Microelectronics News
Fraunhofer MIKROELEKTRONIK
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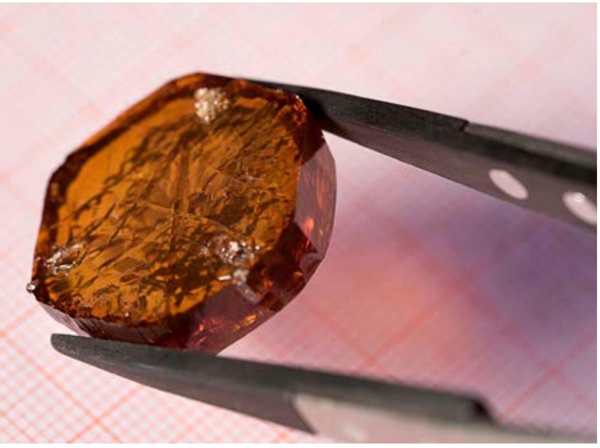
Research Fab Microelectronics Germany

Smaller, faster, more energy efficient – powerful devices for digital transformation



Highly efficient power semiconductors are to pave the way for a wide range of new applications – from electromobility to artificial intelligence (AI). This is the aim of the recently launched project "Power Transistors Based on AlN (ForMikro-LeitBAN)", in which FMD members Fraunhofer IISB and Leibniz FBH are also involved. »» page 8

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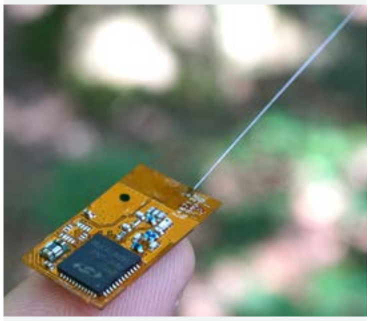

Tracking system for animal research: The research group "BATS" (German acronym for "Dynamically Adaptive Tracking Sensor Networks"), in which Fraunhofer IIS was also involved, has developed a tracking system for bats. © Simon Ripperger

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Interview I

"We must pool our strengths in Europe."

Prof. Albert Heuberger, executive director of Fraunhofer IIS, is the new spokesman of the board of directors of the Fraunhofer Group for Microelectronics. In our interview, he reviews upcoming challenges and opportunities.

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Research Fab Microelectronics Germany

"We support 5G network expansion in the millimeter-wave band."

Dr. Stephan Guttowski reports on the FMD's competencies in RF technology and the challenges in expanding the 5G network.

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… goes to Dr. Jennifer Ruskowski from Fraunhofer IMS

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Optical housings with slanted covers on a 200 mm glass wafer. © Fraunhofer ISIT

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Bat with the sensor.
© Simon Ripperger

Tracking system for animal research

The research group "BATS" (German acronym for "Dynamically Adaptive Tracking Sensor Networks"), in which Fraunhofer IIS was also involved, has developed a tracking system for bats.

Bat research made easy

The tracking system BATS allows observing social networks in free-ranging animals, tracking individual flight trajectories and monitoring physiological parameters such as heart rates. If an animal passes one of the base stations on the ground, the collected data is automatically transmitted and processed. With a total weight of just 1 g including housing and battery, it is also suitable for monitoring small animals without disturbing them.

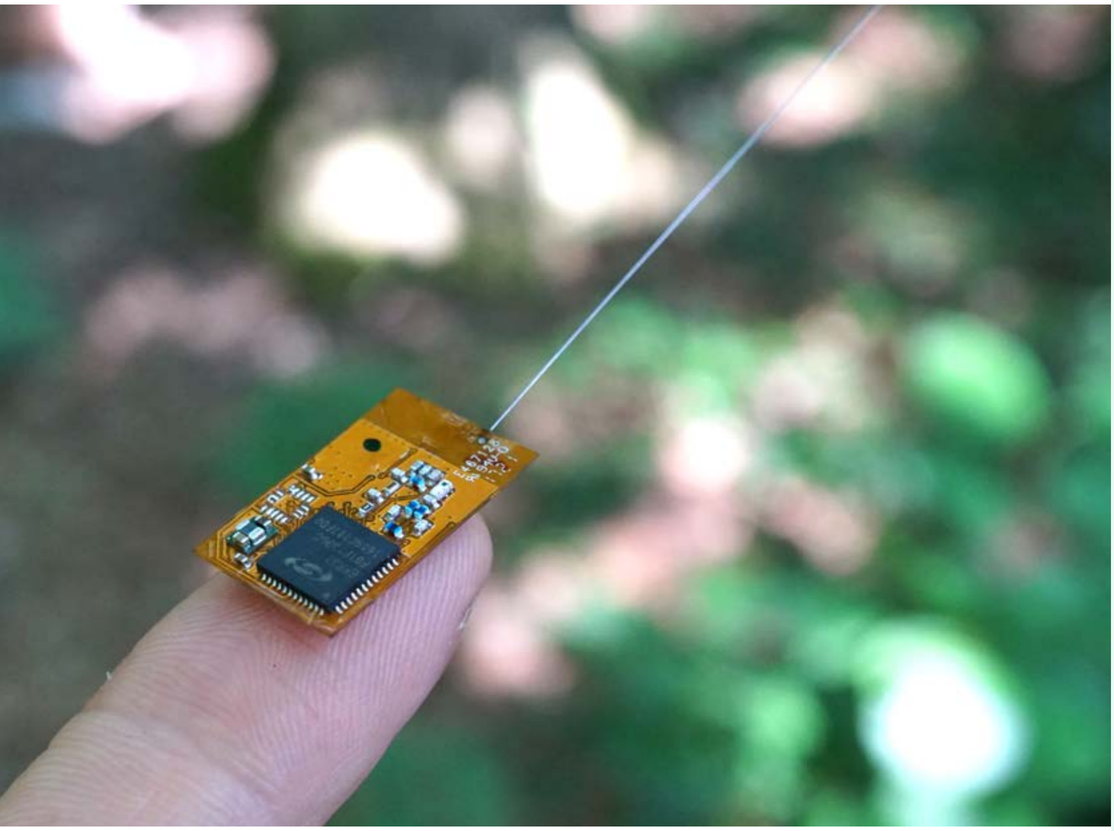
Bats – a challenging application

The tracking system was tested and optimized on bats during several field visits in Berlin, the upland Franconian Switzerland in Northern Bavaria, Panama, Belize and Costa Rica. BATS provides a technology that could also be applied to other small vertebrates such as birds or lizards. An application for monitoring the health of farm animals to improve their living conditions is also conceivable.

