in complex traffic scenarios, such as those found in cities, but also on rural roads with many intersections. The number of possible traffic situations there is very high and therefore requires a huge amount of data to prepare the AI.

Bernd Schäufele heads the Perception and Communication group in the Smart Mobility business unit at Fraunhofer FOKUS. He has participated in large Europe-wide research projects in the field of vehicle communication and cooperative driving, such asSimTD, Drive C2X and TEAM. His research focuses on cooperative positioning and cooperative driving maneuvers as well as environment recognition with LIDAR and camera sensor technology. In Bernd Schäufele's group, the software framework "FLLT.AI" was developed for the automatic and manual labeling of LIDAR data and for the fast generation of high-quality data for artificial intelligence training. Bernd Schäufele holds a master's degree in software systems engineering from the Hasso Plattner Institute in Potsdam.



Data acquisition is performed with the help of cameras and a LIDAR sensor. © Fraunhofer FOKUS

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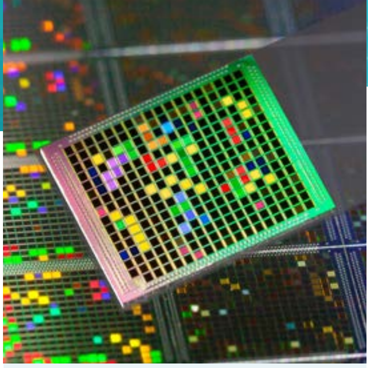

Smart sensors, integrated circuits and software solutions for a better everyday life.
© Fraunhofer IIS / Max Etzold

Change of leadership in the division "Smart Sensing and Electronics" at Fraunhofer IIS

At the beginning of the year, the baton of the Smart Sensing and Electronics research division at Fraunhofer IIS was handed over: The new division leaders are Dr. Denise Müller-Friedrich and Dr. Jens-Uwe Garbas. The founding father and previous division director, Josef Sauerer, retired at the end of March.

The "Smart Sensing and Electronics" research area at the Fraunhofer Institute for Integrated Circuits IIS in Erlangen works on the development and realization of practical and future-oriented solutions in the fields of medical technology, perception-based and integrated sensor systems, as well as on chip development (IC design). The integrated circuits developed at the institute are used in production plants and machines or in vehicles of well-known manufacturers.

As a team in a dual leadership: Dr. Jens-Uwe Garbas and Dr. Denise Müller-Friedrich. © Fraunhofer IIS

In the context of "cognitive sensing", the department researches technologies for sensing and data transmission techniques as well as analysis methods. This adds a cognitive component to the function of the classic intelligent sensor.

The new duo

Dr. Jens Garbas, an electronics engineer, joined Fraunhofer IIS in 2010 after completing his doctorate. Among other things, he was responsible for strategy and business unit development in the field of image sensors and artificial intelligence. Most recently, he established a new business unit for perception-based sensor technology at the institute. His new responsibilities will primarily include overall strategy and personnel management. "My goal is to enhance even more synergies between the business units while building on the strengths of our existing research areas. Strategic initiatives and new partnerships will be of particular importance," says Dr. Garbas.

Dr. Denise Müller-Friedrich received her doctorate in chemistry from the University of Bayreuth. After holding various positions in scientific institutions, she moved to industry in 2014 and was most recently Head of Sales and Strategic Marketing at the Seuffer Group. In 2017, she became an advisor at Fraunhofer IIS responsible for parts of the Smart Sensing and Electronics division. Now she will primarily take care of organizational development, strategy and business processes, and finance. Dr. Müller-Friedrich: "Our vision of developing smart sensors, microelectronics and software for a better everyday life is what drives our research work. We want to build on the technical and strategic successes of the past years, launch new initiatives and optimally network topics and people."

The predecessor

As a man of the first hour, Josef Sauerer has been instrumental in shaping the core competence of microelectronics at Fraunhofer IIS over the past 35 years. In 2014 he began with the establishment of the Smart Sensing and Electronics division, which today has more than 120 employees and an annual budget of around € 23 million. Together with partners from industry and academia, the division is working flat out not only on solutions for today's and tomorrow's markets, but also on building blocks for a sustainable and livable society in the change of digitization.

