Fraunhofer

FRAUNHOFER IN INDIA

NEWSLETTER - ISSUE 1/2024

MICROELECTRONICS

Focus: Sensor Systems, Extended CMOS, Power Electronics

CONTENT

FOREWORD

Ms Anandi Iyer
Director, Fraunhofer Office India

Dear Readers,

2023 was a fulfilling and eventful year for all of us at Fraunhofer. We celebrated 15 years of Fraunhofer in India and on this occasion, a series of events were held at Bangalore from 6 – 9 September 2023. We showcased our exciting journey and activities in India through our Flagship Initiative "6th Fraunhofer Innovation and Technology Platform" and also organised an exclusive Conference on Hydrogen Technologies. The largest-ever Fraunhofer Delegation consisting of over 17 colleagues and over 250 Delegates, deliberated on circular economy and sustainability in the field of mobility, manufacturing, packaging and the food-water-energy nexus. The Knowledge Paper on Circular Economy, which was released by the Chief Guest, Shri Priyank Kharge, Hon'ble Minister for IT& BT, Government of Karnataka, will serve to further strengthen Indo-German collaboration in Innovation and R&D over the next years.

Science and innovation are fundamental to economic growth and prosperity, with research and development being the core of enhanced productivity. Over the last 20 years, Innovation has fuelled technological advances across the globe, including Industry 4.0, digitalisation and smart manufacturing. Multidisciplinary technology applications and focus on the knowledge-driven sectors such as machine learning, optimisation, artificial intelligence, robotics etc will see an upsurge in the coming years leading to greater manufacturing excellence and productivity.

Innovation is at the core of India's growth trajectory. While India has made rapid strides in the Global Innovation Index moving to the 40th position, India's public spending on research has been stagnant at around 0.8% of GDP for over a decade. To address this challenge, the Indian Government has set up a multipronged enabling mechanism to foster innovation infrastructure and policy framework. The mission is to make India a global research and development hub for sophisticated sectors like network equipment, medical equipment, aerospace, automotive, biotechnology and computation, as well as microelectronics. Over 1000 leading companies from around the world have set up research and development centres in India, to reap the intellectual and cost arbitrage that India offers, and this number is only going further up, bringing the largest companies to India. The vibrant and robust entrepreneurial ecosystem in India has led to numerous affordable innovations in areas such as fintech, medical diagnostics and service delivery.

Semiconductors are the next Mission, and the Indian Government has put in place an extensive subsidy and support programme to propel investment and manufacturing of the semiconductor and display ecosystem in the country. Already, the Cabinet has approved the establishment of three semiconductor units under the programme and is inviting international collaborations to fast-track this sector. Our newsletter therefore focuses on Fraunhofer's formidable competencies in the field of Microelectronics and shares the immense potential for a win-win relationship between India and Germany.

Happy Reading!

Anandi

Fraunhofer Research Fab Microelectronics Germany (FMD): Ready for Future Challenges

Fraunhofer Research Fab Microelectronics Germany (FMD) is the world's leading research association for micro- and nanoelectronics applications and systems. 13 institutes from the two research organizations, Fraunhofer and Leibniz, have combined their expertise, thus creating a new quality to the research and development of micro- and nanosystems. It offers new technologies and cross-technology solutions up to a high technical readiness level from a single source for partners in industry and science. As a global driver of innovation and the largest cross-location R&D alliance for microelectronics in Europe, FMD offers a unique diversity of expertise and infrastructure. It bridges the gap between basic research and customer-specific product development. With its member institutes, the FMD demonstrates research achievements of international excellence. In this way, it contributes to taking Germany and Europe into a leading position in research and development.

Based on the scientific excellence of its institutes, FMD continuously develops its technological portfolio and translates it into innovations - for the benefit of society and to strengthen the German and European economies.

What does Fraunhofer FMD do?

- FMD provides impulses for developments and system solutions in the high-tech sector, cooperates with international partners and actively shapes the German and European research agenda.
- FMD bundles its resources across the entire value chain of micro- and nanoelectronics to maintain technological sovereignty in Europe and to strengthen Germany's competitiveness as a business location.
- FMD enables comprehensive and easy access to new applications of micro- and nanoelectronics at different technical levels of maturity and offers complete solutions from a single source.
- FMD lowers the entry threshold into future-oriented high technologies for all users of micro-electronics in industry and science and is an important innovation partner also for small and medium-sized enterprises.
- FMD offers training and further education opportunities for future careers in microelectronics and supports the transfer of knowledge by brains.
- FMD supports start-ups in high technologies - The "FMD Space" offers start-ups direct access to Europe's largest machine park in the field of nano- and micro-electronics.

Many sectors are facing seismic changes because of digitalization. What challenges does the field of microelectronics need to overcome?

Artificial intelligence (AI), Industry 4.0, and 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

> **“We’re ready for current and future challenges in electronics research.”**
>
> Dr. Stephan Guttowski
> Managing Director
> Fraunhofer Research Fab Microelectronics Germany (FMD)

FMD in numbers

- 4500 employees, including 2800 researchers
- 13 innovative research institutes
- 13 cleanrooms with 2200 devices on a total of more than 19,500 sq.m space
- More than 10 million moves per year
- Wafer-sizes from 2“ to 300 mm
- ≤ 200 mm CMOS and MEMS Line, 200 mm Si Line, 150 mm SiC Line, 200 mm (Bi)CMOS Line, 100 - 300 mm Packaging Line, 300 mm Screening FAB
- Semiconductor materials from Si over SiGe to Compound Semiconductors like SiC, GaN, GaAs, InP processing up to 4“.

Participants of the Fraunhofer FMD

- Fraunhofer Group for Microelectronics with its member institutes:
- Fraunhofer EMFT
- Fraunhofer ENAS
- Fraunhofer FHR
- Fraunhofer HHI
- Fraunhofer IAF
- Fraunhofer IIS
- Fraunhofer IISB
- Fraunhofer IMS
- Fraunhofer IPMS
- Fraunhofer ISIT
- Fraunhofer IZM
- Ferdinand-Braun-Institut
- IHP GmbH

Fraunhofer FMD: Range of Applications

- Transport and Smart Mobility
- Energy
- Digital Industry
- Digital Life
- Health & Wellbeing
- Civil Security and Occupational Safety

Fraunhofer FMD: Services

- Industrial Surface Research

1. R&D projects
2. Technology consulting
3. Feasibility studies
4. Technology and process development
5. Pilot production

- Services for manufacturers

1. Demonstrator and prototype development

- Technology Transfer

1. Technology and process licensing

- Collaborative projects

1. Research and development projects in collaboration with industry and the public sector

Fraunhofer FMD: Range of Technologies

- Sensor Systems - Sensor design, fabrication, integration, characterization, and testing within systems.
- Extended CMOS - Design, fabrication and system integration of CMOS circuits.
- Power Electronics - Design and fabrication of power electronic devices, including integration in modules and systems.
- Microwave & Terahertz - Cutting-edge devices and circuits for frequencies up to and including the THz range.
- MEMS Actuators - Design and fabrication, as well as characterization, testing and system integration of MEMS actuators.
- Optoelectronic Systems - Fully integrated optoelectronic systems for image acquisition and processing, and communication up to Tbit/s speed.

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.

How does Fraunhofer FMD help the industry address these challenges?

Fraunhofer FMD designs comprehensive, innovative electronic systems for new research fields requiring this kind of wide-ranging expertise. Examples:

(i) In the TRAICT (TrustedResourceAware ICT) project, eight FMD institutes collaborate with ten other Fraunhofer institutes to establish the framework for trusted and data protection-compliant ICT. The primary focus lies in validating and securing critical electronic components and systems within globally interconnected supply chains.

(ii) With many vital components manufactured outside of Europe, there's a growing dependency that could pose risks to Germany. To counter this, Fraunhofer FMD has initiated the "Velektronik" platform to develop coherent concepts for trusted electronics. The aim is to develop and apply appropriate standards, norms, and processes based on a national and European chip security architecture.

(iii) Despite efforts to enhance energy efficiency in electronic components, overall energy consumption in ICT continues to rise, fuelled by developments in self-learning systems. To address these challenges, the Fraunhofer FMD is planning a competence centre for resource-efficient information and communication technology, or "Competence Centre Green ICT".

Six hot topics of the Fraunhofer FMD

Sustainability

Areas of application:
- Green ICT
- Green Energy Systems
- EcoDesign

Security

Areas of application:
- Trusted electronics
- Critical infrastructure protection
- Space surveillance

Next Generation Computing

Areas of application:
- Neuromorphic computers
- Quantum computers

Mobility

Areas of application:
- Alternative drive systems
- Communication and networks
- Sensor technologies

Communication

Areas of application:
- Development of 5G technologies & transfer of research results to industry
- Research into the future technology 6G

Production

Areas of application:
- AI and machine learning
- Smart digital production
- Digital twins

An interview with

Mr. Vinay Shenoy

Managing Director, Infineon Technologies India
Chairman, Infineon Technologies Semiconductor India

1. Infineon is an industry leader in semiconductor manufacturing. Could you please elaborate on the biggest technology trends in this industry?
Artificial Intelligence (AI) and Machine Learning (ML) technologies are rapidly accelerating, Major cloud computing providers are increasingly employing generative AI. Large language models (LLMs) are driving a surge in demand for Data Centres running specialized processors optimized for AI workloads.

While these technologies offer remarkable capabilities, they are more power-hungry compared to traditional processors and this poses a significant challenge in terms of energy consumption. Energy-efficient power stages are needed to reduce power losses and cooling efforts. Advanced power semiconductor technologies improve energy efficiency to reduce operating costs and integrate renewable energy sources such as wind & solar to reduce reliance on fossil fuel and lower carbon emissions to offset the environmental footprint.

Further, Edge Computing technologies offload AI and ML workloads to distributed edge devices, reducing the need for long-distance data transmission, thereby saving energy and improving latency as well.

Infineon is a global leader in power systems and IoT serving Electromobility, Renewable Energy, Autonomous Driving and Data Centres. We are actively doing everything possible to drive decarbonization and digitalization. We are investing heavily in R&D and manufacturing of compound semiconductors based on silicon carbide (SiC) and gallium nitride (GaN) extending the options beyond silicon-based solutions to enable highly efficient, compact end applications that consume less power.

2. How can India enable itself as a global hub for electronics manufacturing and design? What are the measures needed?
The Indian Government has made significant investments in infrastructure development such as power, transportation and logistics which are critical for the electronics industry. The industry has noticed far-reaching simplification of regulatory framework and procedures. Further streamlining will provide a more conducive business environment to attract global and domestic investment in electronics. Developing a robust domestic supply chain is crucial to reduce reliance on imports and ensure the availability of competitively priced electronic components, intermediates and services.

An end-to-end innovation eco-system of semiconductors is being established at the national level., Academic Centres of Excellence in application-oriented research are being set up at top Universities with strong industry participation, covering Integrated Sensors & MEMS, Power Electronics, 6G Systems Design & Architecture, Predictive Modelling, Semiconductor Materials: Device & Packaging Electrical Test, Electronic Substrates and Thermal Management to name some. Partnerships with international research organizations will only help expedite this process.

The electronics industry is "global for global" – a global supply chain serving global markets. This drives a highly competitive landscape. The Indian electronics Industry will need to differentiate through quality and cost efficiency and with an emphasis on innovation. We are already seeing various stakeholders – both domestic and international investing in the wide value chain of electronics either directly or via partners in India.

Brief Profile of Mr. Vinay Shenoy
Vinay Shenoy is the Managing Director of Infineon Technologies India and Chairman of Infineon Technologies Semiconductor India.

In this role, he is responsible for Country Strategy, Business, R&D, Government Relations, and Eco-system
Development. Infineon India is over two thousand employees strong and is headquartered in Bangalore with branches in New Delhi and Pune.

In a career spanning 33 years of diverse experience in Semiconductors, Consumer Electronics, Telecom and Broadcasting Industries, Vinay has successfully handled multiple leadership roles in Marketing & Sales, New Business Creation, and Innovation. He has led the creation of new products and services, and indigenously developed, industrialised and launched products for India and emerging markets, both in Multinational Companies and start-ups.

Prior to Infineon, Vinay worked with Philips and Texas Instruments. He has a Bachelor's Degree in Electronics and Communications Engineering and Masters in Computer Engineering.

Vinay was the Chairman of India Electronics & Semiconductors Association in 2015. He enjoys middle distance running, road cycling and is a Do-It-Yourself hobbyist.

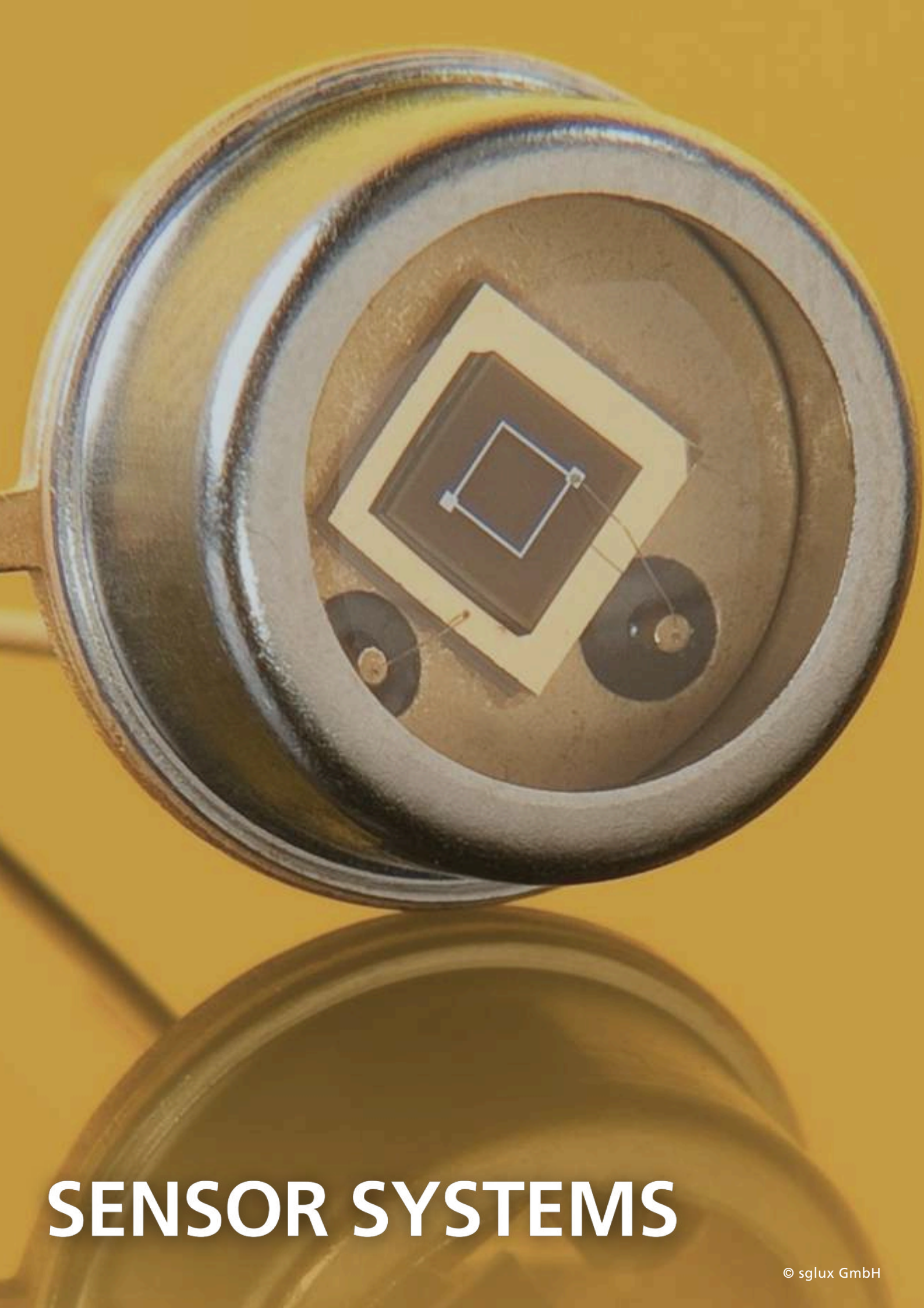
3. How imperative is it to have an indigenous Semicon Fab in India? How will it benefit the local SMEs and suppliers in the value chain of the ecosystem?
From a long-term strategic perspective, India needs to have free access to emerging and state of art technologies emerging as a rapidly developing and geopolitically significant country. While friendly relations with countries possessing these capabilities have helped, India nevertheless needs to reduce technology dependency on others. Semiconductors are foundational to emerging technologies such as 5G, Artificial Intelligence, the Internet of Things, Autonomous Vehicles, renewable energy systems and strategic electronics. Indigenous semiconductor manufacturing combined with design and engineering capabilities enhances India's economic stability, preparing it to lead in these transformative technologies and contribute to innovation and competitiveness on the global stage.

The mid-term benefits related to supply chain resilience, job creation, reduced trade deficits and investments in allied industries such as equipment manufacturing, special materials, chemicals and gases are relevant as well.

The value chain will offer opportunities to local industries many of whom will need to establish stronger processes to meet the unique requirements of semiconductor manufacturing such as high purity, specialized formulations, precise handling and storage, rigorous safety measures and environmental responsibility. Overall, semiconductor manufacturing represents a strategic investment in the long-term sustainability and competitiveness of India's economy.

4. What are Infineon Technologies' ambitions for the Indian market? Are you doing R&D specifically for the Indian market?
Infineon provides a strong portfolio of products addressing decarbonization and digitalization tailored to the specific needs of various applications, markets and geographies, each of which has unique needs related to cost, quality and functionality. This approach empowers our customers to choose based on their value proposition to their end markets. We provide strong technical support for Indian customers to design our products into their applications rapidly.

Government investments in infrastructure and the rapidly rising disposable income among Indians enabled by an already digitalized nation are driving the consumption of electronics. Infineon's focus on Decarbonization and Digitalization has strong relevance to India, It is committed to supporting startups, SMEs, large players and the Government and being an integral part of India's growth.



SENSOR SYSTEMS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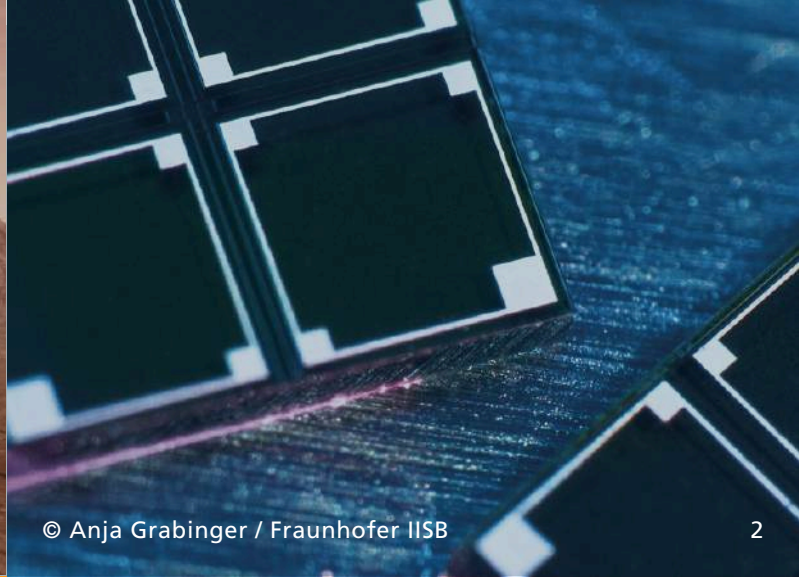
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Sensor Technology with Silicon Carbide for Use in Space: UV Diodes on Mars Mission

Regarding particularly low-loss semiconductor components and highly efficient power electronics, there is no way around silicon carbide (SiC) today. The wide-bandgap semiconductor material SiC is superior to conventional silicon in many respects and is conquering more and more new areas of application, for example, optoelectronics, sensor technology or solid-state quantum electronics. SiC demonstrates its outstanding physical properties even in space: A SiC UV photodiode from the Berlin-based company sglux is on board the current NASA mission Mars 2020. The SiC chip with the heterostructures for the UV photodiode was processed at Fraunhofer IISB in Erlangen on the institute's CMOS line. Since the Mars rover "Perseverance" landed on the surface of Mars on February 18, 2021, the SiC photodiode has been functioning with absolute reliability under extreme environmental conditions. The UV sensor is a component of the SHERLOC deep-UV Raman spectrometer, employed by NASA to search for traces of past life on the surface of Mars. Fraunhofer IISB offers SMEs, mid-sized companies, and low-threshold industry access to high-tech infrastructure and unique know-how in the field of semiconductor technology.