BATS was developed by an interdisciplinary research group from the fields of electronics, computer science and biology; the project was funded by the German Research Foundation DFG. The Fraunhofer Institute for Integrated Circuits IIS supported the DFG research group in the development of the base stations, i.e. the infrastructure on the ground, whose primary task is tracking.

BATS
Besides Fraunhofer IIS, the following partners were involved in the project:
- Friedrich-Alexander-University Erlangen-Nürnberg (project management)
- Museum of Natural History Berlin
- Technical University of Braunschweig
- University of Paderborn
- Brandenburg University of Technology Cottbus-Senftenberg
- University of Bayreuth

The circuit board shown here weighs only about 0.5 g, the finished, encased transmitter in its most robust form weighs 1g. This allows the bats to be monitored fully automatically and to the split second without affecting them. © Simon Ripperger



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Since 2011, Prof. Heuberger has been executive director of Fraunhofer IIS. As spokesperson for the Fraunhofer Group for Microelectronics, he wants to promote collaboration between Fraunhofer Institutes.
© Fraunhofer IIS / Karoline Glasow

"We must pool our strengths in Europe."

Prof. Albert Heuberger, executive director of Fraunhofer IIS, became the new spokesperson of the board of directors of the Fraunhofer Group for Microelectronics and chairman of the steering committee of the Research Fab Microelectronics Germany (FMD) on January 1, 2020. In this interview, he talks about upcoming challenges and the importance of collaborating with European partners.

Prof. Heuberger, microelectronics plays a decisive role in almost all areas of life. The digitization of entire industries gives rise to new applications and requirements. What tasks are associated with this?

In my view, the main requirements for next-generation microelectronic components are flexibility, data efficiency and energy efficiency, as well as reliability.

For sensors, we need modular platforms that can be adapted to special requirements. The trend towards strong networking in industry and the consumer sector is continuing, although I believe that not all data must and can be sent to a cloud. For many applications, local data processing and decision-making are important. To achieve this, we must develop energy-efficient distributed components. In general, the challenge is to position ourselves organizationally and technologically in such a way that the different requirements of industry can be served by research at Fraunhofer and that we can work together efficiently.

Let us look beyond the borders of Germany: what challenges do you see for Europe in terms of technological sovereignty, and how can these challenges be met?

At the European level, we have to ensure the supply of components and innovations. To this end, we want to drive forward the strategic research field of "Next-Generation Computing" within the Fraunhofer-Gesellschaft. The topics there are neuromorphic hardware, trusted electronics and quantum computing. We have expertise in all these areas to make technological contributions. In order to generate a real impact as a third player alongside the United States and China, we must pool our strengths in Europe. We want to do this by working with what are known as "Research and Technology Organizations" (RTOs) in Europe. To this end, we have to organize collaboration between the RTOs and invest in the technological infrastructure. For this, we need the support of the European Commission, which is funding infrastructure and projects within the Horizon Europe program. In this context, the FMD is considered a role-model when it comes to setting up various institutions with a common strategy and focused offers to industry.

Apart from that: where would you, as spokesman of the Group for Microelectronics, like to set special priorities?

As spokesperson, I am responsible for organizing collaboration between the microelectronics institutes. It is a dear issue to me that the office of the Research Fab Microelecronics Germany and the Group for Microelectronics continues to operate well and is engaged in the design of strategic initiatives.

Furthermore, I would like to strengthen the significance of microelectronics in industry and politics. We all know that microelectronics is the cross-sectional technology that has an impact on all industries. We therefore need an awareness of the importance of technological sovereignty and of the opportunities that emerge in new industries through the advancements in microelectronics. To achieve this, we must act together by further promoting collaboration between the Fraunhofer Institutes. This is what I would like to advocate as spokesman for the Group for Microelectronics, together with my deputy Christoph Kutter and the Executive Board.

Thank you for the interview!

About Prof. Heuberger:
Prof. Heuberger has been executive director of the Fraunhofer Institute for Integrated Circuits IIS since 2011. The institute has over 1100 employees; research is focused on two main topics: "Audio and Media Technologies" and "Cognitive Sensor Technology". Prof. Heuberger is, among other memberships, 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 Nürnberg 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.

“Via a clear strategy to success.”

For nine years Prof. Hubert Lakner, head of the Fraunhofer Institute for Photonic Microsystems IPMS, was chairman of the Fraunhofer Group for Microelectronics’ board of directors and since April 2017 chairman of the steering committee of the Research Fab Microelectronics Germany (FMD). Together with Prof. Lakner, we took a look back on his term of office.

“The Fraunhofer Group for Microelectronics was represented internationally at the INC conference series. The exchange at eye level with the partners in Europe, the USA and Japan was important to me.”

May 2012 *The 8th International Nanotechnology Conference on Communication and Cooperation (INC8) in Japan: The Group for Microelectronics receives the mandate to host the international conference in Berlin in 2013. © Toyohiro Chikyo (NIMS)*

“The Group for Microelectronics is a strong alliance within the Fraunhofer-Gesellschaft. We have often been a pilot – for example, in creating a Group strategy.”

May 2016 *Fraunhofer President Prof. Reimund Neugebauer presents Prof. Lakner with the Fraunhofer Medal for his services. The award ceremony took place during the 20th anniversary celebrations of the Group for Microelectronics. © Fraunhofer Mikroelektronik / Grützner*

About Prof. Hubert Lakner:
Prof. Hubert Lakner studied physics at the Eberhard-Karls-University of Tübingen. After one year of industrial activity in the development of coating processes, he moved to the Gerhard-Mercator-University – GH – Duisburg in 1987, where he worked on research projects in the field of nanocharacterization of mesoscopic compound semiconductor systems and received his doctorate in 1993. Since January 2003, Prof. Lakner has been the managing director of the Fraunhofer Institute for Photonic Microsystems IPMS. At the same time, he was appointed professor at the Technical University of Dresden. From January 2011 to December 2019, Prof. Lakner held the position of the chairman of the Fraunhofer Group for Microelectronics. Since April 2017, he was also chairman of the steering committee of the FMD. His deputy for these three terms of office was Prof. Anton Grabmaier, director of the Fraunhofer IMS in Duisburg.

"Via a clear strategy to success. The FMD is a fine example of consistent strategic work and has advanced all institutes of the Group for Microelectronics."