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Karsten Roscher. © Fraunhofer IKS

Robust quantum computing for practical applications

Quantum computing has the potential to massively and sustainably change a wide range of industries and enable numerous new applications. These include, for example, simulations of new materials for more efficient solar cells and batteries, as well as data-intensive applications for artificial intelligence (AI) and cybersecurity.

Mr. Roscher, you work in an absolutely trendy area, quantum computing. What is that and how can society be practically advanced by it?

Simply put, quantum computers are X times faster in terms of processing speed for very specific tasks than today's computers. In other words: In the future, quantum computers will solve problems within seconds, for which today's computers would need centuries. This enables numerous new applications. These include solutions for complex optimization problems e.g. in logistics, finance and insurance, but also allows better medical diagnostics.

In which areas do you advance technology development with your daily work?

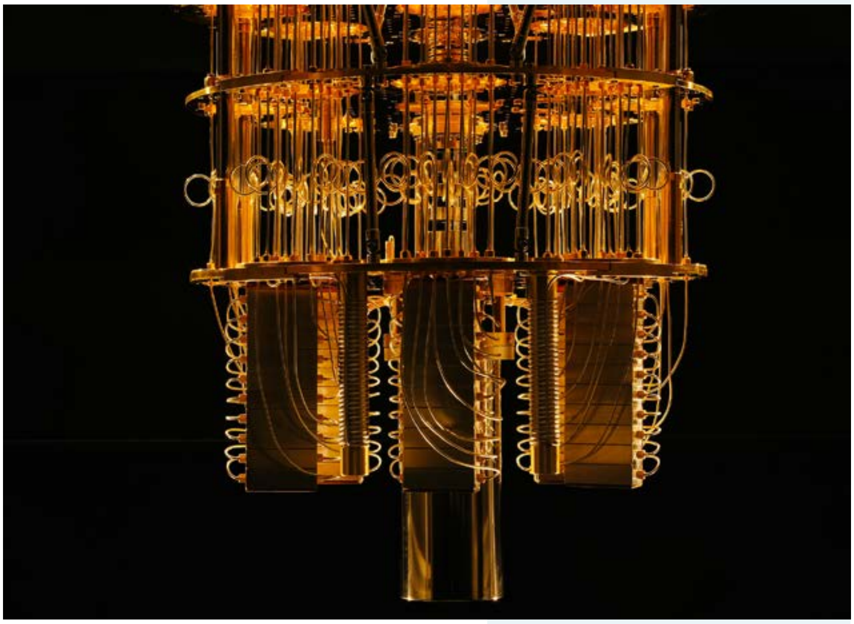
In the context of developing software applications for quantum computing, Fraunhofer IKS focuses its expertise in safety to the research field of "reliable and robust quantum computing". As already mentioned, quantum computing offers many possibilities for innovative solutions, but it can only deliver a real added value, if its calculations are reliable and safe. In addition to pure computing power, the robustness of quantum computing is therefore a basic prerequisite for its successful use in practice.

What specific influence do microelectronics have on your work?

Regardless of the specific quantum computing project, microelectronics is in every device we work with in our daily lives. Without the constantly increasing computing power at all levels, the broad application of machine learning would not be possible at all. The success of artificial intelligence is therefore also a success of microelectronics.

And what are the biggest challenges you are currently addressing?

The use of neural networks in safety-critical environments is very challenging because even small changes to the input, such as an image, can lead to a different result of the calculations. Therefore, a proof of quality for the calculations of neural networks is required. For this purpose, certain algorithms are used, which currently only work for relatively simple networks. With the size and complexity of a neural network, the computation time needed, to verify the results, increases massively. For this reason, Fraunhofer IKS is investigating how the optimization validation and verification of autonomous, networked systems can be improved with the help of quantum computing.