SiC – The New Silicon?

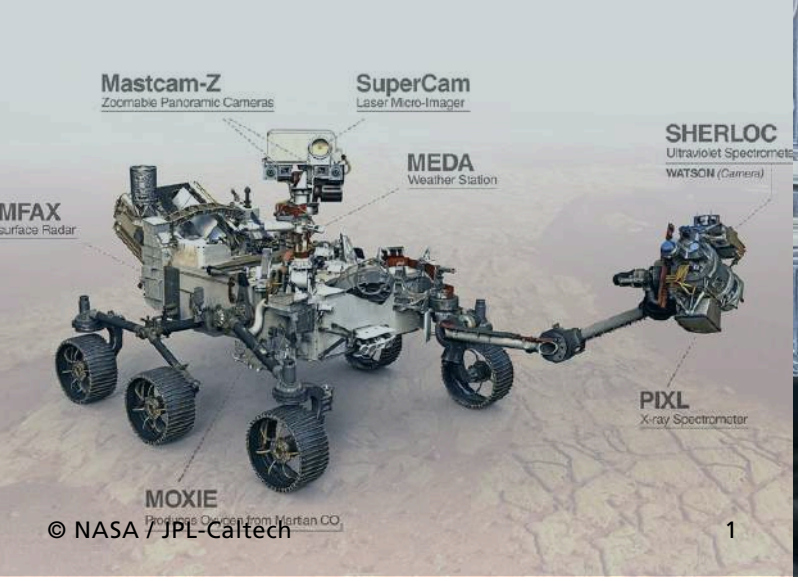
Driven by the energy transition and electromobility, there is a rapidly growing demand for electronic components for the particularly low-loss conversion of electrical energy. Therefore, a prominent topic in semiconductor technology is WBG or wide-bandgap semiconductors, such as silicon carbide, gallium nitride or aluminium nitride. They can handle high voltages at very low forward losses and thus offer the best prerequisites for building highly efficient power electronic systems.

Among WBG semiconductor materials, silicon carbide (SiC) has become particularly popular, and a wide range of commercial products is already available. In applications where the highest power densities and highest power conversion efficiencies are required, SiC devices with their superior electrical properties, are already displacing conventional silicon power electronics. This is the case, for example, with the on-board networks and drive electronics of electric vehicles or the connection of renewable energy sources to the public power grid.

A Class of its Own

The unique physical properties of the WBG semiconductor silicon carbide open up further attractive application options, such as in optoelectronics and sensor technology or for future solid-state quantum electronics. For example, the Berlin-based high-tech company sglux relied on SiC sensor components early and successfully established itself on the market with SiC photodiodes for measuring ultraviolet radiation (UV). These photodiodes are used wherever safety is a top priority. This is the case, for example, in medical technology for monitoring dialysis, in food processing for controlling sterilization processes, or in industry for controlling combustion processes. The core components for the UV diodes, SiC chips with SiC heterostructures, are processed.

1. Artist's rendering of the February 18, 2021 landing of the Mars rover Perseverance on Mars in Jezero Crater. The main goals of NASA's MARS 2020 mission are to search for signs of past life and to collect rock and soil samples for later return to Earth.
2. Close-up of silicon carbide chips processed at Fraunhofer IISB. The SiC substrates each carry a 4x4 sensor array with tunable integrated and ion-implanted UV photodiodes.



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SiC Conquers Space
One of the most challenging operating environments for electronic components is undoubtedly space. All components must function absolutely reliably under extreme conditions, and even the smallest errors or failures can jeopardize the entire mission. Against this background, it is a n excellent success for sglux GmbH from Berlin and for Fraunhofer IISB that even NASA now belongs to the customer base of the SiC pioneers. During the current NASA mission MARS 2020, a SiC UV photodiode from sglux also landed on the red planet with the Mars rover "Perseverance" on February 18, 2021, and has been functioning reliably ever since.

The exceptional environment provides the perfect opportunity to demonstrate sglux's products' reliability and the SiC sensors' quality manufactured in small series at the IISB "Perseverance" – endurance or tenacity – is the most advanced and elaborate rover NASA has ever sent to Mars. The roughly two-and-a-half billion dollar exploration vehicle is searching the Martian surface for traces of past microbial life and characterizing the planet's geology and climate among other things, in preparation for a future manned Mars mission.

Life on Mars
Perseverance has a suite of state-of-the-art science instruments, among which a deep-UV Raman spectrometer attached to the rover's robotic arm plays a unique role. Dubbed SHERLOC (Scanning Habitable Environments with Raman & Luminescence for Organics & Chemicals), the high-tech instrument is the first ever UV Raman spectrometer on Mars. There, it enables non-contact, spatially resolved and susceptible detection and characterization of organic matter and minerals on the surface and near the subsurface. Meanwhile back on Earth, Raman spectroscopy, named after the physicist C. V. Raman is used, for example, to study the material properties of semiconductor crystals.

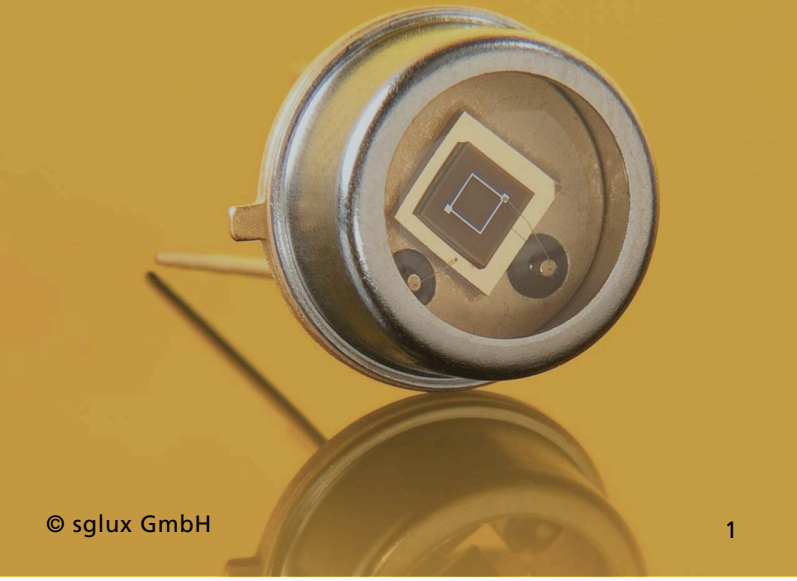
Supported by a special camera called WATSON (Wide Angle Topographic Sensor for Operations and eNgineering) and a UV LASER, SHERLOC detects organic matter and minerals and creates topographic maps from them. Researchers on Earth then evaluate the measurement results and mineralogical maps to see if there is evidence of past water impact and signs of past life on Mars. Based on this, it will be decided which rock samples Perseverance should take and leave sealed in metal tubes on the surface of Mars for a future return to Earth (resample mission).

Ultimate Endurance Test
For its measurements, the UV Raman spectrometer uses a deep UV laser with a wavelength of 248.6 nm focused on a spot less than 100 µm in diameter. A SG01XL-5 SiC UV broadband photodiode from sglux is installed near the laser aperture, and detects the UV radiation power emitted by SHERLOC during spectral map measurements so that the laser output can be monitored when scanning the surface.

Before its use, sglux adapted the manufacturing process of this photodiode to its application and carried out elaborate selection, testing and characterization procedures. Subsequently, NASA subjected the candidates selected in this way to further tests and trials, for example, vibration resistance, behaviour under strong acceleration, high-temperature resistance, and alternating strength.

Unique Material Properties
Due to its unique properties, silicon carbide is currently the best semiconductor material for daylight-insensitive UV detectors and is ideal for use in complex environments. The SiC-based photodiodes are almost entirely blind to light in the visible wave range and impress with their high response speed. The small dark current in the femtoampere range ensures low noise, so that even very low UV radiation intensities can be measured reliably.

1. Cutting-edge technology on the Mars rover: Perseverance possesses seven sophisticated scientific instruments for the detailed study of its environment. The exploration vehicle has a robotic arm with the SHERLOC deep-UV Raman spectrometer mounted on the end.
2. Close-up of the SHERLOC deep-UV Raman spectrometer on the Mars rover Perseverance. The UV spectrometer is equipped, among other things, with a SiC UV photodiode by sglux GmbH Berlin, processed at Fraunhofer IISB in Erlangen. The UV sensor with TO5 housing is mounted to the left of the camera lens and measures the radiation power of the Raman spectrometer in the deep UV range.



© sglux GmbH

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The SiC detectors tolerate comparatively high operating temperatures and operate stable in a temperature range from minus 55 to plus 170 °C. In this case, the temperature coefficient of the signal reaches values of less than 0.1 % per Kelvin, and temperature-related changes in the measurement sensitivity can be compensated well. In addition, SiC has extreme radiation hardness, allowing the devices to retain their excellent electrical properties even when exposed to prolonged and strong irradiation.

Economy and Science

New semiconductor materials such as silicon carbide always enable new applications. This gives newcomers and smaller companies, in particular, the opportunity to actively create value in the high-tech sector with innovative in-house developments. This commonly requires highly specialized vital components that must be reliably available despite low quantities. SMEs and start-ups, in particular, often find it difficult to turn their brilliant ideas into marketable products due to a lack of in-house resources. However, competitive pressure is also increasing for medium-sized companies, and the investment required for technological progress is growing steadily. The big players, on the other hand, need more room for experimentation in their large production environments, where capacity utilization and yield take absolute priority.

Against this background, it is essential to offer SMEs, mid-sized companies and, low-threshold industry access to high-tech infrastructure and know-how in the field of semiconductor technology. Great successes are possible through collaboration between innovative companies like sglux and research institutes such as Fraunhofer IISB, as impressively demonstrated by the example of sglux's SiC UV diodes, which have travelled as far as Mars.

Dr.-Ing. Tilman Weiss, Managing Director of sglux GmbH, sums it up: "Our claim is that our UV sensors always last longer than the system in which they are installed. The mission to Mars so far is great confirmation of this fact and also of our collaboration with Fraunhofer IISB. For the core of our products, we need precisely the technological expertise and system infrastructure available at the IISB. Only the symbiosis of entrepreneurship and research enables us to create sustainable value with exclusive products in demand worldwide."

Oleg Rusch, Group Manager SiC Bipolar Devices at Fraunhofer IISB, gives the following assessment: "Pure semiconductor manufacturing is not actually primary for the IISB, even though the processing of prototypes, special components and very small series is now part of our daily business. Our primary concern is providing scientific excellence, process know-how and outstanding facility infrastructure to SMEs and industry. We see untapped potential for innovation at many companies that could be opened up with scientific support and R&D services in semiconductors."

SiC @ IISB

Fraunhofer IISB's activities in the area of integrated devices are deeply embedded in the institute's strategy of offering outstanding research services along the entire value chain – from semiconductor base materials to power electronic systems. The technological foundation for this is a continuous and industry-compatible CMOS process line for silicon and silicon carbide wafers up to 150 mm and 200 mm in diameter, respectively. As part of the joint initiative "Forschungsfabrik Mikroelektronik Deutschland" (FMD), semiconductor production is also qualified for 200 mm SiC wafers. Within FMD, Fraunhofer IISB has positioned itself as a competence centre for silicon carbide and is consistently expanding its activities in this field.

With its process line, the IISB also has access to advanced nanoscale heterointegration and patterning technologies. In addition, the technological portfolio is continuously being further developed with regard to assembly and connection technology and the reliability of electronic components and modules. The institute is thus expanding its range of products and services for highly reliable and highly efficient power electronics for use in extreme environmental conditions, such as those encountered in the aerospace industry.

1. Highly reliable, space-qualified and daylight-insensitive SG01XL-5 broadband SiC UV photodiode from sglux in a proven TO5 package. The aging-resistant, low-noise and fast-response SiC UV sensor operates stable over a wide temperature range. The 7.6 x 7.6 mm² silicon carbide chip, which was processed at Fraunhofer IISB, can be seen in the center of the housing.

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ASTROSE® – POWER LINE MONITORING

Properties of ASTROSE®
- Designed for 110kV, 220kV and 420kV AC operation
- Data captured every 15 minutes
- Autonomous power sourcing
- Ice load monitoring
- Line ampacity forecasting
- Automatic relaunch of the sensor grid after longer outages
- Redundancy in the communication system
- Available communication protocols: LoRa, LoRaWAN®, Bluetooth

Benefits of ASTROSE®
- ASTROSE® is the basis for weather-aware grid operations
- AI-based data analysis
- Fast installation of the wireless sensor nodes
- Low weight of the wireless sensor node: 4kg
- ASTROSE® requires no additional infrastructure for communication
- ASTROSE® works in windless conditions
- Reliable monitoring even with deenergized lines
- Cloud access by web interface

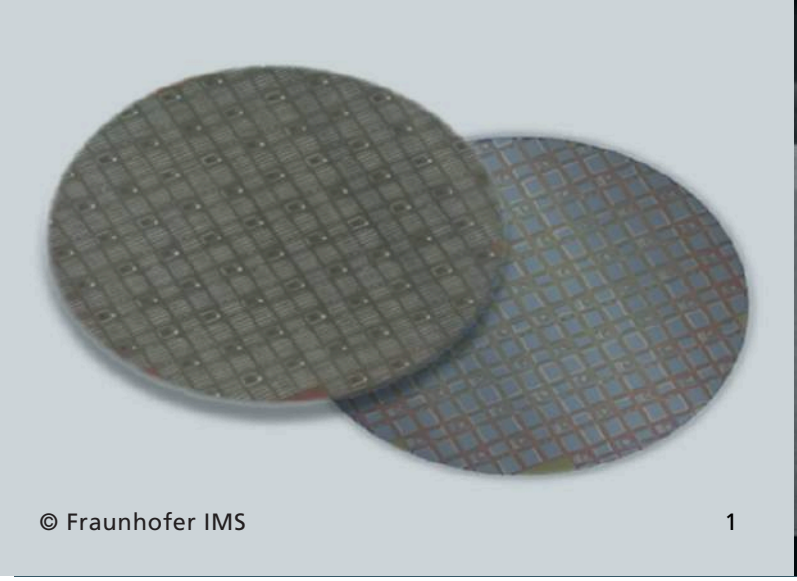
ASTROSE® is a wireless sensor network for monitoring high and extra high voltage power lines.

The technology was developed to address power transmission shortfalls resulting from decentralized power harvesting of renewable energy supplies (wind farms, solar parks, etc.). The non-site-specific sensor system collects data, which is, in turn, applied to modify power line operation. Sensor nodes are attached to each section of a power line in detail. These not only measure line sag but also comprise the smallest units of a wireless data transmission that relay the measured data back to a base station. Two critical technical challenges were met in realizing this system: firstly, autarkic (self-sustaining) upgradable wireless sensors that measure the data and, secondly, a CPS (cyberphysical system) infrastructure for the data communication.

The wireless sensors are at the core of the power line monitoring system. They measure the line sag, line damage, temperature and current. The inclination sensor's required resolution is 0.01°. The wireless sensors' operating conditions make power supply by means of harvesters mandatory. The wireless sensors include communication hardware for data transmission via the freely accessible and non-fee 2.4GHz bandwidth. Special double-slot antennas are used to ensure transmission ranges of over 1000 m. A daisy-chain or linear-type network design is used for the data transfer. This means that the first sensor node sends its measurement value back along the chain of sensor nodes. The following sensor node adds its data to that it receives and sends the total package of data on to the third sensor in the chain, and so on,until the accumulated data package reaches the so-called base station located, for example, in a substation. The data are then saved, analyzed and fed into the grid operator's control technology.

An ASTROSE® sensor network began pilot operation in October 2014 with 59 wireless sensor nodes installed on a 110 kV overhead power line in Germany's Harz mountain range. Over 10 million measurement values have been recorded, relayed and analyzed over 12 months of uninterrupted operation.

The next stage in implementing ASTROSE® is preparing testing and evaluation tools for a wide range of application areas and conditions (see PDF in the Downloads section), paving the way for the broad establishment of the technology.



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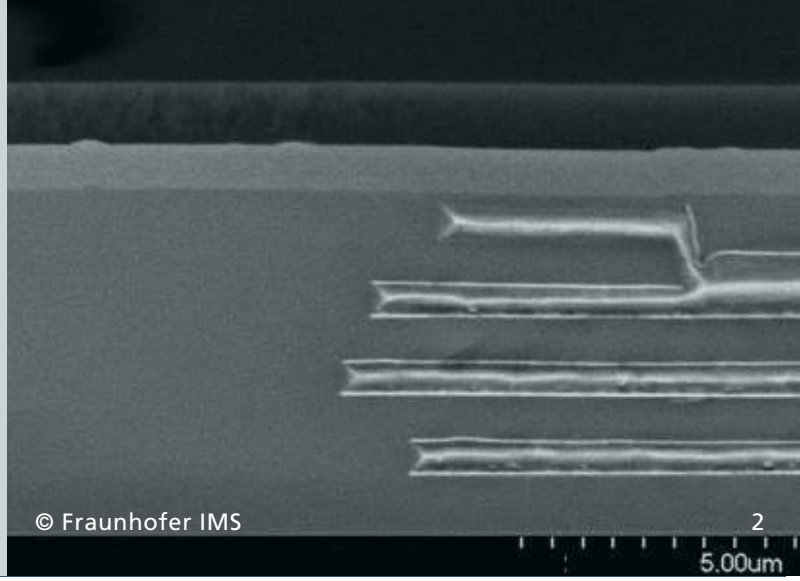

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CMOS Image Sensors

Fraunhofer IMS has more than 30 years of experience in developing image sensors and operates a 200 mm CMOS production line for technologies down to a minimum structure size of 0.35 µm. Fraunhofer IMS develops semiconductor devices and processes from individual sub-steps to complete customer-specific image sensors. Due to the unique combination of an in-house CMOS clean room and a microsystems technology Lab&Fab, the Fraunhofer IMS offers a wide variety of manufacturing processes for realizing new technologies. Our extensive microelectronic expertise in semiconductors, image sensors, and MEMS enables us to take innovative and compact microsystems to pilot series production on request.

Fraunhofer IMS optimizes image sensors in the sense of the "More-than-Moore'' principle by implementing further functions, such as voltage-resistant components for the operation of integrated single photon avalanche diodes (SPAD) or develops technologies that enable the use of the circuit under harsh conditions. The production in the Fraunhofer IMS's own clean room allows the optoelectronic components used in the image sensors to be adapted to the customer's requirements in close coordination with the chip designers to realize the best possible result.

Furthermore, Fraunhofer IMS develops and manufactures analog and digital silicon photomultipliers (SiPM) as CMOS image sensors for detecting single or few photons in various applications, e.g. the nuclear medicine procedure of positron emission tomography (PET). SiPM is based on SPAD technology and exploits the extreme sensitivity and speed of the diodes.