April 2017 *Handover of the grant approvals for the Research Fab Microelectronics Germany (FMD) by former German Minister of Education and Research Prof. Johanna Wanka.*
© Fraunhofer Mikroelektronik / Grützner

June 2018 *Signing of a cooperation agreement between CEA-Leti and the Group for Microelectronics: State Secretary at the German Federal Ministry of Education and Research (BMBF) Dr. Georg Schütte, Prof. Dr. Hubert Lakner, Deputy Director CEA Technology Jean-Frédéric Clerc, Director General at the French Ministry of Higher Education, Research and Innovation Alain Beretz (from left to right). © BMBF / Reiner Zensen*

"With regard to microelectronics, France is Germany's most important partner in Europe in research, development and production. Together we were able to make a difference."

Forschungsfabrik
Mikroelektronik
Deutschland

W-band module with MOSHEMT amplifier. © Fraunhofer IAF

MOSHEMT – novel transistor technology reaches record frequencies

Researchers at Fraunhofer IAF have succeeded in developing a new type of transistor with extremely high cut-off frequencies: Metal Oxide Semiconductor HEMTs, or MOSHEMTs, in short. For this purpose, they replaced the Schottky barrier of the conventional HEMT with an oxide. The result is a transistor that enables even smaller and more powerful components and that has already reached a record frequency of 640 GHz.

In recent years, the high-frequency properties of high electron mobility transistors (HEMTs) have been continuously improved. The transistors have become faster and faster by scaling down the gate length to 20 nm. However, the HEMT encounters a problem with these small structure sizes: the thinner the barrier material made of indium aluminum arsenide (InAlAs) becomes, the more electrons dissipate from the current-carrying channel to the gate. These unwanted gate leakage currents have a negative impact on the performance and lifetime of the transistor. The current transistor geometry of a conventional HEMT has reached its scaling limit. This problem also occurs with silicon MOSFETs (metal oxide semiconductor field effect transistors). However, they have an oxide layer that can prevent unwanted leakage currents for longer than it is the case with HEMTs.

Combining the advantages of both transistor technologies

Researchers at the Fraunhofer Institute for Applied Solid State Physics IAF have combined the advantages of III/V semiconductors and Si-MOSFETs and replaced the Schottky barrier of the HEMT with an insulating oxide layer. The result is a new type of transistor: the metal oxide semiconductor HEMT, or MOSHEMT, in short. “We have developed a new device that has the potential to exceed the efficiency of current HEMTs by far. MOSHEMT enables us to downscale it even further, thus making it even faster and more powerful”, explains Dr. Arnulf Leuther, researcher in the field of high-frequency electronics at Fraunhofer IAF. With the new transistor technology, Leuther and his team have succeeded in setting a record for the maximum oscillation frequency of 640 GHz. “This surpasses the worldwide state of the art for any MOSFET technology, including silicon MOSFETs.”

High barrier to leakage current

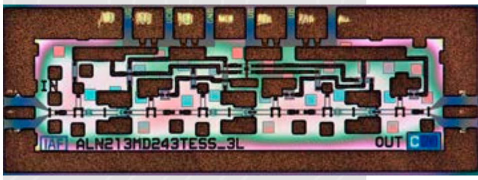
To overcome the increasing gate leakage currents, the researchers had to use a material with significantly higher barriers than the classic Schottky barrier. They replaced the semiconductor barrier material with a combination of insulating layers consisting of aluminum oxide (Al_2O_3) and hafnium oxide (HfO_2). The gate leakage current has been reduced by a factor of 1000.

First integrated circuit worldwide with MOSHEMTs

The ultra-fast MOSHEMT is designed for the frequency range above 100 GHz and is therefore especially promising for novel communication, radar and sensor applications. In the future, high-power devices will ensure a faster data transmission between radio towers and enable imaging radar systems for autonomous driving as well as higher resolution and precision of sensor systems. But it will take some years before MOSHEMTs find their way into applications. Researchers at the Fraunhofer IAF have already gone one step further: they have succeeded in realizing the world’s first amplifier MMIC (Monolithic Micro-wave Integrated Circuit) based on InGaAs-MOSHEMTs for the frequency range between 200 GHz and 300 GHz.

Technology platform “Microwave & Terahertz” in the Research Fab Microelectronics Germany (FMD)

The transistor technology was developed within the FMD. The Fraunhofer IAF is part of the platform along with ten other institutes. It focuses on technologies and competencies required to realize leading-edge components and circuits for frequencies ranging from the microwave to the THz range. Dr. Stephan Guttowski provides an insight into the work of the platform on page 7.



Amplifier circuit with MOSHEMT transistors at 243 GHz. © Fraunhofer IAF

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Dr. Stephan Guttowski is the contact person for the "Microwave & Teraheratz" technology platform.
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About Dr. Stephan Guttowski:
Dr. Stephan Guttowski studied electrical engineering at TU Berlin, focusing on measuring and automation technology, and then went on to do a doctorate in electromechanical compatibility. He then did a post-doc at the Massachusetts Institute of Technology (M.I.T.) in Cambridge. After returning to Germany, Guttowski first worked in the electric drive research lab at DaimlerChrysler AG and, in 2001, moved to the Fraunhofer Institute for Reliability and Microintegration IZM. Here, he was initially chairman of the Advanced System Development group before taking over the System Design & Integration department. Since June 2017, Dr. Guttowski is FMD Technology Park Manager for Heterointegration.

Further information about the "Microwave & Terahertz" technology platform is available at:
www.forschungsfabrik-mikroelektronik.de/Microwave_THz

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"We support 5G network expansion in the millimeter-wave band."

Dr. Guttowski, you are the contact person for the FMD's "Microwave & Terahertz" technology platform. What is the focus of this platform?

As part of our technology proposition, the "Microwave & Terahertz" technology platform pools FMD competencies in the field of high-frequency electronics – with the objective to make them accessible to industry and research partners. By combining the competencies distributed at the institutes, we can offer a comprehensive value chain for RF technology and complete solutions: from design, manufacturing and integration in modules and systems to electrical characterization, testing and reliability verification.

What research topics and technologies does the platform deal with?

Our main research topics are currently the heterointegration of III-V devices with CMOS at wafer and module level to enable advanced communication and radar systems. We are concentrating mainly on future-oriented applications, especially in the fields of communication and sensor technology. Examples of these are vehicle environment detection for autonomous driving cars and 5G.

Can you give some examples?

In order to exploit the superior physical properties of compound semiconductors in applications, the components made from them must ideally be compatible with CMOS technologies. In this way, manufacturing costs can be reduced and price-comparable components can be offered as competition to pure silicon chips. MOSHEMTs can be mentioned as an example (see p. 6). But also the modern radar technology, which is currently mainly realized in SiGe technology, is interesting for us. It is used, for example, in space monitoring or in sensor technology. Intelligent, radar-based sensors – e.g. for vehicle environment detection – enable adaptation to the environment by modifying the waveform. Connected with self-learning systems (AI) for classification, cognitive radar systems are developed.