The Fraunhofer-Gesellschaft brought the first quantum computer to Germany in November; Fraunhofer IKS supports the associated software development with reliable and robust quantum computing. © IBM Research

Karsten Roscher is working at the Fraunhofer Institute for Cognitive Systems IKS (then Fraunhofer ESK) since 2010. He is heading the Department of Certifiable Artificial Intelligence since 2020. Karsten Roscher studied computer science and electrical engineering with a focus on multimedia systems, computer networks and robot vision at Ilmenau University of Technology. He is currently researching on the reliable determination of uncertainties as well as methods to ensure robustness and tractability for machine learning.

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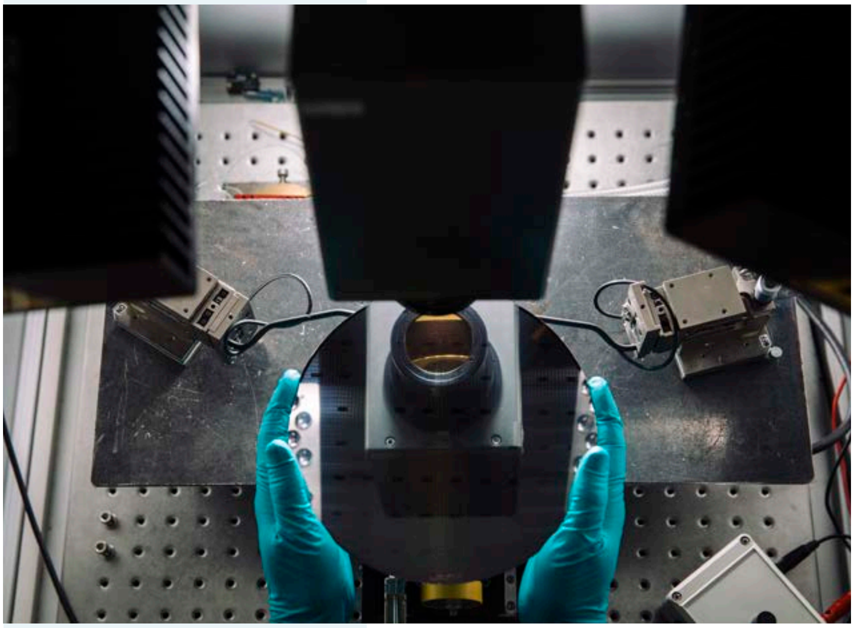
Frank Altmann. © Fraunhofer IMWS

Frank Altmann has been acting head of the Business Unit "Materials and Devices for Electronics" at the Fraunhofer IMWS in Halle (Saale) since 2019. In addition, he has headed the group "Diagnostics Semiconductor Technologies" since 2006 and has been lecturing at Merseburg University of Applied Sciences in the master's program "Mechatronics, Industrial Engineering, Physical Engineering" since 2007. He himself studied physics at the TU Dresden and already wrote his diploma thesis in cooperation with the Fraunhofer Institute in Halle. He has been working at the Fraunhofer IMWS since 1997 and most recently conducted research on fault diagnostics for 3D integrated microelectronics.

Reliable microelectronics through failure analysis with artificial intelligence

The use of machine learning methods offers novel possibilities for automating and thus increasing the efficiency of failure diagnostics. Together with partners, the Fraunhofer IMWS wants to pave the way for this in an international project. The new methods based on artificial intelligence (AI) will help to capture and evaluate complex failure modes.

This is precisely where the project "Failure Analysis 4.0 – Key for reliable electronic devices in smart mobility and industry production" (FA 4.0) comes in. Until March 2023, the partners from research and industry are working on methods for failure analysis tools and workflows. "High integration density is a constant challenge for the quality and reliability of components for microelectronics," says Frank Altmann, who leads the activities of the Fraunhofer Institute for Microstructure of Materials and Systems IMWS within the new project. "Powerful and continuously improved methods for failure analysis are therefore elementary."