Another example of customized image sensors is backside illumination sensors (BSI sensors) with the latest bonding technology for highly sensitive photodetectors. BSI sensors are characterized by enhanced image quality and are, therefore, indispensable in consumer electronics and smartphones. BSI technology can be used to generate large 2D SPAD matrices, which have enormous advantages when the detectors are used as LiDAR sensors in road traffic. In addition, Fraunhofer IMS offers CMOS-CCD structures and sensors with extremely high dynamic range by integrating CCDs into the CMOS process and performing all signal processing and sensor control internally.

Integrating the CCD into the CMOS process allows direct parallel signal processing and A/D conversion on the chip, thus minimizing parasitic interference effects. The main application area for the CMOS CCDs is in time-delay integration (TDI) in space detectors.

Special photosensitive devices such as pinned photodiodes (PPD) and other developed custom CMOS image sensors will be presented in the area of photodetectors. These include high-resolution sensors for indirect time-of-flight applications and line sensors with high sensitivity and gating or short-pulse capability for spectroscopy applications.

Autonomous Driving
The development of autonomously driving cars is of great importance to modern society because the lifetime that a person spends in the car is not lost anymore, but can be used for many purposes. Moreover, people with handicaps because of old age or limited mobility will be able to be mobile again. The drivetrain works highly efficiently which will forward the transition to emission-neutral mobility, especially in the urban sector. Because 90 per cent of all accidents can be traced back to human error, automation will also come with a decrease in the accident rates.

As recent years have shown, we need to be sure to avoid creating new risk factors for traffic by using insufficient assistance systems (ADAS); the development of robust, error

1. Double-sided processed wafer as a basis for 3D integration.
2. SEM cross section of the 4 metal layers of the 0.35µm CMOS technology.

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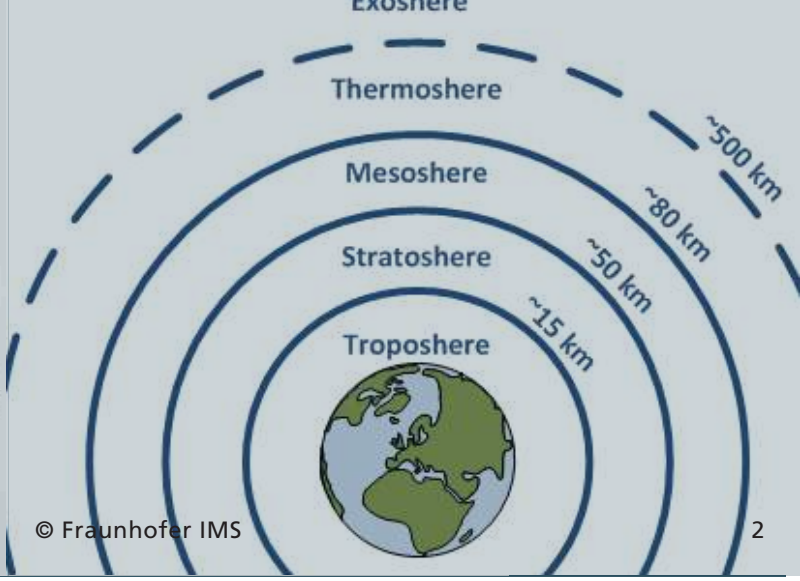

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and failure-free working ADAS technology for autonomous driving is of great importance.

In this context, the three-dimensional detection of the environment in connection with secure object detection is a crucial factor. The Fraunhofer IMS LiDAR (light detection and ranging) measurement process functions as a door opener. Only this technology makes it possible for ADAS systems to be designed to resist interference light and blinding, guaranteeing a reliable determination of the distance and kind of object, regardless of the traffic situation. Therefore, LiDAR cameras depend on fast and reliable detectors, especially in complex and dynamic scenarios, as they occur in traffic. In the Fraunhofer IMS LiDAR cameras for autonomous driving, a three-dimensional image of the environment is generated from a few hundred eye-safe measurements per frame. All of the measurement performance determining elements of a LiDAR system, beginning with the actual scenery modelling, over the characteristics of the laser source and the CSPAD receiver and the high-resolution timepiece (time-to-digital converter, TDC) up to the algorithms for signal filtering, are taken into account for the application in autonomous driving. The core technology of the Fraunhofer IMS CSPAD detectors is available on-site in a certified CMOS process technology according to automotive industry standards.

Space Detectors
Fraunhofer IMS develops special space detectors designed especially for space applications. Currently, two application areas are offered:

Special space detectors, for example, CMOS-CCD in TDI operation, are designed for earth observation from orbit. The focus is on detectors in the focal plane of "small" high-resolution, multispectral optical satellites. These are applied in the following applications:

- Scanning of urban areas to generate current image material from densely populated areas. This material is used primarily for city planning.
- A spontaneous and fast reaction to worldwide crises, for example, natural disasters or war/crisis zones, is becoming increasingly important. High-resolution images of the defined target areas are required to assess the situation quickly and competently.
- For reconnaissance missions, a multispectral distinction of objects is of great interest. Especially the wavelength range in the blue to ultraviolet part of the spectrum is essential for monitoring the oceans. This can be increased by backside illumination.

At Fraunhofer IMS, an in-house developed CMOS process is used for earth observation applications, which allows for the manufacture of CMOS-CCDs with a high dynamic range that can be used in TDI operation.

Another application area is targeting the navigation in space. Unmanned aerial vehicles, like satellites, drones or robots have to be able to navigate autonomously. And tasks like docking manoeuvers to space stations and satellites must also be carried out. Also, sensors to detect unwanted satellites, like parts of satellites or comet residue that orbit around the earth, and the disposal can be carried out efficiently into the earth's atmosphere. For these applications, high-precision 3D space detectors and robust algorithms are needed to realize a millimeter precision navigation. For this purpose, Fraunhofer IMS has developed special LiDAR sensors based on CMOS SPADs that can rise to the challenge.

For the development of Fraunhofer IMS space detectors, process modules are used that are, with the exception of active optical elements, resistant to radiation and, therefore, able to withstand the cosmic radiation of space.

Quantum Imaging
With interesting and novel rules, quantum physics opens up a new world for various applications, for example, in the areas of communication, sensor technology and computing. Impressive progress has been achieved in recent years due to intensive research in quantum technologies.

1. The LiDAR Owl system enables the rover to drive autonomously with independent avoidance manoeuvres.
2. The flight altitude of over 600 km and the speed of satellites place special demands on the image sensors for earth observation.

QUILT

QUANTUM PHOTONICS
by FRAUNHOFER

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This is also true for the domain of quantum imaging. This process uses the quantum physical phenomenon of the entangling of photons to exceed the limits of the classical imaging processes and to enable new applications. From a pair of entangled photons, only one photon is detected. But through the entanglement, conclusions about the features and interactions of the not detected photon can be drawn.

Thus, an object can be depicted without interacting with the detected photons (therefore: "ghost imaging").

Apart from the curiosity and fascination of this phenomenon, it is also of great interest for several applications. One significant advantage is the decoupling from external influences by detecting undisturbed photons instead of the actual interactive photons. In generating the photon pairs, the entangled photons can have different wavelengths. This option allows for the exploitation of the benefits and features of both wavelength ranges and therefore the access to interactions that classic processes can't reach.

For example, in spectroscopic quantum imaging applications, the interactions of photons in the medium infrared range (MIR, approx. 3-15 µm) with molecules can be determined through the entangled photons in the visible range with the help of standard detectors. In the other direction,access to extremely short wavelengths (UV) is interesting for microscopic applications to reach an increased resolution with non-destructive measurement, while the entangled photons in the visible range can be detected conventionally.

Because the entanglement between the single photons occurs, these innovative approaches of quantum imaging require a susceptible and efficient detector technology. For an error-free correlation of the detected entangled photon pairs, an equally high temporal resolution is also necessary. These increased requirements make the SPAD detector technology the preferred candidate in several applications.

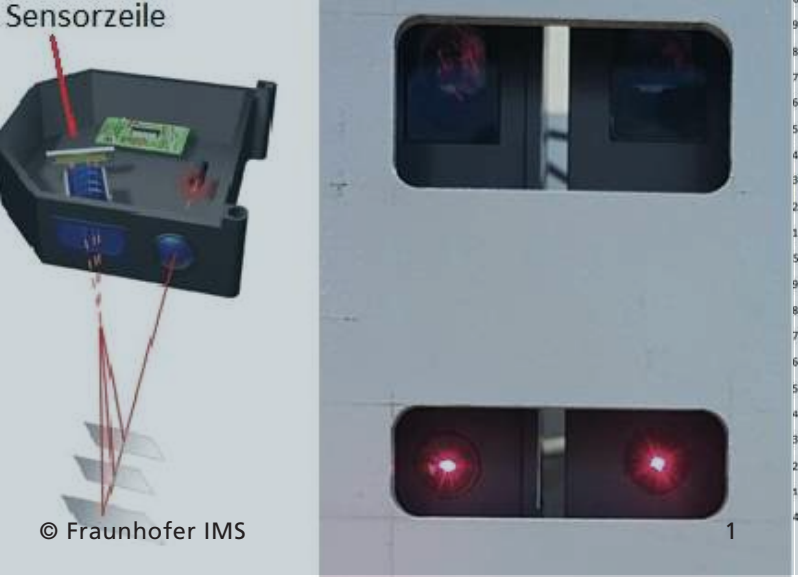
Due to the short dead time, the CMOS-integrated SPADs (CSPAD) of Fraunhofer IMS achieve a very high temporal resolution. The low dark count rate and high quantum efficiency ensure a high sensitivity to the single photon. Detectors manufactured at IMS with SPAD arrays exhibit the optimal features to allow for the detection of single photons both spatially and temporally resolved. The in-house CMOS technology developed and realized read-out circuits can be individually customized to the application.

Within the framework of the Fraunhofer lead project QUILT, (Quantum Methods for Advanced Imaging Solutions), Fraunhofer IMS and five other Fraunhofer institutes make progressive scientific contributions in several research areas of quantum imaging. Because of the combined expertise of the institutes and proactive approach, the Fraunhofer-Gesellschaft is to become the most important player in quantum optical application research. The development, production and optimization of single photon detectors with SPAD technology of Fraunhofer IMS are elemental components of the project.

Surface Inspection

The 60-line high-speed sensor is twice as fast as currently available solutions and delivers high-quality images in a very high resolution. The high-speed sensor detects, for example, banknote sheets– almost like a scanner – line per line when they get out of the printing press. It records 200,000 colour images per second with an exposure time of a few millionths. A software compares the images with the target image and identifies the banknote with faulty security features. Fraunhofer IMS has integrated an individual read-out chain per pixel column to reach the high speed. In addition, special pixels that can work with conventional optics despite the short exposure times were developed. In every pixel column, the three colours red, green, and blue, are equally detected over the whole pixel area. This results in a high-quality colour reproduction. Another feature of the sensor: the high number of lines enables the detection of objects from different angles, which can be used to test surface structures in 3D, like the tilting effects of holograms.

1. 2016 x 60 Pixel Ultra-High-Speed „Xposure" CMOS multi-line sensor with 600 (200) kHz (b/w, colour) line rate for the surface inspection on a wafer (left) and in housing (right).



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The unique architecture of the sensor opens up new room for various applications. Due to the high number of lines, the wavelength spectrum is expendable up to the UV and infrared range. With the ability to also analyze 3D surfaces, the high-speed sensor is suitable for quality control of different materials in industrial production. Another application area is the evaluation of tracks and contact wires of trains. Even at 300 km/h, the high-speed sensor can produce pin-sharp images with a resolution of up to 0.4 mm and, therefore, detect hairline cracking. Near Earth, satellites that are equipped with such a sensor and orbit the Earth at a speed of 26,000 km per hour can record colour images of the Earth's surface with a resolution of three centimetres.

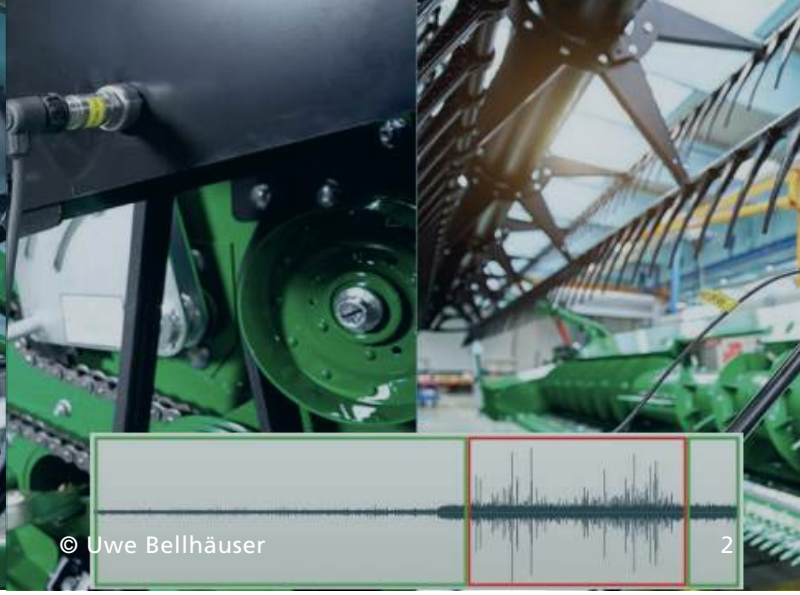
Industrial Measurement Technology

Since the 80s, fast and highly precise systems based on the principle of laser triangulation have been used to measure objects. A laser point or laser line is projected onto the measurement object, and the reflected light hits different positions, depending on the distance, on a line or surface sensor, which allows for the reconstruction of the distance to the measurement object. For example, welding seams can be monitored during the production process, surfaces can be checked for planarity or the tread depth of tyres can be monitored using this technology. These laser triangulation systems deliver a high measurement precision in the 1 µm area and a comparably high measurement speed of up to 50 kHz. Currently, available triangulation sensors contain off-the-shelf sensors (PSDs or CMOS- and/or CCD sensor lines) as detector elements. With this solution, the limits are often reached during the modern production processes about sensitivity and speed.

Fraunhofer IMS has performance-optimized photodetectors and highly integrated sensor ICs in its portfolio, which detect a high overexposure within a few microseconds and have an ambient light suppression of 50 Klux. Apart from that, the sensors of Fraunhofer IMS for the industrial measuring technology show a significantly increased measuring speed of 100 kHz with a sensitivity of up to 500 V/µJcm2 (doubling of the state-of-the-art technology).

The Fraunhofer IMS sensors for industrial measurement technology are based on newly in-house developed and patented pixel structures that can be manufactured in a standard CMOS process. With these pixel structures, it is possible, on the one hand, to detect temporally resolved signals through fast electronic shutters and, on the other hand, to reach a very high sensitivity. The latter is necessary because there is correspondingly less light available per measurement with increasing measurement speed. Fraunhofer IMS has been working in the area of CMOS image sensor systems for over 25 years and can realize new components for industrial measurement technology through the close cooperation of image sensor technology development.

1. 512 pixel laser triangulation sensor - 80 kHz measurement rate for surface inspection.
2. Results of a high-precision profile measurement using laser triangulation.



Cognitive Sensor System "AcoustiX"- Reliable detection of failures through acoustic monitoring of machines and Systems

During operation, machines or systems generate characteristic vibrations and noises. Changes in these noises provide information on assembly errors or other defects. Human hearing is limited in its capability to detect these changes due to a certain amount of subjectivity as well as personnel fatigue or interference from ambient noise.

Acoustic testing systems available on the market allow objective detection of unusual vibrations or noises. However, such systems must often be carefully and explicitly calibrated using representative parts. In addition, the acoustic and vibratory behavior is generally limited to a few parameters, such as frequencies or amplitudes. Even minor design adjustments will require recalibration to prevent a negative impact on testing reliability.

To solve these problems, Fraunhofer IZFP has developed "AcoustiX", an acoustic sensor system based on cognitive signal analysis.

The cognitive approach resembles subjective noise evaluation by humans but it provides objective and reproducible results. The process involves using appropriate sensors for detecting and digitizing operational vibrations and/or noises, segmenting them into short time intervals, filtering and converting them. Finally, successive signal segments are compared using appropriate mathematical methods.

Unexpected vibrations or noises will result in characteristic differences for the segments. This will be pointed out by the system correspondingly. The algorithms developed do not require prior knowledge except for a few reference signals needed for the initial software calibration. Thus, the algorithms will detect anomalies without requiring complex teaching.

Applications

- Final assembly inspection of machines or systems with moving parts
- Monitoring operations at regular time intervals or permanent quality monitoring:
- Monitoring large, autonomously operating machines and systems
- Evaluating the quality of individual assemblies being used, e.g., on test benches

Advantages

- High testing reliability due to objective, simultaneous evaluation of the signals from multiple sensors
- Cognitive quality evaluation without explicit calibration
- Versatile application, e.g., for final assembly inspection or permanent quality monitoring
- Fast inline evaluation: Instant detection of irregular products
- Individualized system setup: Customized testing hardware design and evaluation algorithms
- Option for integrating the evaluation algorithms into existing testing systems
- Onsite feasibility studies using a portable sensor system
- User-friendly and customer-specific adapted operator software.
- User-friendly displayed of test results in the operator and evaluation software
- Standard results display using traffic light indicators; no need for comprehensive training
- Versatile software functions

1. AcoustiX – acoustic sensor system, here on a combine cutter bar.
2. Left: Sensor for structure-borne sounds; middle: acoustic signals with anomalies; right: microphone.

Ultrasound-based proximity sensors for human-machine interaction

Intelligent interactive systems for human-machine interaction (MMI) are increasingly being used in many applications in Industry 4.0, Smart Health, Smart Security and Automotive. Here, sensor systems for non-verbal information exchange in the near-distance and contact range are essential for functionality and security. To meet the increasing demands in terms of performance, energy efficiency and functionality, researchers at Fraunhofer EMFT are working with three other Fraunhofer institutes to develop a modularized MEMS technology and sensor platform.

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

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

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

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

1. Measurement setup for an eight-channel ultrasonic transceiver chip.
2. Test board for an eight-channel ultrasonic transceiver chip.
3. 16 channel evaluation board.

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Intelligent sensor solutions for Industry 4.0

The industry of the future will become more digital, more efficient and more automated. Autonomous driving systems and robots will make human work more manageable. The Fraunhofer Institute for Photonic Microsystems IPMS is developing sensors, optical components and actuators based on microelectromechanical systems that detect the environment and make interaction safe. In this context, sensors are becoming a key technology of digitization: they form the interface between machines and humans.

Microelectronics and microsystems are vital technologies and enablers for various applications. Miniaturized, intelligent and networked sensors and actuators form the basis for IoT, Industry 4.0 and numerous future applications with artificial intelligence.

Customized, highly miniaturized MEMS scanners
Fraunhofer IPMS has many years of experience in developing and manufacturing customized, highly miniaturized MEMS scanners. The devices feature large scan angles and high scan frequencies showing excellent long-term stability. A qualified CMOS-compatible bulk micromachining process is used to manufacture 1D and 2D micro-scanners in small and medium volumes. The eye-safe demonstrator, which will be presented at LASER World of PHOTONICS, illustrates the possible operating modes of a 2D MEMS scanner with a quasi-static outer axis and resonant inner axis. Applications of this technology can be found in scanning imaging, laser scanning microscopy, endoscopy, LiDAR sensor technology for autonomous driving, head-up displays, head-mounted displays, and AMR displays.

Presentation of the first vector scanner modules with electronics
New in the portfolio of MEMS micro-scanners of Fraunhofer IPMS are hybrid 2D vector scanner modules with an electromagnetic drive. Here, Fraunhofer IPMS builds on many years of experience in fabricating gimbaled, monolithic 2D MEMS scanners and combines this with the existing know-how of MEMS micro-assembly technologies.

"This new approach significantly expands the parameter space of previous monolithic scanners. At the same time, we retain the established advantages of Fraunhofer IPMS' MEMS-scanner technology - high optical planarity, decoupling of the scan axes through gimbal suspension, and the fatigue-free nature of the spring elements. The new components allow 2-dimensional quasi-static deflection with larger mirror apertures and a high vectorial positioning speed," explains Dr. Jan Grahmann of Fraunhofer IPMS.