You mentioned the realization of modern communication systems. To what extent is the topic 5G present in the platform?

In the course of the network expansion of 5G for frequencies above 6 GHz, i.e. in the mm wave range, which is planned to begin throughout the EU starting in 2023, the technological requirements and the design of 5G base stations are changing fundamentally. For these base stations, increased demands are being placed with respect to the development, integration of the individual components, signal propagation times and data processing. The existing LTE network, which is used for the 5G frequencies below 6 GHz, is not suitable for this frequency range.

What are the consequences?

The increased requirements are particularly evident at the base stations, which still have to be set up. The density of these stations for 5G will have to be much higher in the mm wave range – we are talking about distances of a few hundred metres. This makes the issue of energy consumption crucial. As the Research Fab Microelectronics Germany, we have comprehensive know-how at many points in the value chain in order to support the planned network expansion with technology made in Germany and Europe.

How does the FMD approach these current problems with its technology platform?

It is our task to gather the decentrally distributed competences and to bundle them across the value chain to an overall product. In this way, we add value for our institutes and industrial partners. Let's take the example of 5G: The competencies to develop components for 5G base stations have been built up over the years by our member institutes in research projects with industrial partners. Now we have to bring these competencies together to realize a joint offer.

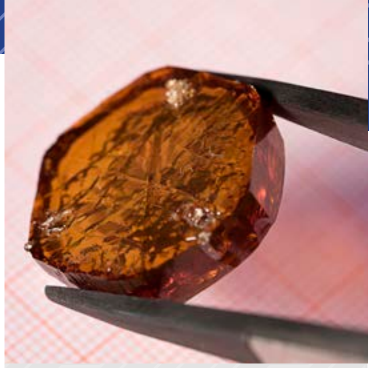
Thank you for the interview!

The interview was conducted by Vanessa Dehn.

![Forschungsfabrik Mikroelektronik Deutschland]

Forschungsfabrik Mikroelektronik Deutschland

Smaller, faster, more energy efficient – powerful devices for digital transformation



Aluminum nitride crystal as semiconductor base material for power electronic devices.
© Anja Grabinger / Fraunhofer IISB

Highly efficient power semiconductors are to pave the way for a wide range of new applications – from electromobility to artificial intelligence (AI). This is the aim of the recently launched project "Power Transistors Based on AlN (ForMikro-LeitBAN)", in which FMD members Fraunhofer IISB and Leibniz FBH are also involved.

Smart energy supply, electromobility, broadband communication systems, and AI applications – the number of interacting and networked systems is constantly growing. However, this also increases primary energy consumption. In particular, the conversion of electrical energy into the form required by a specific application entails losses – in Europe alone already estimated at more than three terawatt hours. This corresponds to the amount of electricity produced by a medium-sized coal-fired power plant. In the future, these losses will no longer be ecologically and economically bearable. In order to enable applications in Industry 4.0, AI and other areas, ForMikro-LeitBAN is researching technological measures to increase efficiency.

New semiconductor materials can save energy and significantly reduce CO_2 emissions

The basic prerequisite for this are efficiently switching power semiconductors that enable high energy density. Used on a large scale, they would make a noticeable energy saving – a relevant contribution to CO_2 reduction. To increase the efficiency of systems, static and dynamic power losses must be reduced. However, efficiency increases are hardly possible with current silicon-based power devices. Therefore, new semiconductor materials with more powerful properties must be researched and brought to market maturity.

Aluminum nitride – raw material with potential

The project partners rely on aluminum nitride (AlN). This semiconductor material, which has been little researched for electronic applications for a long time, could offer an up to 10,000 times lower transmission loss compared to silicon devices. It is also characterized by a very high breakdown voltage strength and thermal conductivity – ideal prerequisites for power semiconductors with high energy density and efficiency. Free-standing insulating AlN wafers are to be used and qualified as the material basis. Compared to AlN epitaxy on foreign substrates, such as silicon carbide, the dislocation density can be reduced by five orders of magnitude. This offers the potential for fast and efficient switching devices with high reliability.

Full process chain – from crystal growth to system demonstrators

The novel AlN devices are conceptually based on the well-researched GaN technology. What is new is the transition from the usual foreign substrates such as silicon carbide, sapphire or silicon to free-standing AlN substrates. ForMikro-LeitBAN researches the development of such AlN wafers and tests them in a tailor-made device process. Test systems for millimeter wave applications and for power electronic energy converters qualify the new highly efficient AlN devices for applications in corresponding systems. They prepare the transfer of this technology into an industrial environment. This is planned as part of a follow-up project. An industrial advisory board supports the work in the consortium: Infineon for power electronics, UMS for millimeter wave technology and III/V-Reclaim for the reclaim of the AlN wafers.

The project is funded by the German Federal Ministry of Education and Research (BMBF) with €3.3 million in the ForMikro program until 2023.

ForMikro-LeitBAN

The following partners are participating in "ForMikro-LeitBAN" and together cover the entire value chain from AlN wafers to millimeter-wave or power electronic systems:

- Ferdinand-Braun-Institut FBH, Berlin: AlN device design and development
- Fraunhofer IISB, Erlangen: AlN crystal growth, wafer manufacturing
- TU Bergakademie-Freiberg: Process module development, analytics
- Friedrich-Alexander-Universität Erlangen-Nürnberg: material analysis
- Brandenburg University of Technology Cottbus-Senftenberg: AlN millimeter wave systems
- Technische Universität Berlin: AlN power electronic systems

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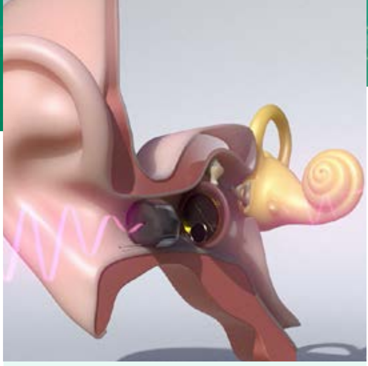


The hearing contact lies directly on the eardrum and thus improves the hearing quality.
© Vibrosonic GmbH

Contact for the eardrum

Together with the TU Berlin, Fraunhofer IZM is developing a microbattery for a hearing contact – an extremely small hearing aid, that attaches directly to the eardrum.

By the age of 70, one in three people will experience a hearing loss of at least 35 dB (the volume of a ticking clock or a room fan) – and will need a hearing aid. However, due to the poor transmission of the air column in the ear canal, traditional hearing aids often cause feedback and distortion effects that make it difficult to hear and understand.