Non-destructive diagnostic methods such as lock-in thermography are one of the focal points in the "FA 4.0" project. © Fraunhofer IMWS

Largely automated error analysis and data management

To achieve this common goal in the project, Fraunhofer IMWS focuses on the research and development of AI methods for signal analysis of non-destructive defect detection – for example acoustic microscopy or lock-in thermography. The idea: to develop concepts of supervised as well as unsupervised machine learning and then integrate them into diagnostic devices for data acquisition and evaluation. On the one hand, the researchers are working on linking individual analytical devices from different stages of the process with standardized hardware and software interfaces and, on the other hand, on defining guidelines and database systems for structuring, processing and storing component-specific characteristic and analysis data. Once a link between data from different analysis methods and the layout of an integrated circuit has been achieved and subsequently analyzed by a trained and self-learning algorithm, defects could be automatically detected, their signature determined, classified and compared with catalogued data on already known causes of defects. These new innovative approaches can identify previously undetectable complex defect patterns and significantly reduce the time and cost of defect analyses.

Successful fault diagnostics with AI-based evaluation

Frank Altmann is optimistic about the future and sums up the project: "In current failure analysis workflows, numerous methods are used that provide complementary analysis data from components. However, these have so far only been linked manually. The automated, cross-process provision and AI-based evaluation of this data, including derivation of failure causes, have enormous potential to further increase the efficiency of quality control in manufacturing and thus increase product reliability and quality with ever shorter development times."

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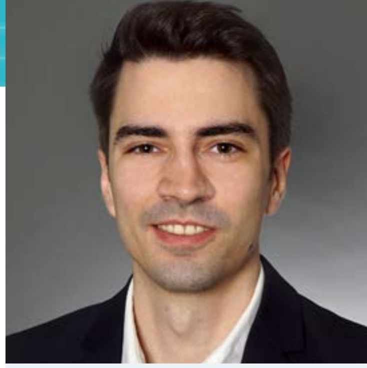
Nondestructive testing system for manual testing



Kevin Becker. © private collection

Kevin Becker, born in 1991 in Homburg, studied electrical engineering and information technology at Technical University of Darmstadt, majoring in "Integrated Micro- and Nanotechnology" and "Sensors, Actuators and Electronics", and graduated with a Master of Science degree in 2020. As part of his master's thesis, he developed a 10 Gbps high-speed transceiver in TSMC's 28 nm HPC technology. Since November 2020, he has been working as a PhD student at Fraunhofer IZFP, where he is conducting research in the field of energy-efficient real-time data processing for sensor systems in nondestructive testing.

Nondestructive testing (NDT) sensor systems are essential for quality assurance in a wide range of industrial sectors. However, the current unwieldy testing system concepts are rather limited. This applies especially to testing, since testing often has to be carried out in areas that are difficult to access. Kevin Becker from Fraunhofer IZFP is researching technologies to facilitate their use.

Mr. Becker, what challenges do you see in the development of new sensor systems for NDT processes?

One of our goals at the Fraunhofer Institute for Nondestructive Testing IZFP is to develop systems that apply new concepts in sensor signal processing. A good example of this is manual testing, where a wide range of boundary conditions must be taken into account; good manageability, miniaturization of the entire sensor system, low latency of signal transmission, and real-time data processing. This requires a close look at the entire signal chain to ensure that data processing and transmission are as energy-efficient as possible and without major delays. It is also important to classify the data in advance in order to simplify error detection for the inspector as much as possible. This can lead to a significant improvement in the quality assurance process.

Eddy current assembly inspECT-PRO as part of our demonstrator. © Fraunhofer IZFP / U. Bellhäuser

What research topics are you working on at Fraunhofer IZFP?

At the core of my research is the development of novel concepts for energy-efficient microarchitectures and AI accelerators. For this purpose, a "Field Programmable Gate Array"(FPGA) initially serves as a development platform. The systems developed on it are intended to accelerate data processing, operate as energy-efficiently as possible, and implement new concepts of biologically inspired information processing. In such and similar research topics, we work in close cooperation with institutes of the Fraunhofer Group for Microelectronics – for example in the innovation program "TRAICT"(Trusted-Resource-Aware ICT). Here, the participating research teams from 18 Fraunhofer institutes jointly investigate system architectures and their components with regard to their trustworthiness and energy efficiency.