The module also provides the mirror position as analog signals to realize a controlled system. The well-known additional features, such as the application of a customized, highly reflective dielectric mirror coating or the realization of the mirror plate as a diffraction grating, are also feasible for these components. To exploit the full performance of the scan module, Fraunhofer IPMS provides suitable control electronics. The required algorithms, which are finely adapted to the mechanical properties of the module, were developed at Fraunhofer IPMS and can be transferred to the digital control of the customer's system electronics (FPGA or microcontroller). In addition, compact control electronics with a precise analogue driver stage and input stages for the position signals are available. It can be addressed both analogue and via a digital interface.

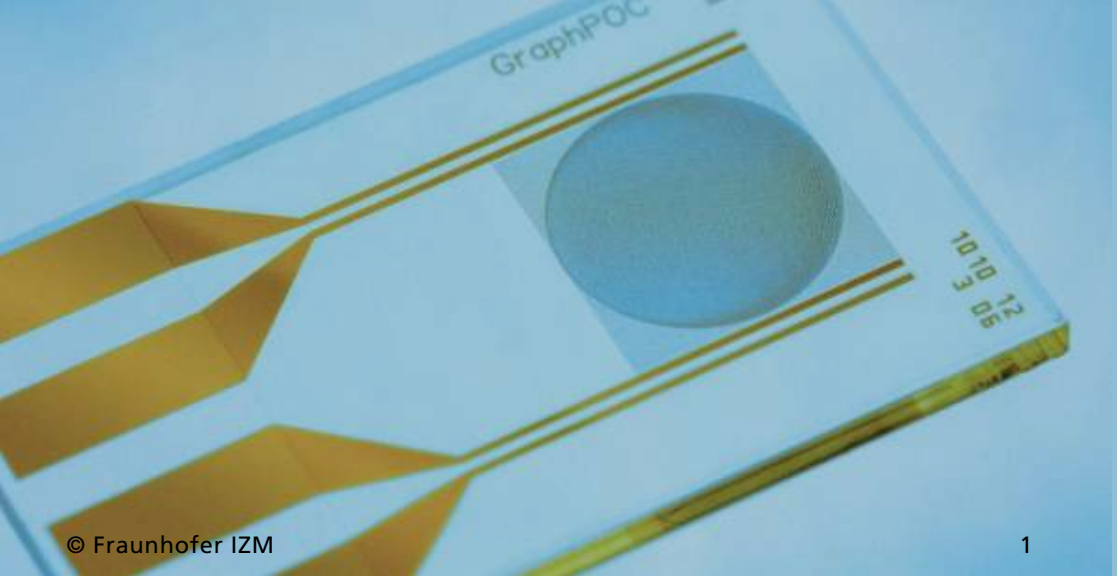
1. 2D vector scanner module I2DQSEM01.

1

Quantum cascade laser with extreme resolution increase for spectrometry
Further research work at Fraunhofer IPMS addresses the detection of the environment using quantum cascade laser spectroscopy. The miniaturized quantum cascade lasers developed jointly with the Fraunhofer Institute for Applied Solid State Physics IAF cover an extensive wavelength range and a broad spectral tuning range at a high scan rate. The micromechanically fabricated diffraction grating developed at Fraunhofer IPMS is an external resonator of the variable frequency quantum cascade laser. It allows one to tune the laser wavelength with a selectable speed or to choose a wavelength and hold it for selectable periods. Spectral ranges can also be scanned without mode hopping and enable, therefore, a very high resolution.

About Fraunhofer IPMS
The Fraunhofer Institute for Photonic Microsystems (IPMS) stands for applied research and development in the fields of industrial manufacturing, medical technology and improved quality of life. Our research focuses on miniaturized sensors and actuators.

1. Fraunhofer IPMS drive electronics for electromagnetic vector scanners.



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Certainty in just 15 minutes – graphene oxide-based rapid test for infection detection

Researchers at the Fraunhofer Institute for Reliability and Microintegration IZM have joined forces with partners in industry and healthcare to develop a handy graphene oxide-based sensor platform to detect acute infections such as sepsis or the antibodies against the coronavirus within minutes.

The current situation with the COVID-19 pandemic underscores the importance of detecting infections quickly and accurately to prevent further spread. Today, symptoms provide clues that help diagnose viral or bacterial infections. However, many infections have similar symptoms, so these signs can easily be misread and the disease misdiagnosed. Blood tests provide certainty, but laboratories only carry these out when prescribed by the family physician. By the time the results arrive from the lab, doctors have often prescribed an antibiotic that may well be unnecessary.

Just one drop of blood for a diagnosis

Researchers at the Fraunhofer IZM in Berlin have been working on the project GraphPOC since April 2018 on a graphene oxide-based sensor platform to rise to these challenges in diagnosing infections precisely. A single drop of blood or saliva is all it takes to perform an accurate analysis. A few minutes after the drop is applied to the sensor's surface, electrical signals convey the test result to the family doctor's office. This rapid test provides certainty within just 15 minutes to replace the protracted blood work in the lab. It takes the error and guesswork out of diagnosis so the physician can prescribe the appropriate treatment or suitable antibiotics.

The test may also be set up to detect antibodies present after a patient has recovered from an infection. Fraunhofer IZM researchers are now focusing on this application to detect earlier infections with the COVID-19 virus, which can help with efforts to trace how the disease has spread. The human body forms molecules or proteins called biomarkers in response to an infection. Capture molecules placed on the surface of the graphene-based sensor to detect these biomarkers. Differential measurements of biomarkers' concentration determines if an infection is present.

3D structure to enlarge the measuring surface

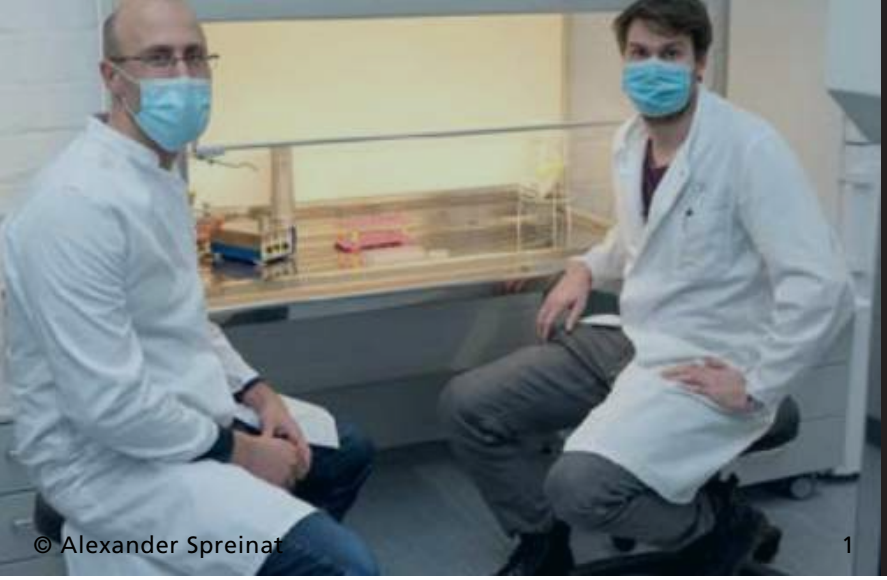
This sensor platform's most remarkable feature is its base material: Electrically conductive and biocompatible, graphene oxide is also a very reliable means of detection. To date, it has only been used in microelectronics in its original form, a 2D monolayer. Fraunhofer IZM researchers are now applying it in a 3D structure in the form of flakes. This 3D form increases the measuring surface and the accuracy of measurements. Manuel Bäuscher, scientist at Fraunhofer IZM and sub-project manager at Graph-POC, sees excellent prospects ahead for these graphene oxide sensors: "We can pivot from the current medical field to also develop in the direction of the point of need; that is, towards environmental technology and the detection of environmental impacts. But of course, the corona application is our priority." The graphene oxide flakes' 3D array and heightened sensitivity also open the door to further applications. For example, it could detect harmful gases such as carbon monoxide or acetone even at room temperature. As it stands, these gases have first to be heated to trigger a surface reaction that today's sensors can detect. The graphene oxide sensor reacts at lower temperatures when metal oxides bond with its sensitive surface.

1. Fraunhofer researchers are developing graphene oxide-based biosensors to detect bacterial and viral infections within just 15 minutes.

About Fraunhofer IZM
As part of the Fraunhofer-Gesellschaft, Fraunhofer Institute for Reliability and Microintegration (IZM) specializes in applied and industrial contract research. Fraunhofer IZM's focus is on packaging technology and the integration of multifunctional electronics into systems. The institute has a staff of more than 438 and saw a turnover of 39.6 Million Euros in 2022. Fraunhofer IZM has two sites in Germany. Apart from its headquarters near Berlin Mitte, the institute is also represented in Dresden and Cottbus, strategically important centers for electronic development and manufacturing. The foru departments at Fraunhofer IZM: (i) Wafer Level System Integration, (ii) System Integration & Interconnection Technologies, (iii) Environmental & Reliability Engineering and (iv) RF & Smart Sensor Systems promote internationally cutting-edge technology development. The departments jointly work on application areas and key development topics, ensuring the research is advanced across technologies. In key development topics, the Fraunhofer IZM researchers monitor and develop highly promising research questions, paving the way for future projects with industry.

Fraunhofer IZM researchers are taking on another challenge to scale the production process up for mass manufacturing: They are looking to apply the graphene oxide coating at the wafer level so that hundreds of chips can be processed simultaneously.

Antibodies detectable after coronavirus infections in about one year
The graphene oxide-based sensors have to be integrated into a plastic carrier, and the system's reliability must be tested before the rapid tests can be deployed. Although the original project to detect infections is slated to run until spring 2021, the researchers expect to wait to be able to verify the sensor for the coronavirus for another year. The partners in this project are the Charité, Aptarion Biotech AG, Technische Universität Berlin, MicroDiscovery GmbH and alpha-board GmbH. It is funded by the German Federal Ministry of Education and Research (BMBF).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New biosensors enable ultrafast detection of 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 you can imagine as tiny 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 glow in the presence of a specific target molecule. In this way, virus particles or bacteria are visually detected. What is unique about our sensors is that they can be used for many applications and are extremely small, fast and ultrasensitive. The current situation shows that more diagnostics should be available to contain pandemics. Imagine having biosensors that are available to everyone, which 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 essential pathogens, such as bacteria, in our laboratory. Thinking about all the applications, we want to expand the detection strategies further 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 sensor concepts closer to the patient. One example is intelligent implants that are applied non-invasively and indicate infections without contact.

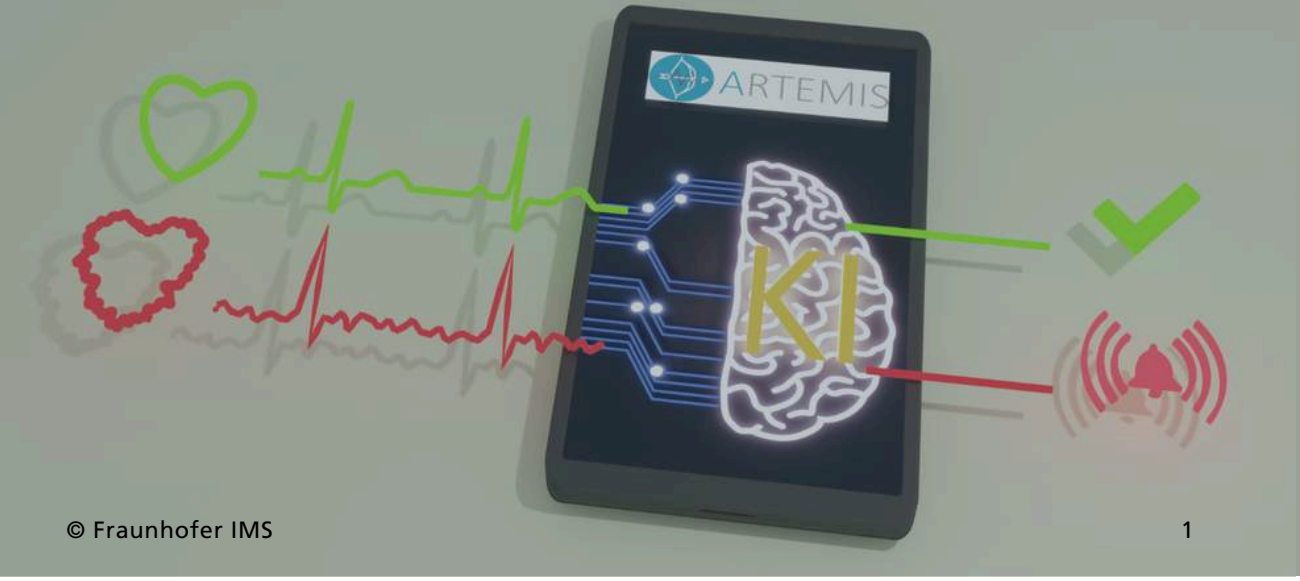
How can we imagine such a detection device?
Biosensors detect chemical structures that are characteristic of a particular issue. An example would be the protein that allows the coronavirus to enter human cells. The nanosensors recognize these structures precisely. Therefore, such nanosensors, for example,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

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

Brief profile of Prof. Sebastian Kruss
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.

1. Part of the research team: Sebastian Kruss (left) and Robert Nißler.
2. Prof. Sebastian Kruss.



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Semiconductor chip with integrated Artificial Intelligence detects heart diseases

With almost two million people affected, atrial fibrillation (AF) is one of the most widespread diseases in Germany. AF that is detected too late can have fatal consequences for patients, such as a stroke. Such severe consequences could be avoided by early intervention.

With significant participation of the IMS, the "ARTEMIS" consortium aims to provide efficient, digital healthcare for this disease.

The main innovation consists of miniaturized ECG electronics based on artificial intelligence (AI), which detects atrial fibrillation directly at the patient in real time.

Critical changes in the ECG are detected through AI data analysis established in a semiconductor circuit and software. . The results are quickly and securely transferred to the electronic patient record using the 5G standard.

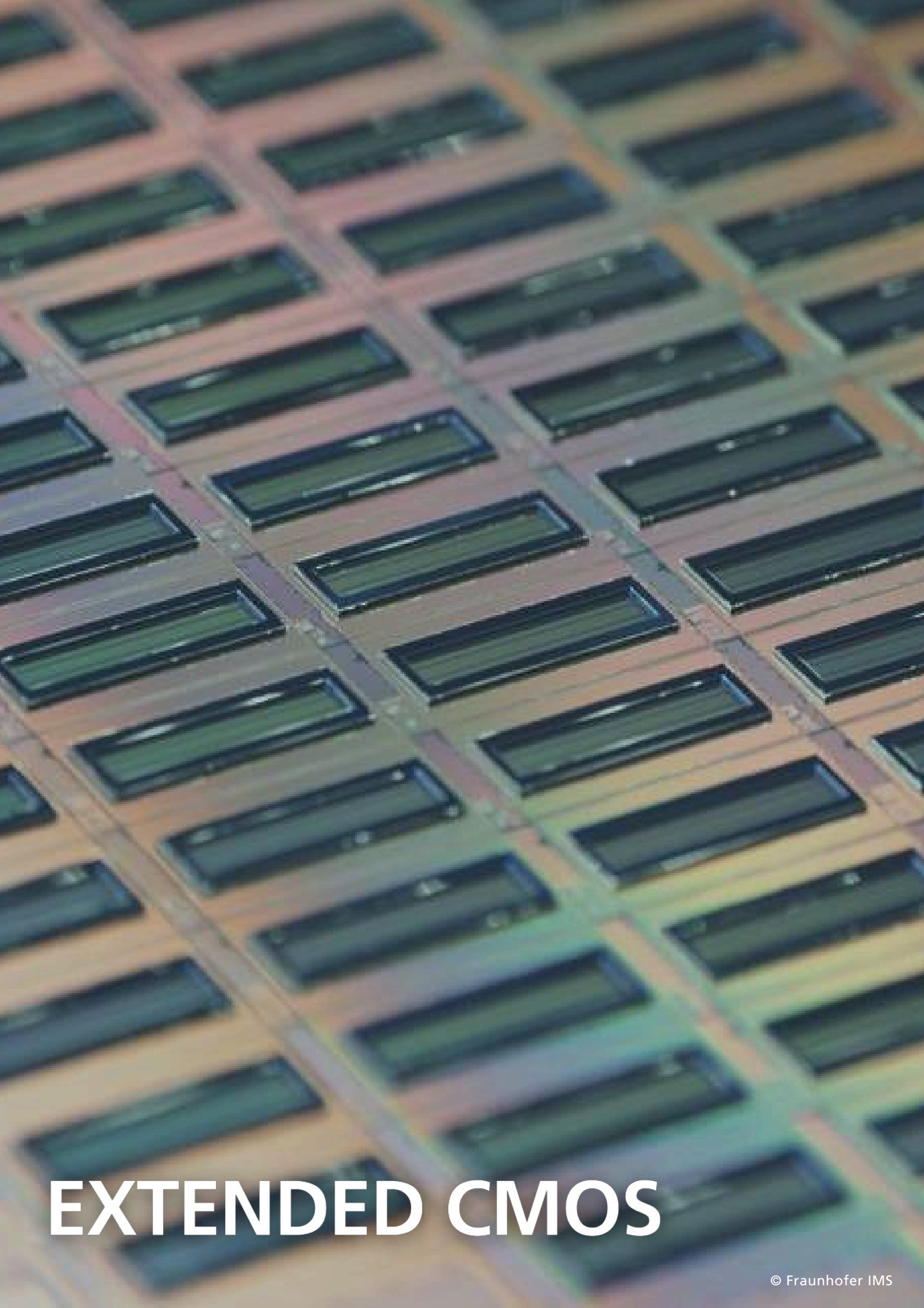
AI" supports by analyzing and processing large amounts of data and providing decision support. Based on the pre-analysis of the patient data, the medical staff is alerted early to a potentially life-threatening situation and can interact accordingly.

The feasibility of detecting cardiac arrhythmias using machine learning has already been demonstrated very successfully by the scientists at the IMS. The low energy requirements of the IMS concept make it possible to create a particularly small monitoring system, which increases wearing comfort and patient acceptance.

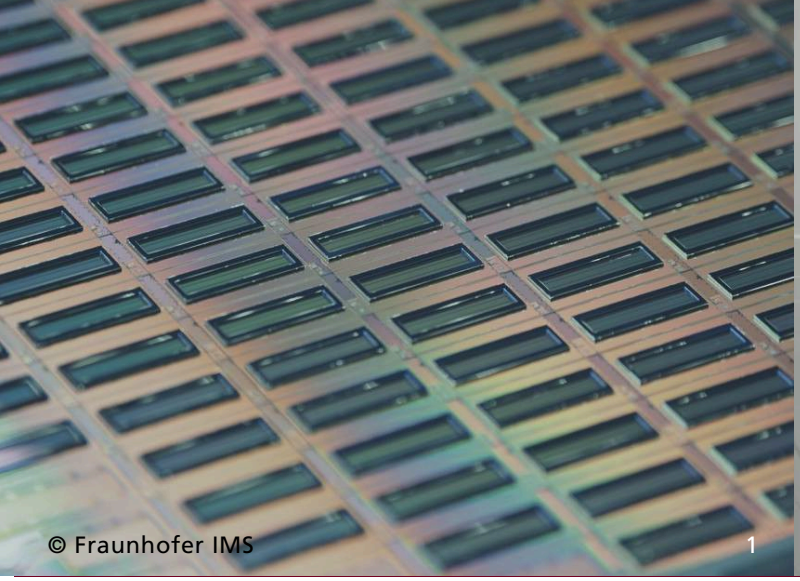
The consortium includes experienced distributors, manufacturers and medical service providers who will ensure targeted commercialization after the three years of the research project. The consortium leader is getemed Medizin- und Informationstechnik AG. Other project participants are Charité - Universitätsmedizin, CYIENT GmbH and SYNIOS GmbH.