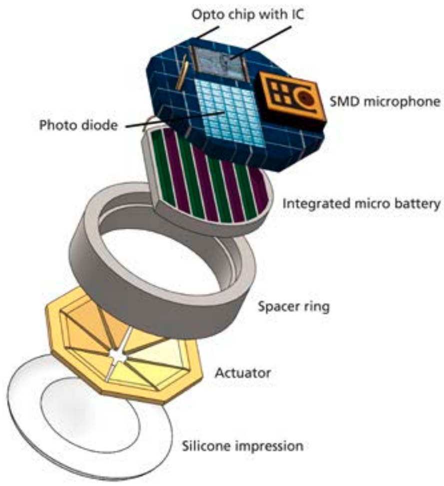
Minimization of disturbing factors

The hearing contact touches the eardrum. This direct contact between the eardrum and the piezo actuator, which is used instead of a loudspeaker, minimizes transmission errors and also allows the perception of a wider sound spectrum. Directional hearing is also significantly improved. In particular, this optimizes speech comprehension both in quiet and in ambient noise environments.

Microintegration for the middle ear

The specially developed ultra-thin transducers and batteries allow the system components to be integrated in a very small space, so that the hearing contact is small enough for use in the middle ear. Once inserted, the system does not to be removed for a battery change. The batteries are charged by optical energy transfer. The demands placed on the micro-battery are extremely high: in addition to the high energy and power density (to enable rapid charging) of the battery, which is only 0.7 mm thick, 2000 full cycles are to be achieved. The concept of the hearing aid has already been presented at the Mikro-SystemTechnik Congress 2019 in Berlin and is currently undergoing clinical testing. CE marking is expected in mid-2020; market entry in Germany is planned for 2021.

Hearing Contact
In addition to the Fraunhofer Institute for Reliability and Microintegration IZM, the following partners are involved in the development of the hearing contact:
- auric Hörsysteme GmbH & Co. KG
- Fraunhofer Institute for Production Technology and Automation IPA
- Research Centre of Microperipheric Technologies at the TU Berlin
- University of Tübingen, ENT Clinic Tübingen
- Vibrosonic GmbH



The components of the hearing contact lens are integrated into a tightest-fitted volume.
© TU Berlin

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Environmentally friendly sensors for smart agriculture

Roll-to-roll printing of antennas. © Fraunhofer ENAS

Rising food demand and climate change require increasingly targeted management of agricultural land. Fraunhofer ENAS is working on the development of cost-efficient and eco-friendly sensor systems based on printing technologies and novel sensors.

Challenge: Efficient agriculture for a growing population

A steadily growing global population requires an increasingly efficient agriculture, which enables food supply through high yields in confined areas. At the same time, the challenges for employees in agriculture are rising due to increasing requirements in environmental protection and in dealing with climatic changes. For a successful agriculture, processes must therefore become more automated, more precise and simpler.

Solution: Cost-efficient sensor systems with printed components

Researchers at the Fraunhofer Institute for Electronic Nano Systems ENAS have developed cost-efficiently manufactured and environmentally friendly sensor systems for this purpose, which support the smart monitoring of cultivated areas. The work is based on novel sensors using printing technologies and environmentally friendly or inert materials.

The first development samples were presented in autumn 2019. The sensors consist of an electronic module with a single-chip radio system and sensors for air and soil temperature, an irrigation sensor, a printed antenna and a printed battery enclosed in a plastic-coated cellulose substrate.

For use, the sensors are anchored underground, and the irrigation sensor is hydraulically coupled to the soil matrix. Some of the sensors protrude above the soil surface and house the electronic module and antenna. The currently used radio system ensures direct communication of the data to a gateway installed in the field. The electronic module is assembled with a circuit board made of compostable, cellulose-based material, which, like the antenna, is manufactured using printing technologies. A circuit made of printed primary cells is used as the energy source. These cells consist of superimposed printed carbon, manganese dioxide, zinc and an electrolyte.

A new type of sensor is used to control fertilization and irrigation. This is a measure of the pressure that plant roots have to overcome in order to be able to absorb water from the soil structure. By using printing technologies, the functional materials used here are also produced in micrometer-thin layers in a resource-saving and at the same time cost-efficient manner.

Outlook: Field tests and commercial readiness

In the future, further sensors for nitrogen, light and leaf moisture measurement will be integrated. First samples of the leaf moisture sensor have already been tested. Following field tests, the technology will be further developed to commercial maturity.

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Fraunhofer ENAS develops technologies for the efficient and sustainable management of agricultural land. © MEV Verlag

In the basement of Fraunhofer IISB: Cogeneration plant and thermal storage.
© Kurt Fuchs / Fraunhofer IISB

Peak load reduction with cogeneration plant

Fraunhofer IISB has integrated a new cogeneration plant into its operating infrastructure. A special operating strategy was used to optimize the plant for peak load reduction.

In a combined heat and power unit (CHP), a generator is operated by a combustion engine. In order to maximize overall efficiency, the thermal energy generated is also used for heat supply. This makes cogeneration units suitable for heating private homes as well as for supplying electrical and thermal energy to energy-intensive industries.

Thermal energy storage systems optimize the running time

The new cogeneration plant at the Fraunhofer Institute for Integrated Systems and Device Technology IISB has also been expanded to include a thermal energy storage system. This allows the CHP unit to be operated largely independently of the current heat demand and thus more flexibly in terms of time. This maximizes the annual operating time and accelerates the cost compensation of the plant.

Peak shaving reduces electricity costs

With a specially developed operating strategy for the cogeneration plant, which contains a finite state machine, the peak loads of the institute could be reduced by 20 %. Peak loads are temporary sharp increases in electricity consumption that often cause high energy costs. The reduction of peak loads (peak shaving) therefore allows to lower the resulting electrical energy costs.

Within the operating strategy, a predefined part of the capacity of the heat storage is reserved to enable the system to operate even when there is a high demand on electricity but a low heat demand. An additionally integrated battery system bridges the start-up time of the power plant from standby to full operation, supports the CHP during high peaks and shaves small peaks single-handedly.

The system is well suited for heat and power supply of medium-sized companies; the Fraunhofer IISB itself serves as a demonstration platform. Specially developed algorithms optimize the individual dimensioning of parameters of the CHP system and its components (e.g., electrical and thermal power, capacity of energy storage) and estimate the potential savings.