What exactly are you working on right now?

I am currently working on the implementation of an eddy current testing system for manual testing. So far, a demonstrator has been realized, which will be optimized in the future, especially with regard to energy efficiency and performance: thus, data can be transferred and displayed on a smartphone via Bluetooth after an analog-to-digital conversion of the sensor signal. For this purpose, we have carried out the necessary programming of the microcontroller in our team and developed an app that displays the data on the smartphone screen.

What do you find particularly exciting about it?

For us, it is interesting to achieve the lowest possible latency between the physical interaction with the test object, the data processing on the microcontroller and the final display on the smartphone screen. A latency of 100 ms is already clearly too long for manual testing. In the future, the linking of several sensor signals and the associated classification of the data will be realized.

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Prof. Sebastian Kruss.
© RUB / Marquard

Sebastian Kruss studied chemistry and biophysics at the University of Heidelberg and earned his doctorate at the Max Planck Institute for Intelligent Systems on nanostructured surfaces. He then moved for a post-doctoral stay to the Massachusetts Institute of Technology (M.I.T.) in Cambridge, USA. After his return, he initially led a research group at the University of Göttingen. In 2020, he was appointed to a professorship in physical chemistry at Ruhr University Bochum. At the same time, he established the biosensors group at the Fraunhofer IMS as part of the Attract program.

New biosensors detect viruses and bacteria in real time

Optical biosensors have the potential to detect bacteria and viruses within seconds. Patients would no longer have to wait days for their test results, and sterile rooms, medical equipment, production processes and food could be monitored in real time. A new team has been formed at Fraunhofer IMS in Duisburg to make this possible.

Prof. Kruss, detecting bacteria and viruses in real time sounds like a great prospect for the future. Can you explain how your planned detectors work?

We are working on nanosensors that can be imagined as extremely small tubes – 100,000 times smaller than a human hair. They glow in a range that is not visible to humans (near infrared light). These nanotubes can now be chemically modified to change their glowing in the presence of a specific target molecule. In this way, the presence of virus particles or bacteria is visually detected. What is special about our sensors is that they can be used for a wide range of applications and are extremely small, fast and ultrasensitive. The current situation shows that much more diagnostics should be available to contain pandemics. Imagine having biosensors which are available to everyone, would give a result in minutes and would not be as error-prone as current tests.

What further research is needed to make it real?

We can already distinguish important pathogens such as bacteria in our laboratory. Thinking about all the applications, we want to expand the detection strategies further to be able to detect as many things as possible at the same time. Furthermore, we are also working on a prototype for reading out the nanosensors. In the long term, however, we aim to use such sensor concepts much closer to the patient. One example are intelligent implants that are applied non-invasively and indicate infections without contact.

How can we imagine such a detection device?

Biosensors detect chemical structures that are characteristic of a particular issue. An example would be the protein that allows the coronavirus to enter human cells. The nanosensors recognize precisely these structures. Therefore, such nanosensors, for example integrated in a hydrogel or on paper, are always needed. The readout can then be done with a wide variety of devices or detectors optimized for this purpose.

Part of the research team: Sebastian Kruss (left) and Robert Nißler. © Alexander Spreinat

What role do microelectronics play in your project?

Our nanosensors provide precise information about biological samples. To receive the information, light is used and this must be detected. Single photon detectors from the Fraunhofer Institute for Microelectronic Circuits and Systems IMS are used for this purpose. In addition, a highly integrated device must be developed for a biosensor that can be used by end customers, in which microelectronics and optics play a decisive role.

Why did you decide to advance your research at Fraunhofer IMS?

The development of biosensor technology requires expertise from various fields: From chemistry and physics to engineering and medicine. The Fraunhofer IMS provides an excellent expertise in the field of system integration and in highly sensitive optical detectors. This complements perfectly with my expertise in nanosensors. Together, we can develop the next generation of diagnostic tools.

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