The BMBF funds the project under the grant number 13GW0579D.

1. Schematic representation of how the miniaturized ARTEMIS system works. The AI analysis for the evaluation and classification of patient data helps to maintain the health of the patient and at the same time leads to a relief of the medical staff.



EXTENDED CMOS



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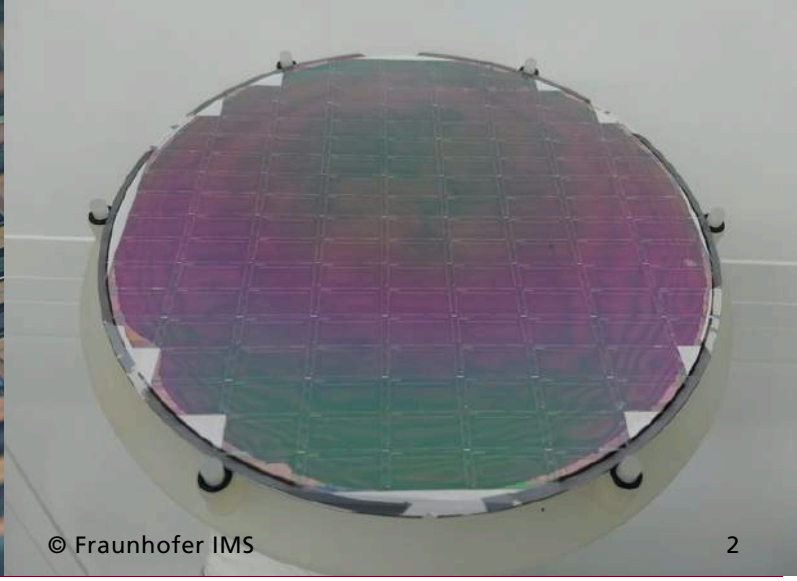


2

3D-Integration technologies - Wafer-to-Wafer-Bonding (W2W) and Chip-to-Wafer-Bonding (C2W)

The Fraunhofer IMS offers various technologies for 3D-Integration to continue the trend of microelectronics: faster, more compact and more powerful.

In recent decades, research and development in micro-and nano-electronics has led to ever smaller structural sizes and continuously increasing integration densities of sensors, memories and processing circuits. Due to physical limitations, the enormous technological growth regarding a wafer level is stagnating.

The 3D-Integration of micro- and nano-electric construction elements allows a vertical arrangement of different system devices and offers a way to continue the trend of compact and powerful devices ("More than Moore")

3D-Integration offers further advantages:

- Cost reduction
- Shorter connecting paths
- Higher integration density

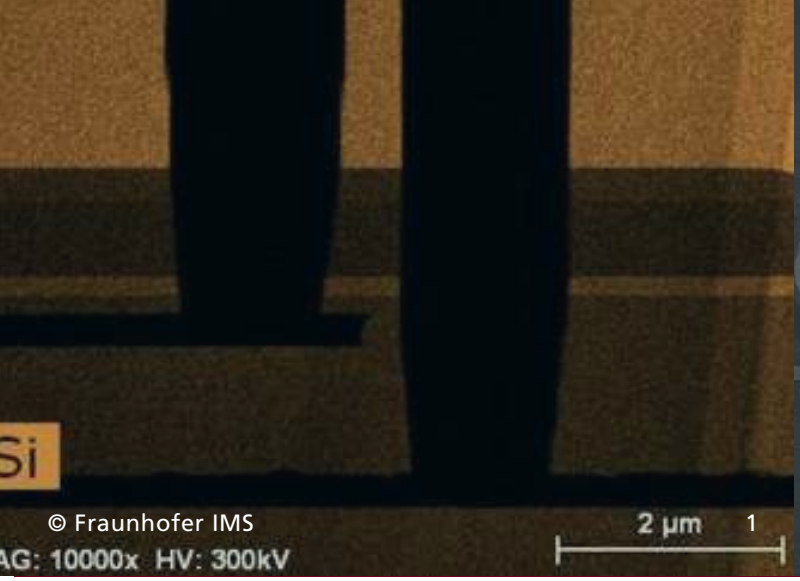
By exploiting the third dimension and the possibility of heterogeneous integration, structures from different process lines can be combined with a heterogeneous integration. Through 3D-Integration, e. g., optical sensors can be manufactured directly with the associated interpreting and signal processing circuit logic. Since new developments place ever higher demands on the detectors, it is increasingly necessary to manufacture them directly with the signal-processing circuit logic. Thus, for example, the interpreting circuit can be moved into the third dimension to increase the optically active area and, thus, the sensitivity.

Fraunhofer IMS supports various technologies for 3D-Integration on 200 mm-wafers.

Wafer-to-Wafer-Bonding (W2W)
The Fraunhofer IMS offers a direct oxide-to-oxide bonding process for 3D-Integration at CMOS compatible temperatures below 400 °C. The bonding process is based on forming covalent siloxane (Si-O-Si) compounds. For this purpose, the wafer surfaces were activated in the oxygen plasma to generate silanol (Si-OH) groups under an H2O atmosphere. The wafers are aligned to each other and conducted so that hydrogen bonds are formed in the area of the bond interface. Finally, the pair of wafers is heated to over 250 °C to create covalent siloxane compounds by diffusion of water. The following surface properties must be observed to produce a high-quality bond:

- Topology
- Microroughness
- Bend
- Particle contamination

1. 3D-Integration of detector chips with signal-processing circuit logic using SLID bonding techniques.
2. Wafer bond consisting of sensor and circuit wafer before post-processing.



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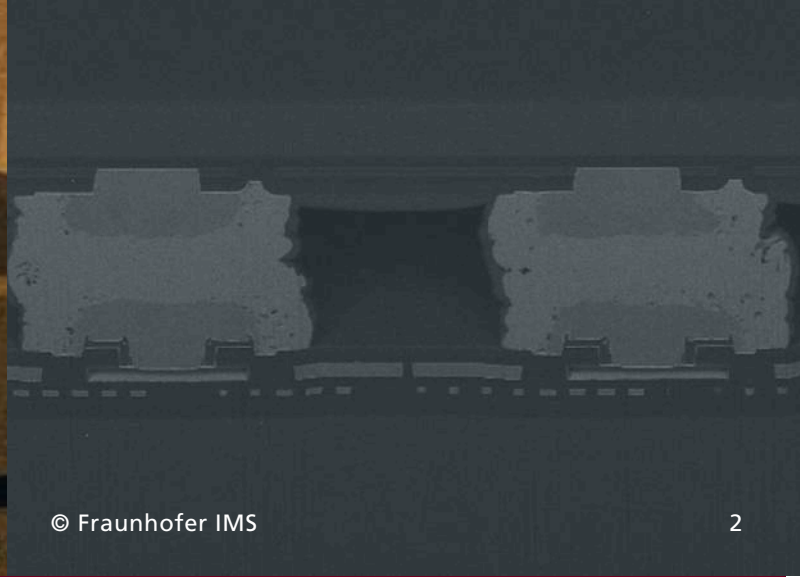


2

Through many years of experience at the Fraunhofer IMS in CMOS and MEMS processes as well as in assembly and interconnection technology, optimized stress compensation and chemical mechanical planarization (CMP) methods as well as adapted layout designs for W2W-bonding could be developed with many years of experience in CMOS/MEMS processes, assembly and interconnection technologies. With these process optimizations, a shear strength of over 4 kg/mm2 and a precision accuracy of the wafer bond of less than 7 µm can be achieved. The front side interconnection (TSV, Through Silicon Vias) is realized through µVias, filled with an optimized ALD (Atomic Layer Deposition) material stack. The process can be adapted to individual customer design specifications by different µVia variants.

Chip-to-Wafer-Bonding (C2W)
The Fraunhofer IMS offers chip-to-wafer bonding with a solid-liquid interdiffusion (SLID) process. The SLID bonding is based on a two-metal-system to create high-temperature stable contacts at low process temperatures. For this purpose, a low-melting metal is brought into contact with a suitable metal partner with a higher melting temperature and then melted. Diffusion processes occur at the interfaces, and an intermetallic phase is formed. Contacts with a temperature stability from 400 °C up to 600 °C can be produced depending on the material combination.

The Fraunhofer IMS uses the flip-chip method for 3D-Integration. The chip is soldered onto the wafer for the assembling process with the active surface facing downwards.. The chip size can vary from only a few mm to the µm range. The contact is made by micro bumps, aligned with high precision (precision accuracy < 5 µm). The bump size ranges from a few µm to 100 µm. The Fraunhofer IMS offers galvanic deposition of the following materials for the production of micro bumps:

- Copper (Cu)
- Tin (Sn)
- Gold (Au)
- Nickel (Ni)

Based on many years of process experience, the CuSn and Ni/Au/Sn-SLID bonding processes are established at the Fraunhofer IMS. The manufactured CuSn and Ni/Au/Sn bump contacts are stable at temperatures up to 675 °C and 522 °C respectively, and withstand over 1000 temperature cycles (-55 °C to 150 °C).

With the wafer-to-wafer and chip-to-wafer bonding, we have two strong and established processes for 3D-Integration at your disposal.

1. µVia-structures for front-side silicon through-hole plating in wafer-to-wafer bonding.
2. Cu/Sn-Microbumps for contacting via SLID process.

1

2

Atomic Layer Deposition (ALD) Technology

Fraunhofer IMS offers innovative thin film deposition processes based on ALD technology. Precise deposition control, excellent conformity and an extensive range of materials pave the way for new applications.

Progressive process technology for new MEMS and NEMS devices
Medium-resistant protective layers for sensors, optical coatings, high-capacity trench capacitors, new NEMS devices for gas sensors, biosensors with nanowires, and ultrathin freestanding membranes: All of this is possible with modern ALD technology (Atomic Layer Deposition).

ALD is a deposition process, which is based on the chemical surface reaction of at least two precursors. The process allows for an increase in high-quality layers with thicknesses in the range of 1-100 nm. A steadily increasing selection of ALD materials enables new, innovative sensor applications. Within the framework of the Forschungsfabrik Mikroelektronik Deutschland (FMD), Fraunhofer IMS acts as an ALD competence centre. At Fraunhofer IMS, we offer the ALD technology for 200 mm wafers.

Application area of ALD technology
Because the process temperature during ALD deposition is low compared to conventional CVD processes, ALD layers can be deposited on substrates with integrated circuits, i.e., on CMOS wafers. Therefore, the ALD technology can be applied for different MEMS, NEMS or CMOS-related applications, for example:

- Cost-efficient 3D NEMS technologies for generating freestanding nanostructures on CMOS surfaces with high reproducibility have been developed and patented by Fraunhofer IMS.
- Medium-resistant layers for sensor applications, for example, for pressure sensors or encapsulation of medical implants. Aluminium oxide (AI2O3) and tantalum pentoxide(Ta2O5) are available for ALD passivation. Further ALD materials can also be implemented at Fraunhofer IMS if required.
- Electrical or optical shields can be manufactured through metallic layers like ruthenium (Ru). Moreover, ALD layers can be used as transparent, conductive electrode layers, for example, for optical sensors or solar cell applications.
- Due to the high conformity of the ALD process, dielectrics can be used as an ideal isolation in trench capacitors. For trench capacitors, there are high- and medium-k dielectrics available. Fraunhofer IMS has experience in developing trench capacitors for high-temperature applications (more than 250 °C) based on ALD layers.

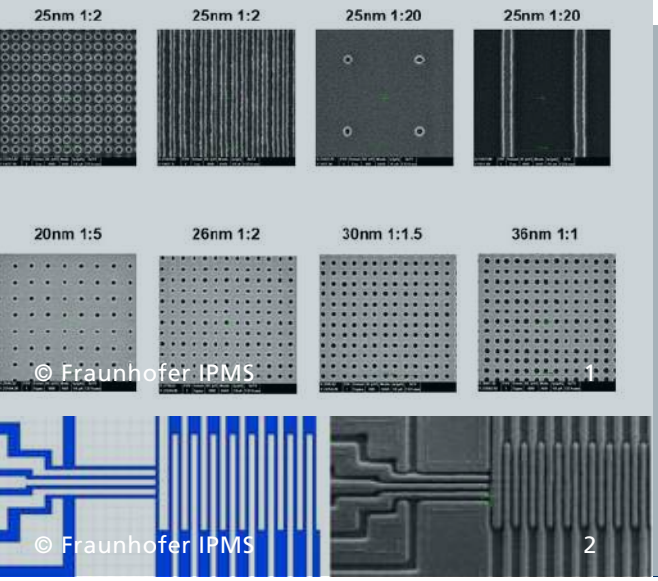
The ALD technology offers the option to realise freestanding 3D MEMS or NEMS structures with wall thicknesses in the nanometer range on CMOS surfaces. The combination of different ALD materials allows the exact configuration of the physical and chemical parameters of the freestanding structure. Due to the nanoscale wall thickness and the low mechanical and thermal mass, the 3D structures are perfectly suited for progressive sensor application in gas and bio-sensor systems. Furthermore, nanowires, ultrathin membranes and cantilevers can be manufactured at Fraunhofer IMS using ALD technology.

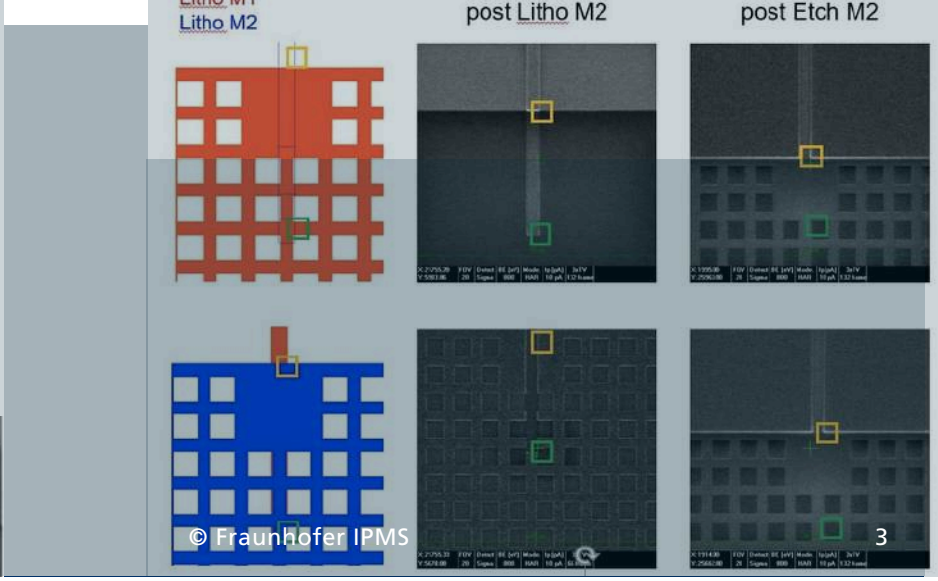
Special solutions for arbitrarily shaped devices, for example, packaged sensors or coatings with special materials, can be realised upon request.

ALD benefits summarized

- Very high conformity of the deposited layers. The excellent side wall coverage of ALD layers in cavities with a high aspect ratio allows for applications for 3D technologies.
- Precise layer thicknesses through monolayer growth.
- The deposited layers are of a high quality and nearly free of pinholes.
- An increasing material variety is available: metals, insulators, high-k dielectrics, functional materials for sensors (e.g. metal oxides), optical materials as well as transparent conductive oxides are provided by Fraunhofer IMS

1. Fraunhofer IMS develops the smallest nanosensors on the basis of ALD for cell contacting in its project ZellMOS.
2. Picosun R-200: Single wafer processes (200 mm).





Nanopatterning - Electron Beam Lithography

Creating nano-scale structures is necessary for a wide range of applications in the semiconductor business. Key challenges are creating precisely controlled patterns with small dimensions, flexible and adaptable layout generation and processes, and uniform and reproducible wafer-scale integration.

Fraunhofer IPMS offers state-of-the-art nanopatterning capabilities using electron beam direct write lithography and reactive ion etching. Thus, customized structures with sizes below 40 nm can be created on various wafer sizes and substrate types. Starting from the customer's design, the whole package involves layout generation and modification, data preparation, e-beam lithography, pattern transfer using etch processes together with the needed in-line metrology and analytics up to separation into single chips.

Application examples

- Fabrication of test structures for technology development
- Structuring of Application-Specific Integrated Circuits (ASICS)
- Design tests of innovative devices and cell concepts and their variation on a wafer (Chip Shuttle)
- Calibration pattern for metrology development
- MEMS and NEMS patterning with productive quality
- "Mix & Match" with optical exposure techniques

1. Example of different LS and CH nanostructures after lihtography and after etching steps.
2. Nanostructure as designed (left) and after e-beam nanopatterning and etching (right). Smallest pitch 80 nm, trench width 28 nm (in cooperation with Infineon Dresden, RWTH Aachen, and FZ Jülich).
3. Example of the Mix & Match Variations. As designed (left), SEM images after exposure of the second lithography layer (middle), and after etching step (right). The work is done in the frames of SAB Project FOKUS (Advanced Concepts for Patterning and Metallization in MOL and BEOL) in the joint project FD-REX (MOL and BEOL Process Development for Roadmap Extension of FD-SOI Technology- Fully Depleted SOI Roadmap Extension).

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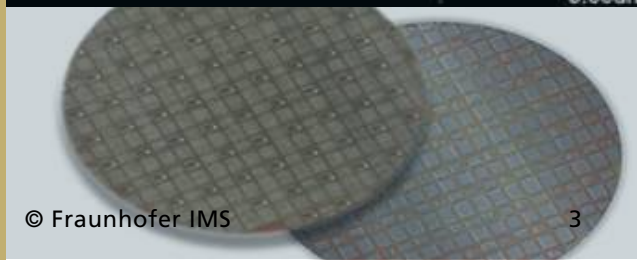
High Temperature Electronics - High Temperature SOI CMOS Technology (H035)

In the SOI-CMOS technology H035 developed at the institute, application-specific integrated circuits (ASICs) can be developed for a temperature range from -55 °C up to 300 °C. In high-temperature technology, precise analogue components, e.g. for sensor readout, can be realized, as well as complex digital functions up to a microcontroller. Additional technological steps, which take place in the microsystem technology clean room of the Fraunhofer IMS, also enable the realization of sensors, e.g. for measuring pressure or acceleration. Electronics and sensor technology can thus be integrated on a standard silicon chip, resulting in cost-effective and reliable solutions for measurement technology in harsh environments. This can involve the development of complete ICs and subcomponents or the support of individual development steps.

The high temperature 0.35 µm SOI-CMOS technology offers the technological basis for the fabrication of complex integrated circuits for the temperature range mentioned. The technology was developed at Fraunhofer IMS and currently represents the most advanced technology for high-temperature integrated circuits worldwide. The minimum structure size of only 350 nm is unmatched in other high-temperature technologies and allows the realization of mixed-signal systems even with complex digital parts up to a microcontroller.

The basis for new development projects is the circuit design know-how available at the Fraunhofer Institute. In the high-temperature technology H035, many frequently used components, such as amplifiers, analogue/digital converters, microprocessors, interface circuits, etc., have already been developed and are available for future projects. Rewritable non-volatile memories in the form of EEPROMs are available for storing, e.g. calibration data, and are particularly interesting for applications in sensor signal processing. To develop new blocks, the design team can draw on a wealth of experience. In principle, all analogue and digital functions known from the normal temperature range can also be implemented in high-temperature technology.



CMOS and CMOS-compatible processes

Fraunhofer IMS develops semiconductor devices and processes from the individual sub-step to a customized CMOS process. In addition to pilot production at the Fraunhofer IMS, these can be implemented directly in customer CMOS lines.