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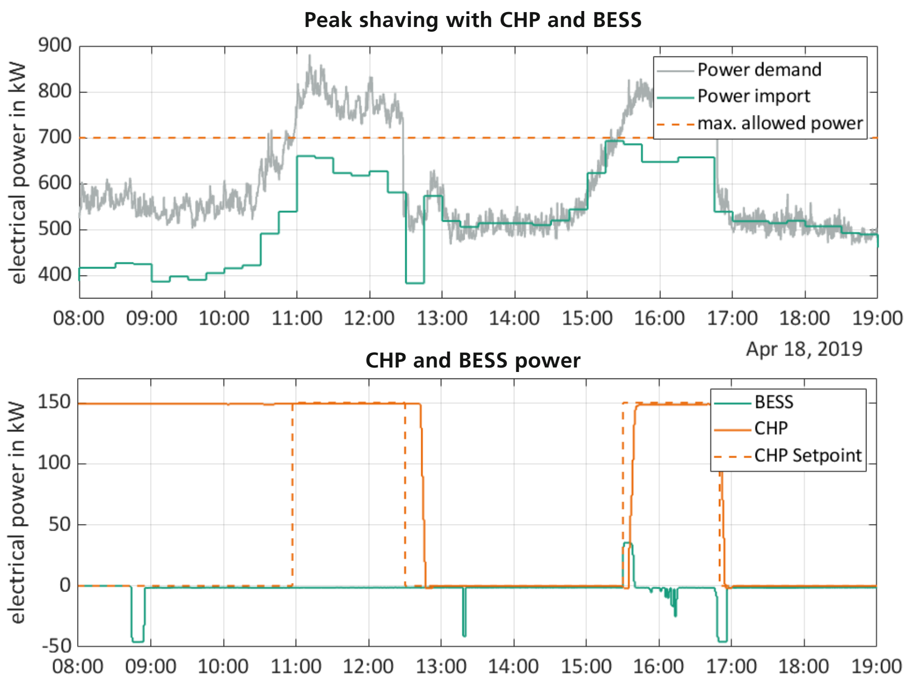

Series of measurements of a peak load reduction carried out at Fraunhofer IISB: With a maximum permissible reference power of 700 kW, the peak load could be reduced by approx. 20 %.
© Fraunhofer IISB

In the "ElKaWe" lighthouse project, six Fraunhofer Institutes are working on the development of electrocalorific heat pumps for heating and cooling. © Fraunhofer IPM

Development of refrigerant-free, energy-efficient electrocaloric heat pumps

Heat pumps play a decisive role in the energy transition in Germany: Sustainably generated electricity provides heat in winter and a good climate in summer. Nowadays, heat pumps work almost exclusively on the basis of compressor technology. However, this technology requires harmful refrigerants, the use of which will be restricted even further by law in the future. In the Fraunhofer lighthouse project ElKaWe, six Fraunhofer Institutes are developing highly efficient electrocaloric heat pumps that operate with nonhazardous fluids such as water.

The materials and components of the solid-state heat pumps must be stable over the long term, sufficiently available, cost-effective and nonhazardous in every respect. Fraunhofer IKTS has extensive experience with ceramic electrocaloric materials. Fraunhofer IAP and Fraunhofer LBF contribute their expertise in the development of polymer materials. Fraunhofer FEP develops special coatings to insulate and functionalize components. In addition to the functional polymers, Fraunhofer LBF will also investigate the service life and reliability of the materials and systems. Fraunhofer IAF will develop the electrical control for the heat pumps. Fraunhofer IPM ensures rapid heat dissipation by means of a new patented system approach based on heat pipes in combination with thermal diodes, thus creating the conditions for particularly efficient heat pumps.

More information about the project can be found at www.elkawe.org.

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Terahertz technologies for future mobile radio networks

With technologies from the Fraunhofer Institutes HHI and IAF, wireless terahertz transmission over a free space distance of one kilometer was achieved for the first time.

Applications such as Industry 4.0, Autonomous Driving, Smart Cities or Augmented Reality will in future require extremely high bandwidths that can be achieved with wireless terahertz technology. With frequencies far above those of 4G LTE and 5G mobile radio, this technology fits ideally into the infrastructure of existing communication networks. In the future, it will enable the connection of mobile radio cells with data rates one hundred times higher than those of 5G.

In an outdoor demonstration, 56 Gbit/s were transmitted wirelessly over 1 km at a carrier frequency of 300 GHz. The transmission system used a high-performance terahertz modem with signal processing algorithms from Fraunhofer HHI and indium gallium arsenide-based fast ultra-high frequency electronic circuits from Fraunhofer IAF.

The experiment provides important insights into stable system operation under the influence of atmospheric attenuation – an important step on the way to marketability. The next step will be to develop a weatherproof prototype, increase the data rate to 100 Gbit/s and integrate the system into a fiber optic test network at the Campus Berlin omitting any additional digital interface at the fiber-optic THz-wireless interface.

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Picture of the receiver side set up for the outdoor demonstration of a data transmission of 56 Gbit/s over 1 km. In the foreground: high-speed oscilloscope and high-gain Cassegrain antenna. © Fraunhofer IAF

The camera pill makes gastroscopy easier for both medical staff and patients. © AdobeStock

Camera capsule for gastroscopies

Together with Ovesco Endoscopy AG and SENSODRIVE GmbH, Fraunhofer IZM is developing a camera pill for minimally invasive stomach examinations. Pain in the upper abdomen, swallowing disorders, chronic coughing, vomiting or weight loss – the thought of a gastroscopy is dreadful for many patients. The method of tube endoscopy, which has been established up to now and is performed daily, is not only unpleasant – it can also only be performed by specially trained personnel at a special infrastructure. Hence, those who suffer often have to wait for a long time.

Thus, a completely wireless system is being developed within the framework of the "nuEndo" project: The person to be examined swallows a camera pill which arrives in the stomach within 20 s and from there transmits images in real time while being magnetically controlled from outside. This procedure significantly reduces the level of suffering and enables general practitioners to operate the mobile system without special training. This enables faster diagnoses and uncomplicated monitoring of the course of therapy.

The nuEndo project runs until 2022 and is funded by the German Federal Ministry of Education and Research (BMBF). Within the project, the Fraunhofer IZM is responsible for the miniaturization of the capsule.

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Optical housings for packaging components at wafer level

The Fraunhofer ISIT operates state-of-the-art production lines for processing silicon with an accuracy in the nanometer range. These precise methods of structure generation in silicon have been successfully transferred to other materials, for example the shaping of different glasses – a process that allows the production of precise optical components at wafer level. These cost-effective components can be used for various applications.

Glass consists mainly of silicon dioxide. Thus, some chemical and mechanical properties of glass and silicon are similar. For this reason, silicon wafers and glass wafers with approximately the same coefficient of thermal expansion can be firmly joined together by anodic bonding. This material compound remains stable even under large temperature changes.

If the silicon wafer is previously provided with structured recesses, the glass can be moulded into these embossed structures if the silicon-glass compound is increased to temperatures above the transformation temperature of the glass. The glass then becomes a highly viscous fluid that can be pressed into molds, for example, when the external pressure exceeds the gas pressure in the recessed molds. The resulting glass structures are exposed by dissolving the original silicon wafer in a caustic solution at room temperature.

The structured glass wafer can be used in so-called wafer-level bonding processes which lead to low production costs, since many components can be manufactured in parallel. With suitable automatic wafer bonders, a vacuum or other defined gas volumes can also be included in this process. Applications include camera chips, light sensors and optical scanners with micromirrors.

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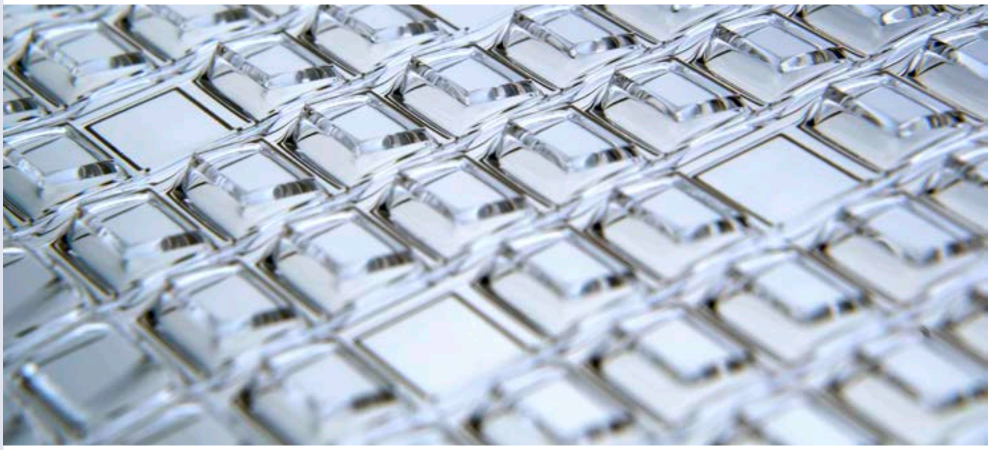

Optical housings with slanted covers on a 200 mm glass wafer. © Fraunhofer ISIT

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AI Platform for Autonomous Driving

Within the scope of the "KI-FLEX" project, a powerful, energy-efficient hardware platform for autonomous driving, is being developed together with an associated software framework.

With the help of artificial intelligence (AI), data from laser, camera and radar sensors will be processed and combined reliably and quickly in order to permanently generate a precise image of the real traffic conditions. The vehicle can thus make the right decision in every driving situation. The system adapts dynamically to different operating conditions and thus functions e.g. even in the event of malfunctions or failures of individual sensors. Autonomous driving thus becomes safe and reliable. The flexible design of the ASIC structure enables continuous optimization of the system by integrating future improved NN architectures.

The Fraunhofer Institutes IIS and FOKUS participate in KI-FLEX together with partners from industry and research. The project is funded by the German Federal Ministry of Education and Research (BMBF) and will run until 2022.

Partners

The following partners are involved in KI-FLEX:

- Daimler Center for Automotive IT Innovations (DCAITI, TU Berlin)
- FAU Erlangen-Nürnberg (Chair of Computer Science 3: Computer Architecture)
- Fraunhofer Institute for Integrated Circuits IIS (consortium leader)
- Fraunhofer Institute for Open Communication Systems FOKUS
- Ibeo Automotive Systems GmbH
- Infineon Technologies AG
- TU Munich (Chair of Robotics, Artificial Intelligence and Real-time Systems)
- videantis GmbH

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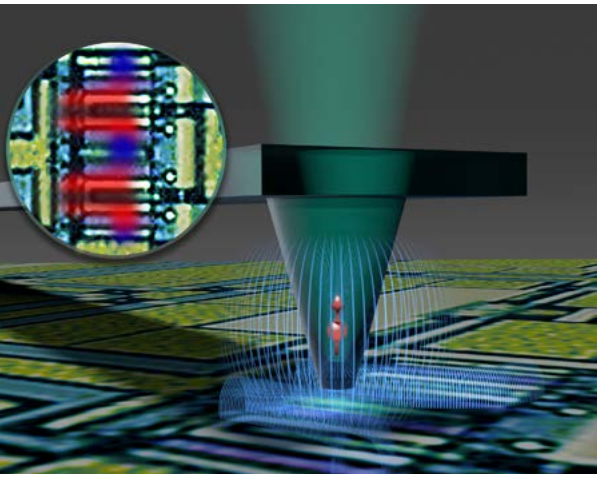
Fraunhofer IAF establishes an application laboratory for quantum sensors

Many industrial sectors are currently experiencing rapid technological development towards more precise monitoring of their production. The resulting increasing demands on accuracy and drift stability of sensor systems will require a technological leap towards quantum sensor technology in the near future. Up to now, research in this field has mainly taken place in an academic setting and the quantum sensors developed in this context have proven to be too large and not robust enough for use in innovative products.

In order to advance the transfer of research developments from the field of quantum sensor technology into industrial applications, an application laboratory is currently being established at the Fraunhofer IAF in Freiburg. Interested companies and in particular regional SMEs and start-ups will have the opportunity to evaluate the innovation potential of quantum sensors for their specific requirements. This concerns for example the booming semiconductor industry, but also areas such as medical technology, security technology, navigation, geology and satellite-based earth observation. These will benefit from a faster transition of quantum sensor research into industrial applications.

The application laboratory is being set up as part of the Fraunhofer lighthouse project "QMag", short for quantum magnetometry. In this project, researchers from six Fraunhofer Institutes are working with university partners to develop quantum sensors for the highly sensitive detection of magnetic fields. Both the state of Baden-Württemberg and the Fraunhofer-Gesellschaft are supporting the four-year project with €1 million each.