Experience and offers in the field of CMOS technology development at the Fraunhofer IMS
Fraunhofer IMS has over 30 years of experience in CMOS technology development and a complete, professionally operated 200 mm CMOS line with various robust CMOS processes, down to a development base with a structure size of 0,35 µm.

The IMS optimizes CMOS processes in the sense of the "More than Moore principle" by integrating additional functions such as high voltage resistant devices, high-frequency circuits, and sensors or by developing technologies that enable the use of the circuit under harsh conditions. Preparing CMOS wafers as "intelligent" substrates by e. g. planarization is also an important development task. These "intelligent substrates" layers are deposited and structured by post-CMOS processes to create new additional devices on the CMOS circuits.

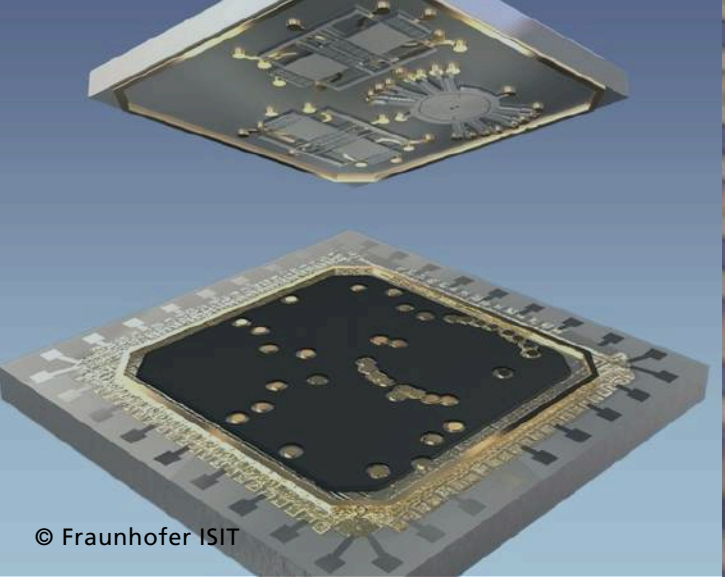
Development of application- and customer-specific CMOS processes
Examples of the complete development of customer- and application-specific CMOS processes are the mixed signal 0.35 µm automotive CMOS process and high-temperature (300°C) processes. Accompanying processes and component simulations (TCAD), as well as electrical characterization, including parameter extraction and reliability investigations, are part of the activities of Fraunhofer IMS.

Another important field of activity is the integration of unique devices and process modules into our or the customers' CMOS processes. This also applies, for example, to sensors in the form of optically sensitive devices such as SPADs (Single-Photon Avalanche Diodes) or pressure sensors. Our further fields of activities are circuit devices like non-volatile memories (EEPROM or flash cells), including specific circuit development, as well as high voltage devices. Special process modules for UV-transparent passivation and the removal of dielectric layers over a photodiode with subsequent deposition of an anti-reflective coating are also part of the Fraunhofer IMS repertoire.

Besides the integration into the CMOS, Fraunhofer IMS is also engaged in the development of CMOS-compatible processes for discrete devices such as SiPM (silicon photomultiplier), DEPFET (depleted p-channel field-effect transistor) or DOEs (diffractive optical elements), which also includes the development of corresponding interconnection technologies such as double-sided wafer processing.

Post-CMOS process for sensor integration
Planarized CMOS surfaces serve as the basis for post-CMOS sensor integration. Combined with "Micro-Electro-Mechanical Systems' ' MEMS or "Nano-Electro-Mechanical Systems' ' NEMS, sensor elements such as optical, mechanical, physical, chemical and biosensors can also be realized. Examples are uncooled bolometer arrays and nanowire gas sensors. Combining CMOS and MEMS (or NEMS) results in innovative and highly compact microsystems for use in medicine, industry, automotive, aerospace and consumer applications.

1. Professional CMOS Line.
2. CMOS wafer with 4-layer metallization and planarized passivation.
3. Front- and back-side of the double sided processed wafers.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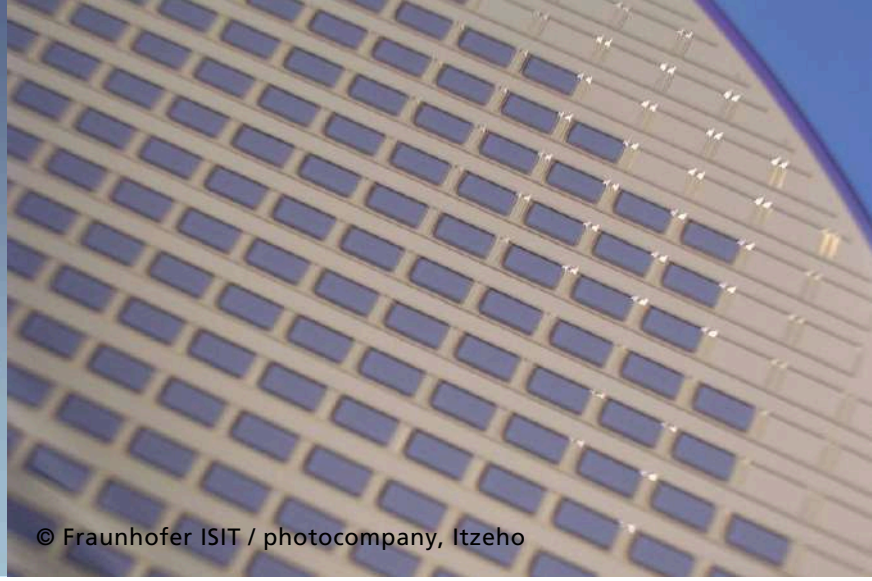
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Wafer-Level Packaging

The packaging of micro components on the wafer level uses the precision of semiconductor and microsystem technologies to realize robust and highly compact setups. The particular focus at ISIT is on the hermetic (vacuum) capping of microsensors and actuators as well as micro-optical components using different joining technologies such as glass solders or metals (IR imager wafers with IR windows made of Si). Packages with optically transparent window areas for the visible range to far infrared can be produced for micro-optical components.Wafer-level packaging is also suitable for post-CMOS processing of customer-supplied wafers. Applications for the technology platform include IR sensors and IR imagers, inertial sensors, magnetic field sensors, harvesters and MOEMS devices.

To maintain a vacuum in a very small package, the outgassing and desorption of gas molecules from the enclosed surfaces must be controlled. So-called getter layers make it possible to permanently bind free molecules of the most critical gas species - effectively acting as an "in-situ" pump that remains active throughout the service life of the final product.

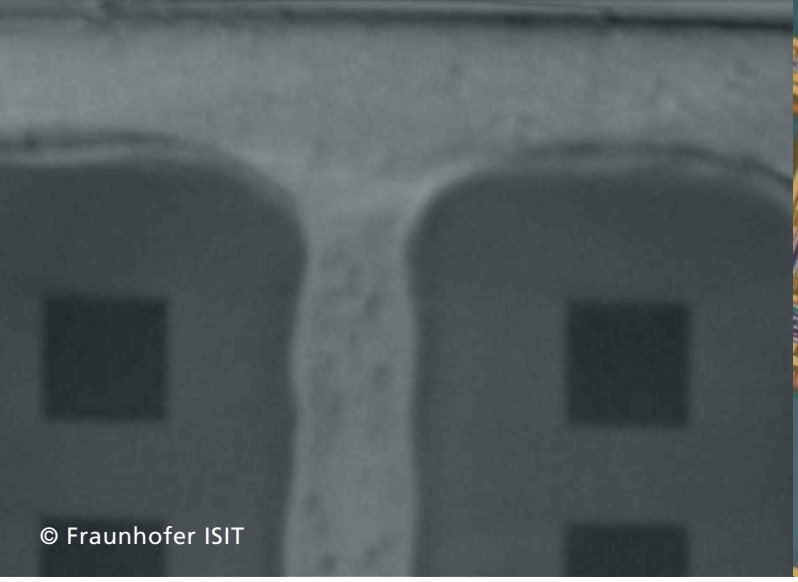
Checking the internal pressure in a wafer-level package can be important to estimate the expected product lifetime. To date, no general-purpose method exists that is cost-effective and sufficiently accurate to apply to any MEMS. However, ISIT has developed the "Neon Ultra-Fine Leakage Test" for MEMS resonators, which allows the detection of ultra-fine leaks based on the Q-factor of the electromechanical resonant circuit (damping fraction of the trapped gases) and, from this, a prediction of the expected pressure rise over the product lifetime.

WLP TECHNOLOGIES AT FRAUNHOFER

Cap Wafers
Developing and producing functionalized cap wafers is one of its core competencies. Depending on the application, glass or silicon wafers are used as base material. Glass wafers are usually processed with 3D glass micromachining, whereas KOH or reactive ion etching is used to form silicon cavities. Applications requiring a vacuum utilize getter layers as "in situ" pumps, whereas anti-reflective coatings are applied for optical applications.

Glass-Frit Bonding
One of the industrially most used processes for encapsulating MEMS structures in the past decade was based on glass-frit pastes, applied by screen printing to form sealing frames. The process is relatively robust, and in principle, it can be compared to soldering. However, to allow melting of the glass paste already at around 425°C, it contains lead oxides as an additive. A somewhat higher melting (ca. 440°C) lead-free glass frit system is available to reduce the environmental footprint of electronic packaging materials. The process technology requires about 200 µm wide seal frames that may be deposited on 300 µm wide silicon frames on the cap wafer.

Eutectic Bonding
Eutectic bonding is the connection of two wafers by forming an eutectic using one or several metals as an intermediate layer, e.g. gold and silicon. Despite the high melting points of gold and silicon in their pure form, a mixed phase already exists that is liquid at 363°C. This eutectic point allows a material engagement between both elements at the solid state. Bringing the surfaces into tight contact, the influence of heat and pressure leads to forming an interdiffusion zone that becomes liquid and thus accelerates the formation of the eutectic phase.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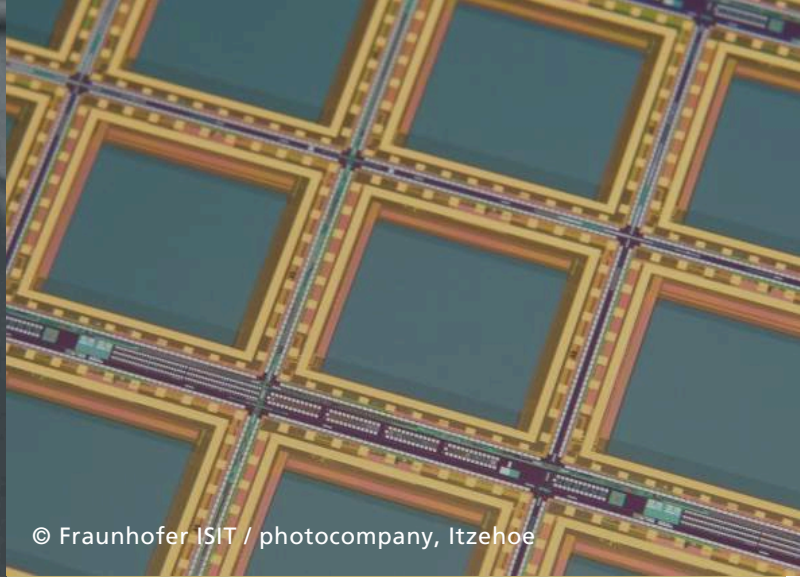
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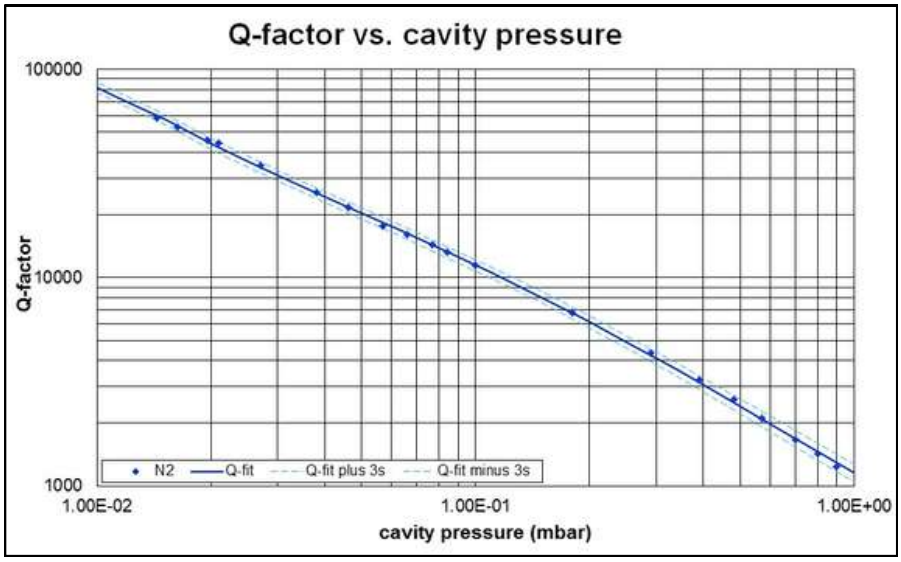
Only the precise control of force and temperature in this process and additional design measures allow to control the liquid phase and avoid non-intentional wetting of surrounding structures. Eutectic bonding is insensitive to surface roughness and tolerates even more significant r topography of the joining surfaces.

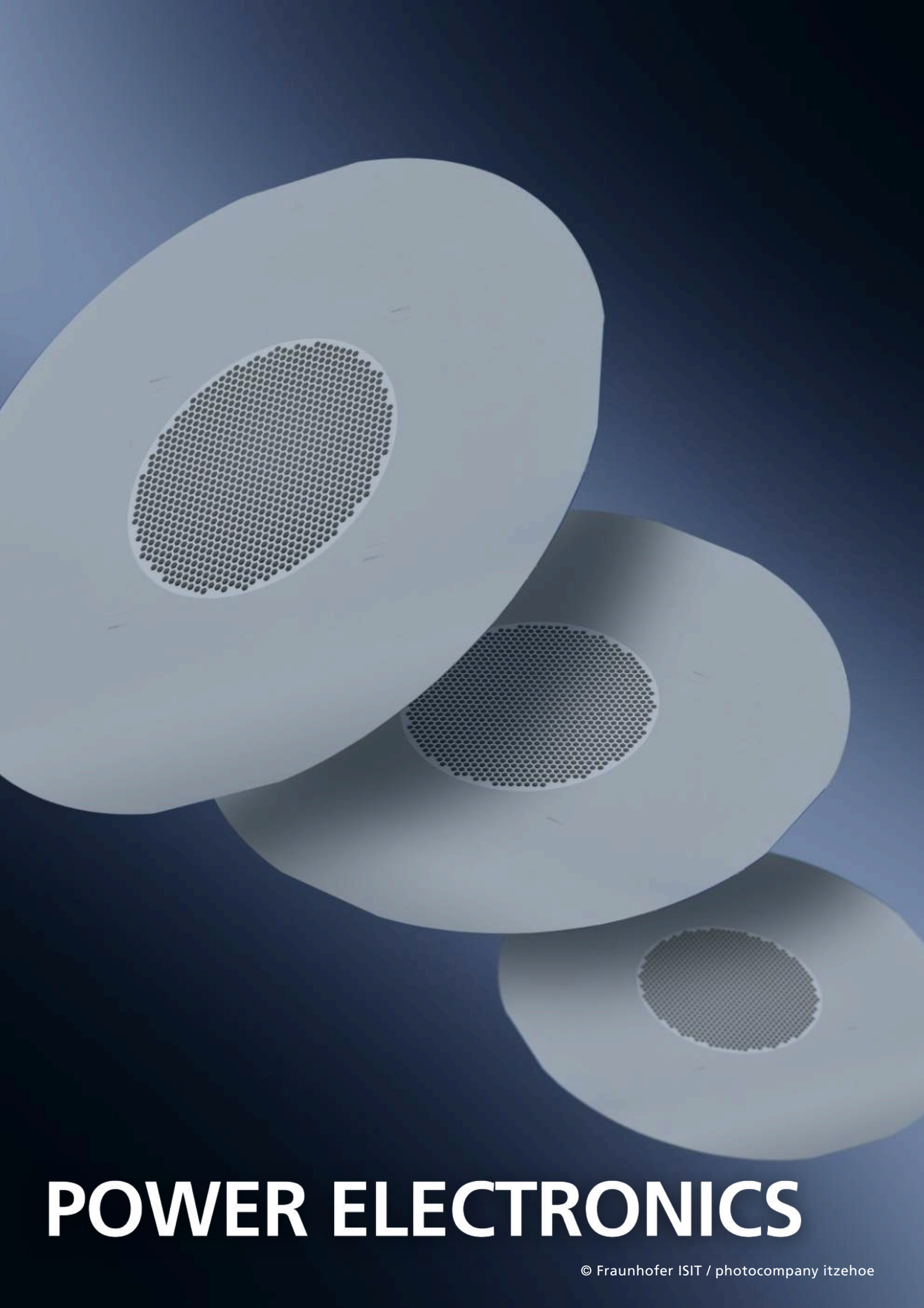
ISIT uses this process to package MEMS resonators and other wafer-based components with pre-fabricated cap wafers.

Anodic Bonding
Anodic bonding is a crucial technology for silicon glass wafer bonding. A similar thermal expansion coefficient of the two wafers is required to realize a low-stress wafer bond. Furthermore, a sufficiently high concentration of alkali ions is needed. These requirements can be fulfilled with borosilicate glasses like Borofloat® and Pyrex®. Nearly defect-free bonds can be realized with the aid of special cleaning techniques. Careful tuning of the wafer warpage enables further cleanroom processing. Despite the requirement of a polished surface, even prestructured wafers can be processed.

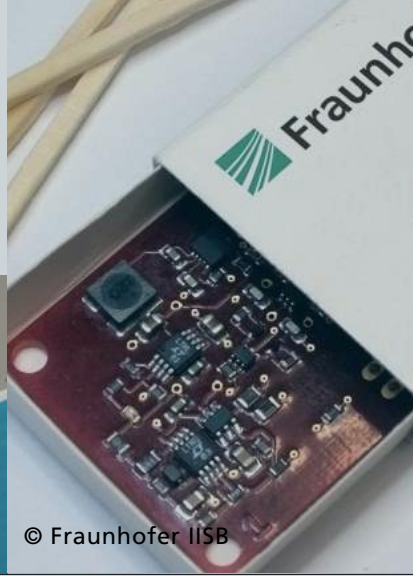
Neon Ultra-Fine Leak Test
An extremely long lifetime of up to 20 years is required by many applications today. To fulfill this requirement, the hermeticity of the sealing has to be verified. The air leak rate, which quantifies how much gas penetrates the sealing per time, is the main criterion for calculating the estimated lifetime of the device. If this value is known, the required getter capacity can be calculated easily. In the case of very small cavities, as they are formed by wafer-level packaging, air leak rates smaller than 10-14 mbar l/s must be measured, which is nearly impossible by conventional techniques.

The patented Neon ultra-fine leak test has been proven to detect leak rates as small as 10-17 mbar l/s. The only requirement is a micromechanical resonator with a high Q-factor. During the test, a batch of wafers is placed in a pressure chamber, which is filled with Neon. After some hours, Neon is diffused into the leaky devices. Since the getter does not interact with the Neon, the cavity pressure increases rapidly, resulting in a mechanical damping of the resonator. A following measurement of the Q-factor allows quantitative statements on the gas leakage.





POWER ELECTRONICS



Vehicle Electronics - Electronics with lowest energy consumption

Fraunhofer IISB takes a leading position internationally in power electronics for electromobility. This is evident from the numerous development projects with all large automotive manufacturers and suppliers. Many of the results have gained international attention.

We permanently strive to open up new applications and functionalities. The grid integration of electric vehicles, for instance, will gain more and more importance in the future. For avionic applications, the new possibilities of modern power electronics will pave the way towards the "more electric aircraft". This means powering many more actuators electrically to improve the overall fuel economy and reduce the maintenance efforts associated with hydraulic systems.