In the application laboratory, among other things, a quantum magnetometer is being set up that can measure the smallest currents in semiconductor circuits. © Fraunhofer IAF

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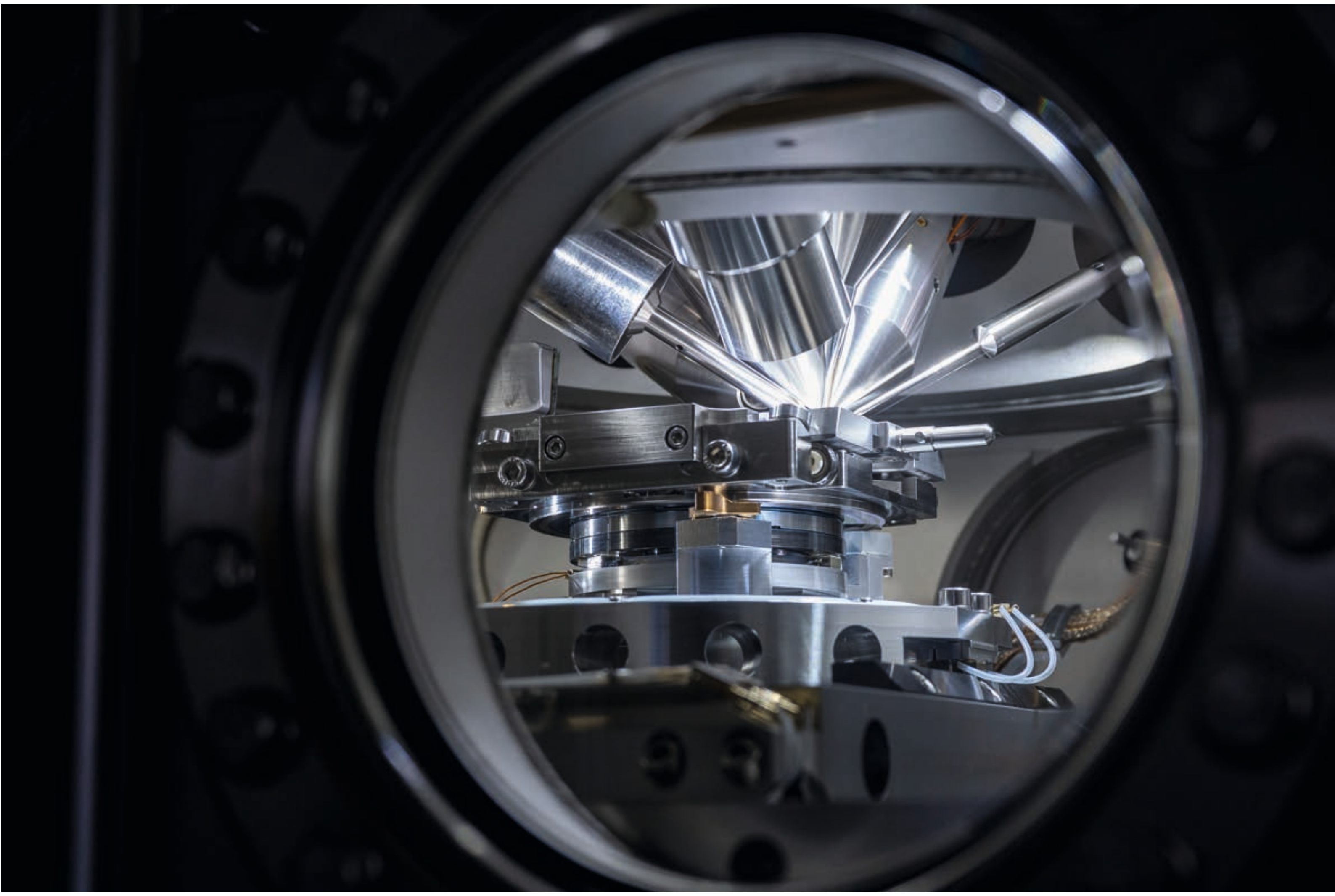

Secondary ion mass spectrometer (SIMS) for material analysis: The method enables e.g. the analysis of III-V materials and epitaxial layer sequences with a depth resolution of 1 nm. © Fraunhofer IAF

Editorial notes

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The Fraunhofer Group for Microelectronics, founded in 1996, combines the expertise of 16 Fraunhofer institutes, with a total of more than 3,000 employees. Its main focus is the preparation and coordination of interdisciplinary research projects, conducting studies and to assist in the process of identifying strategies.

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… goes to Dr. Jennifer Ruskowski from Fraunhofer IMS

Dr. Ruskowski, you are working on the FMD project "miniLIDAR". What exactly is done in this project?

The project is developing innovative components for a miniaturized LiDAR (Light Detection And Ranging) system in the field of robotics. In addition to our institute, three other FMD institutes are involved: Leibniz FBH in Berlin is developing the lasers, Fraunhofer IPMS in Dresden is implementing the development of the beam deflection device, and Fraunhofer IZM in Berlin is working on optical phased arrays.

What are your responsibilities within the project?

Fraunhofer IMS realizes the detector development in the project. Our goal is to develop a Single Photon Avalanche Diode (SPAD) array with high pixel resolution for the detection of reflected beams including the read-out electronics (ROIC) and the evaluation algorithms. The histogram programming in the Field Programmable Gate Array (FPGA) to evaluate the detector data is also implemented at the Fraunhofer IMS. Both, the increase of the number of pixels and the vertical integration of the detector with the ROIC by means of wafer-to-wafer bonding are important new developments.

How has the FMD changed your professional life and where has it concretely added value?

The FMD has greatly expanded the cross-institute work. It is particularly gratifying that we not only discuss the joint strategic approach and the technological roadmaps, but have also become active in concrete projects that create significant added value for the FMD institutes. In my area of responsibility, the FMD brings together the distributed competencies in the LiDAR area. Besides the miniLIDAR project, we are also involved in a project with the start-up OQmented, in which a demonstrator for a scanning LiDAR system is being realized. The FMD has increased our customer contacts, and our international visibility has also been enhanced.

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

At the FMD institutes we have extensive expertise in the area of innovative components for LiDAR systems. From my point of view, it would be desirable to have a large project to help us to continue to combine these competences in a complementary way, and also to look into the future. There are many exciting approaches in the field of LiDAR that are worth investigating and further developing.

You are a physicist. What did you want to become as a child and why?

As a child, I was fascinated by questions about our solar system and its planets. All the more reason for me to look forward to projects in which our sensors are used in space and in the future you will have even more reasons to look at the starry sky. But my entry into the world of physics is not only due to the cosmos. My early interest in the inner workings of my computer, my love for mathematics and the question of always finding new solutions certainly had an influence on my choice of career.

Dr. Jennifer Ruskowski.
© Private Collection

About Dr. Jennifer Ruskowski:
Born 1983 in Duisburg. Married. Studied physics at the RWTH Aachen and did her doctorate in electrical engineering and computer science at the University of Duisburg-Essen. Dissertation on "Fine-pitch connections for the 3D integration of sensors with CMOS wafers" at Fraunhofer IMS. Accordingly working at Fraunhofer IMS, since 2009. Since 2016 group leader of 3D sensors. Since 2018 also deputy head of the department Optical Sensor Systems.

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As a diver, Dr. Ruskwoski is fascinated by the vitality of the sea.
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