FOCUS AREAS

Drive Inverters & Mechatronics
We are working on innovative integration concepts and on new device, interconnection, and cooling technologies that foster a 3D integration, increase ruggedness, and decrease the costs of power electronics.

Battery Chargers
We provide on-board battery chargers (AC/DC converters) in the range from 3.7 to 22 kW for plug-in and pure electric vehicles, as well as DC battery chargers (DC/DC converters) in the range of 3 kW and much higher for ultrafast, high power applications.

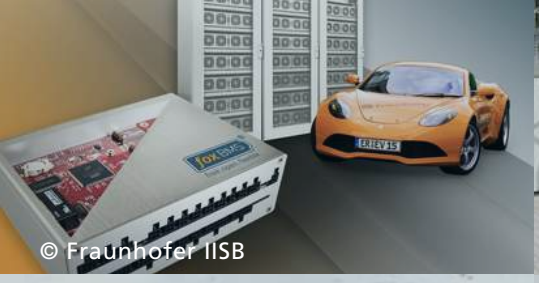
DC/DC Converters
We provide custom-specific DC-DC Converters for automotive, aircraft and stationary applications.

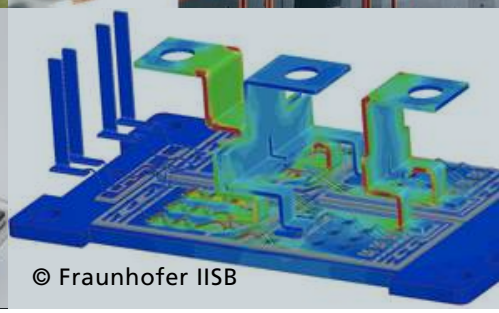
SIC/GAN Converters
Be our partner for innovative solutions with wide bandgap power semiconductors, and participate now in the future of power electronics!

Battery Systems
We offer advanced and innovative solutions for electrical energy storage systems. Our focus is on full-custom cost-efficient electric energy storage and management systems for mobile and stationary applications.

Aviation Electronics
We provide technologies for the High Voltage "Backbone" of a More/All Electric Aircraft: non-/isolating DC/DC converters, AC/DC motor/grid inverters, battery systems, and DC grid control technologies.

Medium Voltage Electronics
Multi-level systems are the key technology for efficient and cost-effective ship- and vehicle drivetrains and stationary energy distribution units in the voltage range of 1 kV up to 30 kV.





CHARACTERIZATION, INTEGRATION & SERVICES

Vehicle Test Center
Vehicles with electric drive trains place new demands on measurement and testing technology. The Fraunhofer IISB test centre offers a unique infrastructure explicitly tailored to these requirements, in which individual components from electric vehicles to complete vehicles can be measured and optimized.

Inductive Power Transmission
We develop and realize complete inductive power transfer systems from the FEM-Simulation, over power electronics analysis/simulation and mechanical integration to complete prototypes.

Device Characterization
With our comprehensive test facilities, we evaluate the potential of new active or passive components in close coordination with you. We also offer to convert measurements into powerful simulation models for your virtual prototype.

Electromagnet Compatibility
The EMC lab offers a wide range of services, from tests on prototypes over consulting in case of EMC problems and measurements according to harmonized standards to very detailed circuit and layout optimizations.

Power Electronics and Grid Integration

In Power Electronics and Grid Integration, we research, develop, test and evaluate power electronic components, circuits and innovative system concepts. We strive to set new standards, working together with our partners from industry and research to bring advanced ideas to the market.

Electricity from renewable energy sources is the future. It is the key to a sustainable and economical CO2-neutral energy supply. Power electronics are indispensable for successfully implementing the transition in the energy and transport sectors. Power electronic converters are required to ensure efficient conversion of electrical energy and regulate voltage and frequency in the future grid.

In modern energy systems, power converters connect photovoltaic and wind power plants, battery storage, electrolyzers, power consumers and electric vehicles to the grid. Power converters are increasingly used to regulate energy flows in the power grid, for example, in HVDC or STATCOM systems. Different types of power converters are required to address electrification in all areas of mobility. i.e., from vehicles to aviation. Furthermore, using power electronics in industrial environments allows more efficient production methods, and they are being used increasingly in modern heat supply concepts. The overall demand for power electronics and application-optimized system concepts is enormous today.

With the shutdown of conventional power plants, the question arises of how reliable voltage and frequency controls can be ensured in future converter-based grids. Today's implementation of power electronics in the grid is one of the most critical challenges for stable power grid operation. With our concepts for grid-forming converters, we offer integrative solutions that support the grid every millisecond. We simulate and test the secure operation of future electricity grids based on 100 % renewable energy. We constantly develop and improve our approaches and methods based on our learnings and experience.

We have extensive modern laboratory equipment at our disposal, which we use for our research work and services. For example, we can operate power converters in the low and medium voltage levels and address grid integration issues up to the multi-megawatt range.

Converter Based Power Grids
The current control in the European interconnected grid is based on the physical properties of the synchronous generators in large-scale conventional power plants. With their rotating masses, these generators provide the necessary electrical stability for the power supply. Therefore, a sufficiently high proportion of these so-called "must-run units" must be connected to the grid at any time to ensure a stable system operation. In an energy system based on 100 % renewable energy, power converters must assume all necessary system services, such as in photovoltaic and wind power plants or large-scale battery storage systems.

Various types of power plants connected by power electronics, such as PV plants, wind turbines, and battery storage systems, as well as HVDC converters, STATCOMs and electrolyzers, are suitable for grid-forming. However, since these converter-based plants, in contrast to electro-mechanical synchronous generators, do not inherently possess the corresponding electrical behaviour, appropriate new control structures must be developed, implemented, and tested.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This is the only way to ensure stable grid operation at any time in the future without large synchronous generators. For this purpose, we are developing novel grid-forming control methods for power converters, which can provide the grid with all system services and stabilize it during normal operation and during major disturbances.

Furthermore, the structure of the power grid will change fundamentally due to the decentralized installation of renewable generators. Therefore, we develop methods for the control and stability analysis of such decentralized converter-based grids of the future. In doing so, we investigate interactions between different power converters and between power converters and other grid components.

Verifying these new system services and behaviours is central to a stable, reliable, and resilient grid operation. We develop methods for verifying the grid-forming behaviour of power converters and new grid control methods. Furthermore, we test the new behaviour and grid services as well as the verification methods at the Multi-Megawatt Lab.

High Power Electronics and System Technology
To bring forward the renewable energy expansion set down by the German government, small decentral power plants, large multimegawatt-scale photovoltaic plants and large-scale storage systems must be installed. In addition to the classic grid feed-in, hybrid power plant solutions (e.g., PV/storage power plants), and industrial prosumer concepts, become important.

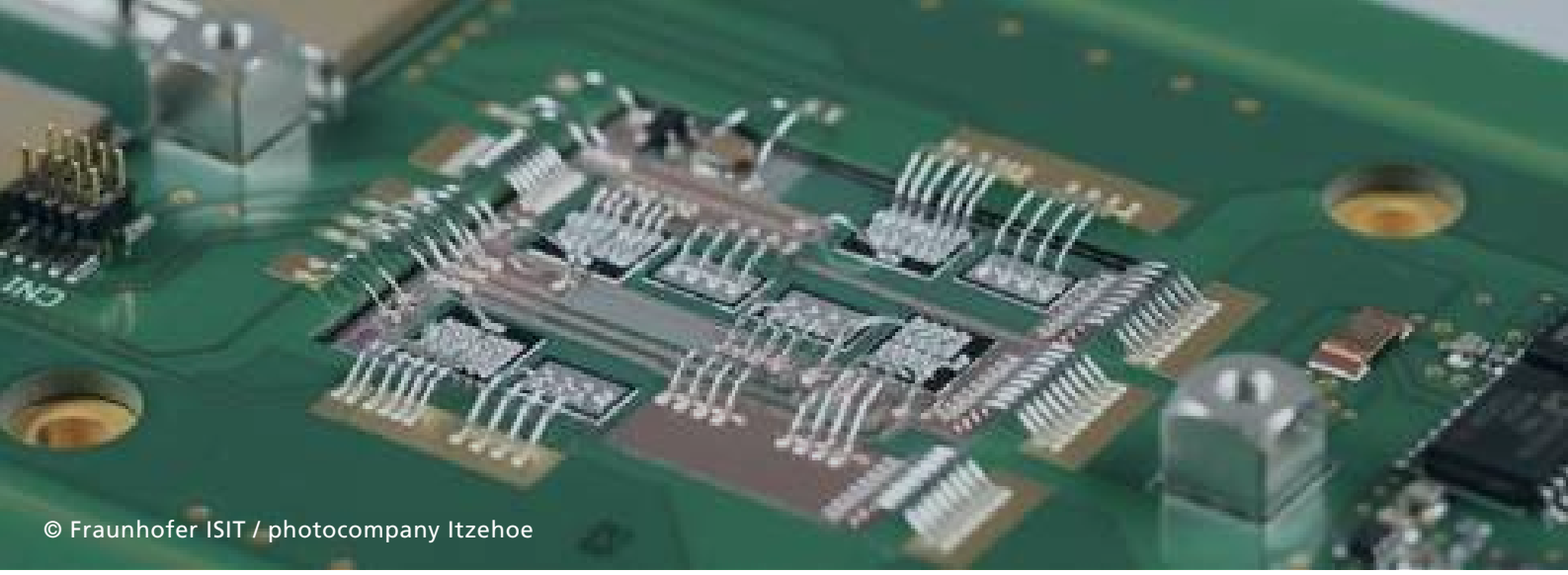
Within the scope of numerous developments for the industry and research projects, we have built up in-depth expertise around power converters from the low and medium voltage range up to the multi-megawatt range.

Our R&D objective has always been to optimize the overall system by applying new technological approaches to reduce the costs of power electronic systems during manufacture, installation, and operation. Our extensive laboratory infrastructure with test and development facilities for DC and AC systems in the voltage range up to 40 kV and power ratings up to 20 MVA forms the basis for our services on behalf of our industrial partners and contracting authorities.

In the low and medium voltage range, silicon carbide (SiC) transistors can be used to build compact and efficient power converters with and without galvanic isolation. The resulting higher switching frequencies open up new possibilities, e.g., for circuits with medium frequency transformers or compensation of harmonics up to the kHz range. In the future, single and three-phase inverters can operate directly on medium voltage without a transformer. This opens up new application opportunities, especially for renewable energy and power grids. SiC transistors also play a significant role in mobile applications, such as railroads, when saving weight and installation space.

Power Electronics for Electromobility, Photovoltaics and Storage Systems
In the domain of power electronics for electromobility, photovoltaic, and storage systems, we harness our extensive expertise and unique laboratory infrastructure. Our research focuses on enhancing power density, power-to-weight ratio, and integration density of these systems. Specializing in custom solutions up to 350 kW, we develop efficient converters for on and off-grid applications. The rising demand for sustainable mobility necessitates highly efficient, high-power converters to increase driving range and reduce charging times. Collaborating with OEMs and suppliers, we deliver innovative power electronic solutions.

Characterization Power Converters for Low and Medium Voltage
Our Multi-Megawatt Lab has unique equipment for testing power electronic devices and systems up to the multi-megawatt range. With an exclusive connection to the 110 kV high-voltage grid and our medium-voltage grid (available exclusively for the lab), we have ideal conditions for developing and improving measurement procedures and researching new characterization methods for power electronics.



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Packaging for Power Electronics

Besides die-attached soldering and Al- heavy wire bonding, new packaging concepts are being pursued to build power electronics systems that will shall provide improved thermal performance and higher reliability. By replacing the wire bond with an area contact on both sides of the chips, the thermal performance can be improved.

Silver sintering is one of the new die- attach technologies that results in a longer life of the whole power package. Silver is ductile; it has a high melting point and a very high thermal conductivity. Therefore, especially for a higher performance and higher operating temperatures, Ag sinter joints are very promising. There is another new joining technology currently under development that is referred to as "transient liquid phase soldering" or "bonding" (TLPS or TLPB). The idea behind this technology is that the Sn-based solder is transformed into intermetallic phases that have a higher melting temperature than the solder alloy had before the joining was carried out. The higher melting point is necessary to withstand higher operating temperatures or to withstand subsequent soldering processes during manufacturing.

The wire or ribbon bonds may also be improved regarding their lifespan. Using Cu wire instead of Al reduces the thermal mismatch between the Si die and the wire bond material. In order to be able to use Cu bonds, the power chips have to have a Cu metallization on top. The IZM has the capability to deposit Cu layers on semiconductor wafers using electroplating.

Last but not least, the power package is accomplished by applying an encapsulation material, which can also be done at the Fraunhofer IZM.

IZM-services relating to packaging and interconnection

- Die-attach for high-temperature applications (Ag sintering and transient liquid-phase bonding)
- Development of alternative technologies like flip-chip, ultrasonic bonding, Cu heavy wire and ribbon bonding, and sandwich assemblies (double-sided cooling of chips)
- Ultrasonic welding of load connections
- Heavy wire bonding (up to 500 µm) of power modules
- Ribbon laser bonding
- Packaging of GaAs, InP, SiC, and GaN, as well as thinned semiconductors
- Encapsulation of power modules
- Wafer-level packaging of power semiconductors
- Embedding of power modules

SYSTEM DESIGN FOR POWER ELECTRONICS

The energy efficiency of power-consuming products, from switched-mode power supplies to electric and hybrid cars and railway traction drives to large industrial drives, is crucial. All of the latter technologies and more rely on power electronics, and each makes individual demands on the system, which have to be taken into account during the circuit design and layout.

Good solutions for improving energy efficiency and miniaturizing of inverters include wide-bandgap (WBG) semiconductors like silicon carbide (SiC) and gallium nitride (GaN). However, taking advantage of their capability requires a particularly tightly integrated electrical, thermal, and mechanical design of the complete system, in order to facilitate the possibly high switching speeds and to take into account all relevant EMC aspects, while ensuring optimal thermal management of semiconductors and the package as a whole. This trend is leading to complete system solutions, where the switching cell itself incorporates passive components such as DC-link capacitors and output filters. Control and regulation, as well as safety functions are integrated into the package directly, rather than connected at a later stage.


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IZM-services relating to system design

- Design and optimization of power modules for SiC/GaN /Si
- Topology investigation, design and miniaturization of power converters
- Miniaturizing drivers for power assemblies, particularly for WBG-semiconductors, to enhance control
- Passive components, particularly the design and qualification of inductive components
- EMC-compatible design using modelling and simulation of electromagnetic interference phenomena at the system level
- Development of EMC concepts, filters, and shielding
- A broad range of simulation tools for all design phases, including Matlab, Simplorer, Portunus, Solid Works, FEM- and PEEC-Tools, including thermal design (supported by thermal and fluidic simulation)
- Building prototypes, especially with WBG -semiconductors
- In-house laboratory for prototype testing and characterization

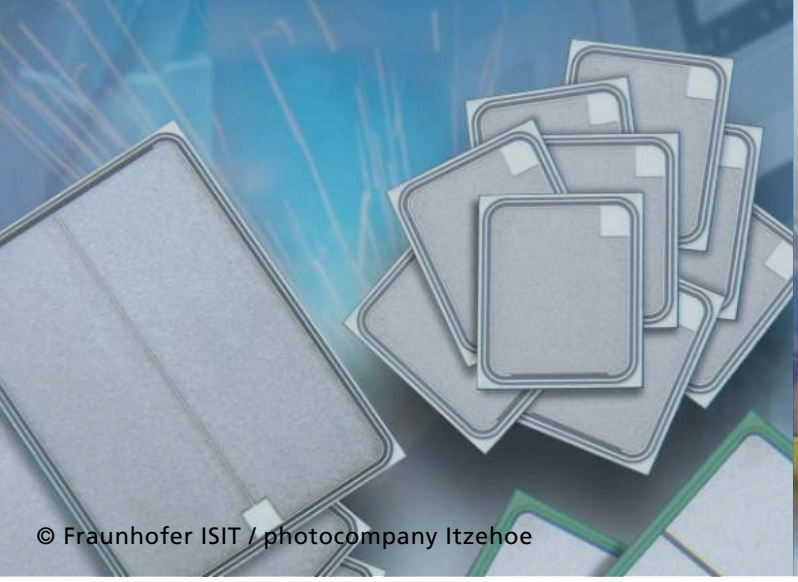
TEST AND RELIABILITY FOR POWER ELECTRONICS

Apart from ensuring the best possible thermal system design, understanding thermo-mechanical behavior at package, component, and module levels is critical for ensuring overall system reliability. Thermally and thermo-mechanically induced failure mechanisms can lead to premature failure and limit life.

Smaller package dimensions result in shorter diffusion outlets for external humidity stress. This can result in increased electro-chemical degradation mechanisms that usually lead to failure and, thus, a shorter lifetime of the electrical circuits. For this reason, it is very important that crucial parameters such as (extreme) operating conditions with system-level impact (e.g., operating temperatures and humidity) are already modeled and optimized in the early stages of the design process. The aim is to maximize reliability while keeping costs and effort low.

IZM-services relating to testing and reliability

- Selection and qualification of suitable materials
- Failure and damage analysis
- Test benches for combined and accelerated lifetime testing (vibration, temperature, temperature cycling, moisture)
- In-house testing and characterization of prototypes
- Modelling failure mechanisms for new material combinations
- Simulation for cost-efficient design changes and their potential for success compared to existing geometries
- Investigating the driving forces and influence parameters of failure mechanisms relating to corrosion and migration effects
- Improving design with a view to harsh environments
- Metallography, EBSD, FIB, REM, and EDX
- Ultrasonic and X-ray microscopy, as well as X-ray CT
- Quality and reliability analysis
- Condition monitoring concepts derived from system and failure analyses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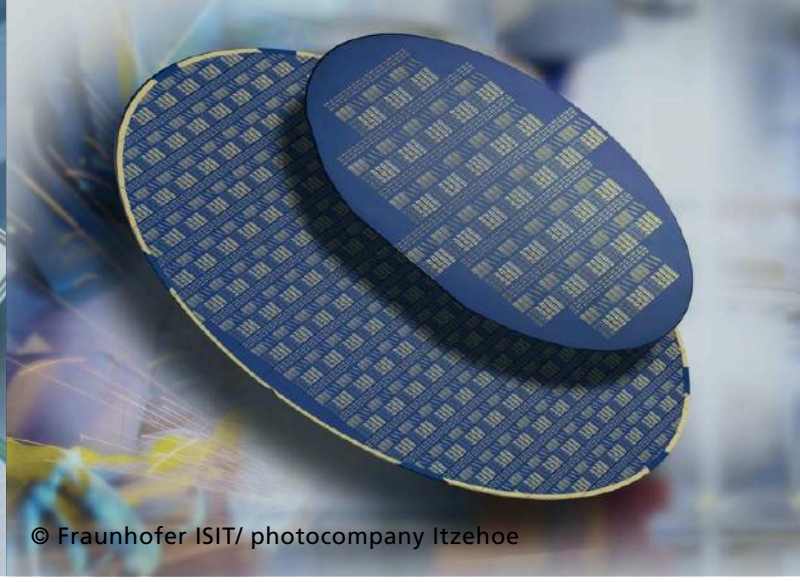
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Development of technologies, components and system concepts for high-performance energy systems

The business unit Power Electronics at Fraunhofer ISIT develops and manufactures innovative active and passive power semiconductor components based on silicon and gallium nitride develops power electronic systems and integrates them with high-performance accumulators for special applications towards high-power storage systems.

The advanced power transistors and diodes from Fraunhofer ISIT enable applications in a wide voltage range from 10V to 1200V. The development portfolio ranges from silicon-based IGBTs, diodes and MOSFETs to diodes and transistors for the highest switching frequencies in the MHZ range based on gallium nitride in a modern 8" manufacturing environment.

On a system level, the ISIT offers the development of novel circuit topologies and integration concepts for highly efficient DC/DC and DC/AC power converters using application-specific power semiconductors targeting an optimized overall system performance and long-term reliability. Key fields of application for these ISIT services are in the fields of renewable energies, e-mobility, and electric flying.

ADVANCED DEVICES

From Planar to Vertical: Custom Solutions for Advanced Si- and GaN-based Power Electronics
Fraunhofer ISIT supports the continuous miniaturization of power electronics applications while increasing power density on system and device levels and offers the development of devices such as application specific silicon based PowerMOS transistors, IGBTs and diodes with reverse bias capabilities up to 1200V as well as advanced gallium nitride-based power transistors and diodes with excellent electrical properties and switching speeds down to the ns range.

Your Benefits
A particular R&D focus is application-specific device design and developing new device architectures. Another important research topic is the development of new processes for advanced power devices at the wafer level. ISIT is also developing front and backside contacting methods for gallium nitride devices for bulk GaN wafers and GaN-on-Si wafers.

For system integration of passive devices, Fraunhofer ISIT offers the development of chip capacitors, precision resistors and inductors, and corresponding chip-level circuits. At ISIT, the complete development chain from simulation and design to the development of single processes and entire process lines on 8" manufacturing equipment and numerous characterization tools is offered.

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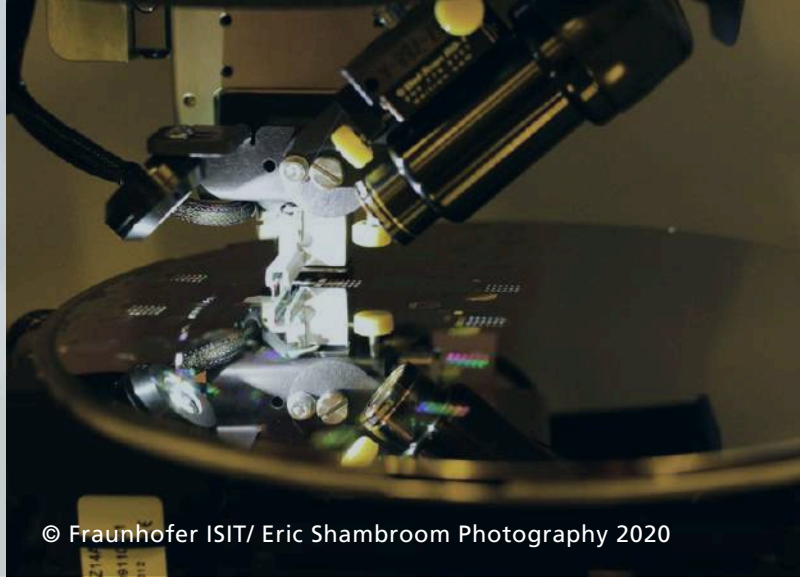

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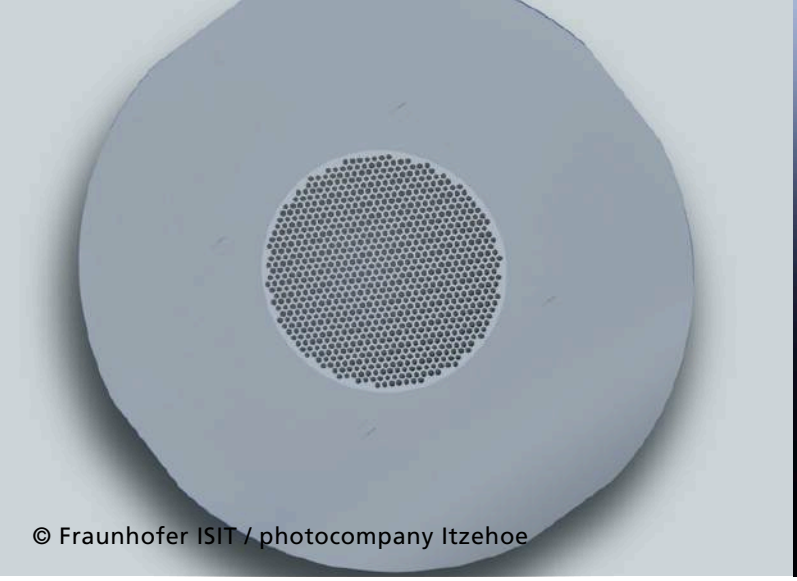
ELECTRONIC ENERGY SYSTEMS

Highly available and efficient power conversion
Fraunhofer ISIT supports the energy transition and the expansion of power electronics-based energy conversion to mission-critical applications.To this end, the institute develops a broad spectrum of competencies ranging from designing and manufacturing power devices to understanding and considering application-specific constraints and their interactions.

Optimal performance is achieved by combining innovative hardware and software solutions such as e-mobility and its charging infrastructure, low and medium-voltage microgrids (renewable energy, hydrogen and battery integration, smart transformers) and other mission-critical applications such as data centres.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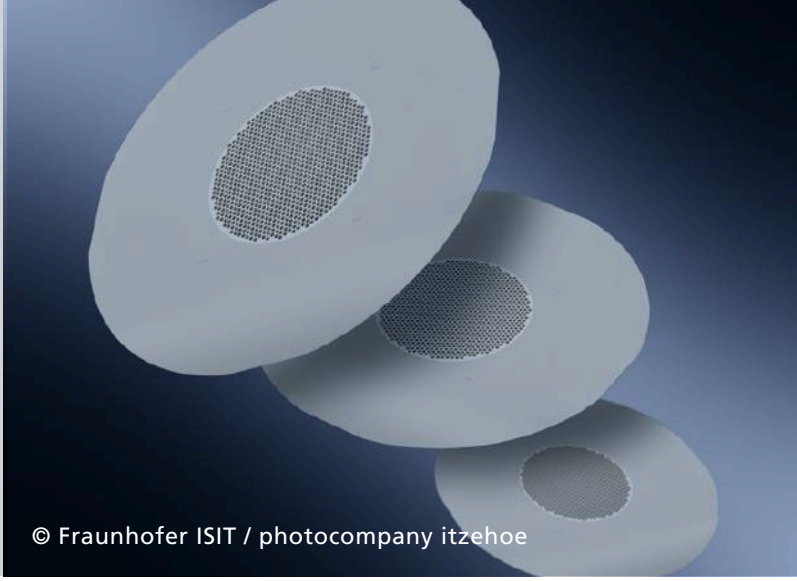
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Silicon Membrane Technology - Smallest structures for detection & analysis of micro/nanoparticles

UNIQUE ADVANTAGES AND APPLICATION POSSIBILITIES OF MEMBRANE TECHNOLOGY

Technical specifications
- Pore sizes: 200 nm and higher
- Membrane thickness: 2 µm
- Coating materials: Al, Au
- Filter diameter: 25 mm (filtration area 10 mm)

Examples of application
- Filtration against contaminants (micro/nanoplastics, viruses, etc.)
- Gas and liquid filtration
- Lab-on-chip diagnostics
- Optical filters

Smallest structures for detection and analysis of micro/nanoparticles
Fraunhofer ISIT has developed a silicon membrane technology to create filters for various material analyses. The technology offers a polymer-free realisation of filter structures to analyse micro- and nanoparticles. The filter structures enable particle visualisation, sizing and identification. Different surface coatings can be used to achieve low spectroscopic interference. Numerous pore diameters can be realised for different filtration ranges.

Silicon membrane technology offers all design dimensions of filter structures with the advantages of diverse surfaces such as aluminium oxide and gold coating. Our silicon membranes have a homogeneous filter surface (unlike polycarbonate or glass microfiber filters).

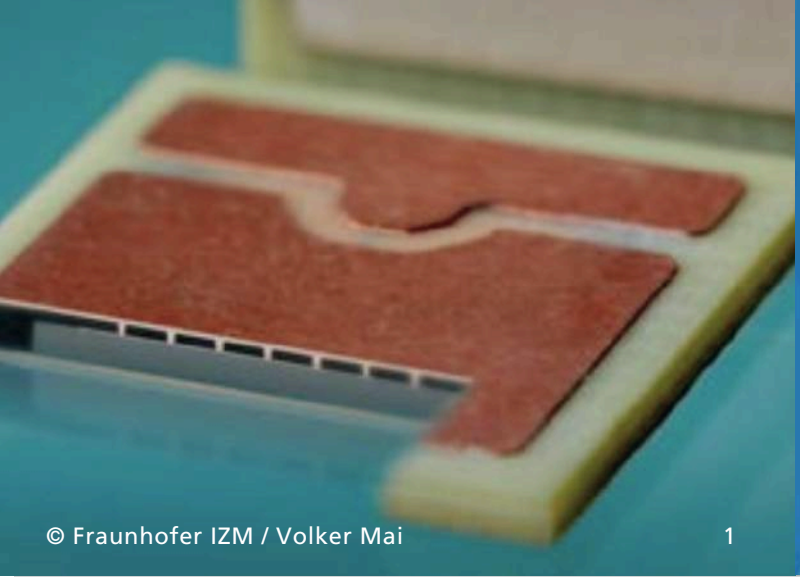
Examples of applications are Micro/nanoplastic detection, gas and liquid filtration, diagnostics and optical filters.

TAILOR-MADE POROUS SILICON MEMBRANES

Objectives & Challenges
- Filter membrane structures reaching nanometer level opening
- Ultra-flat surfaces with the highest pressure withstand
- Numerous degrees of freedom in geometry and dimensions

Development & Production
- Design of the porous silicon membranes
- Pores adaptable in d
- Adaptable, regularly distributed pores (nanometre scale)
- An Integrated system that allows orientation on the filtration surface
- Surface treatment to achieve a higher contrast level
- Pilot production by electrochemical etching
- Aluminium and gold coatings

Achievements
- Filter membrane structures up to 200 nm aperture
- Ultra-flat 2 µm surfaces
- Precisely regularly distributed pores (sizes from 200 nm and higher) with an integrated orientation system



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Longer ranges for electric cars with silicon carbide

The performance of electric cars depends primarily on the power electronics installed. Semiconductors based on silicon carbide (SiC) play a unique role in this context because SiC chips promise longer range, higher energy efficiency, less weight, and lower costs.

When installing electronics for electric cars, space, weight, and efficiency are the most important. SiC is not only highly efficient; it can also be installed in a remarkably compact manner. This is a decisive advantage compared to conventional silicon semiconductors.

New assembly and connection technology

The key to SiC´s success lies in packaging. In the SiC Module project, researchers from the Fraunhofer Institute for Reliability and Microintegration IZM and seven other partners from industry and research are working together to develop a robust assembly and interconnection technology that enables the material to be used in large-scale industrial production. For this reason, the module the researchers are developing is based on a classic printed circuit-board structure already established in the industry.

With embedding technology towards series production

At the same time, the module incorporates the latest findings from research: the semiconductor is not contacted with a wire bond connection but is embedded directly into the circuit via a galvanic copper contact. This way, the cable length is shortened, and power conduction is optimized. The research team also involves potential customers in the development process: in the first year of the project, a specification sheet was drawn up together with the project partners, in which the electrical, thermal, and performance-related requirements for the module and semiconductor were defined.

Lars Böttcher, group leader at Fraunhofer IZM and sub-project manager for the SiC project, explains: "We are going beyond general feasibility" because the project is intended to develop more than just a prototype. The goal is to bring both the new semiconductor material SiC and the embedding technology towards series production. The project is funded by Germany's Federal Ministry of Education and Research (BMBF) within the framework of the E-Mobility call with a project volume of €3.89 million and runs from January 2018 to December 2020.

Power electronics at the Research Fab Microelectronics Germany

Fraunhofer IZM and six other institutes are part of the Power Electronics Technology Platform of the Research Fab Microelectronics Germany (FMD). Here, the skills are bundled into individual components from the institutes. This way, a product range covering the entire power electronics value chain – from devices and integration to system-level developments – is created. In an interview (see page 5), Dr. Andreas Grimm, platform manager for power electronics, discusses the need for energy-efficient components.

1. Embedded silicon carbide – the SiC Module project is researching new assembly and connection techniques.
2. Power electronics is the heart of e-mobility. Space, weight, and efficiency are decisive for the performance of e-cars.

Active Power Cycling Lab

KEY DATA

Devices:
- IGBTs / MOSFETs / Diodes
- Semiconductors: Si, SiC, und GaN

Test system 1 to 4:
- Three load strands with 6 measurement stations each
- Up to 30 V at 800 A / 120 V at 200 A
- Three NTC measuring points per strand
- Zth measurement
- Recording of cooling curves

Test system 5:
- Independent tests with constant temperature swing
- 48 measurement/load stations
- 30 V constant with max. 10 A per sample

Temperature control:
- Air- or liquid-cooling
- Different coolant mediums depending on the application
- Heat sink temperatures from -40 °C to +200 °C
- Flow measurement and pressure monitoring

Calibration:
- IR-camera
- Climate chamber
- Coolant

The suitable test method
Quality assurance of power electronics is an essential factor in product reliability. The active power cycling test provides instant lifetime data for power modules. The corresponding area of application (e.g. wind energy, photovoltaics, automotive) determines the related test parameters and procedures. We offer comprehensive consultation to find the correct test method about the specific mission profiles.

Life time of power electronics
Based on the active power cycling tests, we can create lifetime models of the power modules and advise you on the correct design for the power devices and the interconnection technology (e.g., wire/ribbon bonds, die-attach).

PowerLab
We design client-specific test conditions and settings for the tests of power components or overall systems. Automated test systems are used to carry out lifetime studies by active power cycling perautomotive standard LV 324.

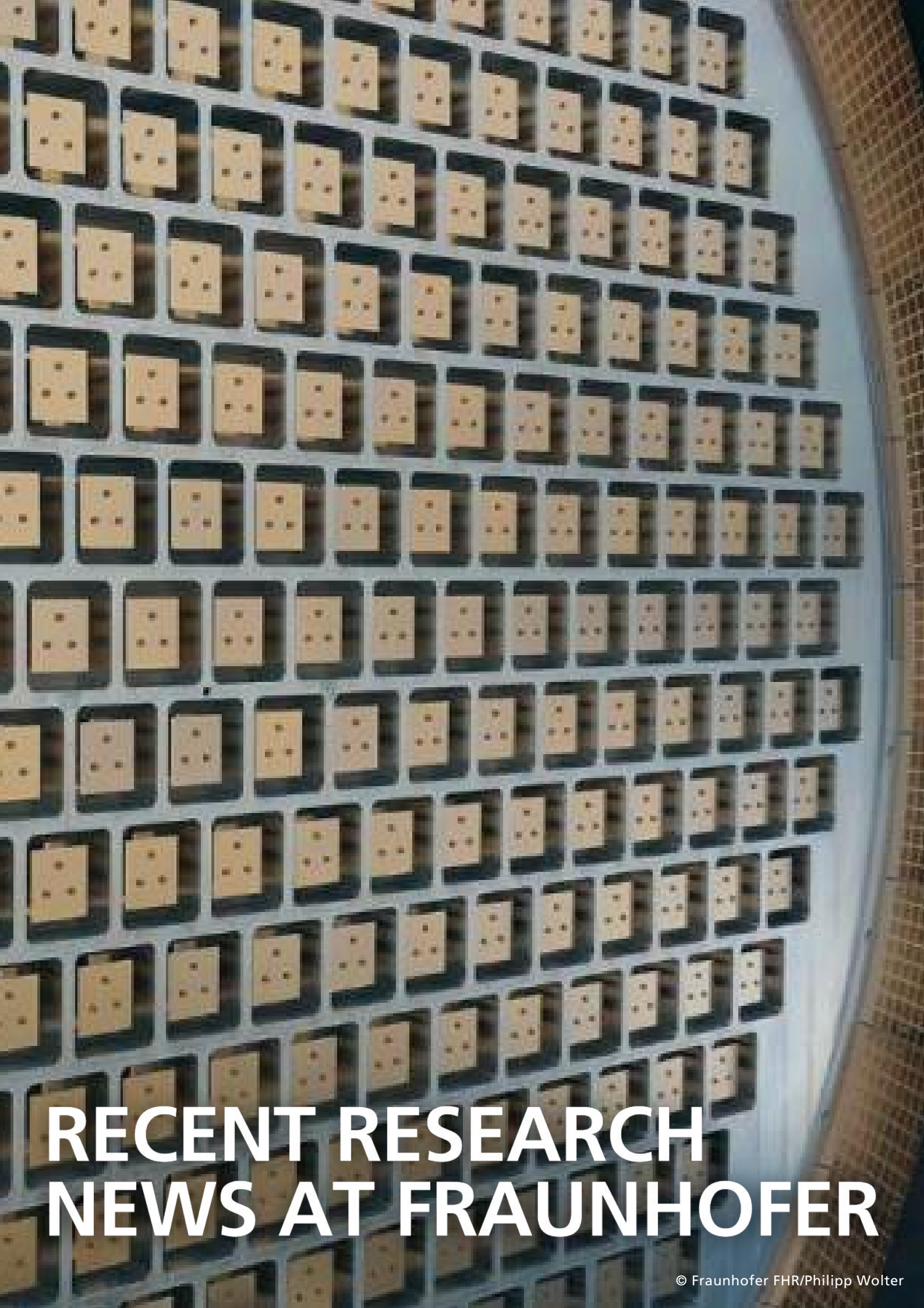
To reach a specific temperature swing, the DUTs are actively loaded with direct current while taking measurements of the forward voltage and of other thermal and electrical parameters. The heat sink temperatures are controlled with several adjustable tempering devices.

Implementing combined tests of active power cycling with different temperature profiles for heat sinks and ambient air with defined humidity in the climate chamber. Thus, long-term tests can be conducted under precisely defined ambient conditions.

Services
Fraunhofer IZM meets its customers' special requirements with highly individual solutions. Monitoring of additional parameters with measurements in the MHz range is possible over a period of several months. Additionally, infrared thermal visualization of open modules' chip surface temperature is possible.

Superimposed failure mechanisms can be tested at Fraunhofer IZM by advanced test setups. Combined testing of active power cycling with humidity and temperature is also available.

Fraunhofer IZM can advise with planning of such tests as well as conduct these and perform evaluation towards lifetime assessment.



RECENT RESEARCH NEWS AT FRAUNHOFER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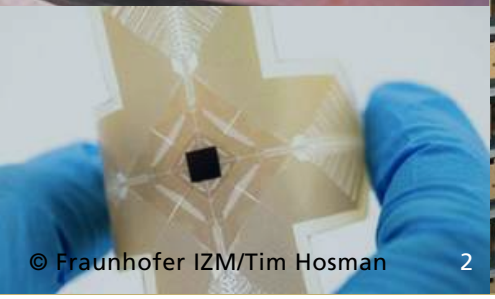
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Smaller, faster, more energy-efficient, and powerful devices for digital transformation
Highly efficient power semiconductors are paving the way for a wide range of new applications, from electromobility to artificial intelligence (AI). This is the aim of the project "Power Transistors Based on AlN (ForMikro-LeitBAN)," which was started in 2020 and in which FMD members Fraunhofer IISB and Leibniz FBH are also involved.

GESTRA: The near-earth orbit always "in sight"
In order to monitor the near-Earth orbit and to know which objects are moving there, a phased array radar with high beam agility is required. Fraunhofer FHR has built such a system on behalf of the German Federal Ministry of Economics and Technology. In autumn 2020, the researchers officially handed over the semi-mobile space surveillance radar GESTRA to the German Aerospace Center (DLR).

Electricity, not pills—a flexible implant with 324 electrodes
Fraunhofer IZM and the Delft University of Technology are developing electroceuticals for the drug-free treatment of chronic diseases. Electroceutical implants can electrically stimulate nerve cells in a targeted manner to trigger or block body signals or to send them to other places in the body. Physiological processes can thus be activated or inhibited, depending on the nature of the disease.

Reliable localization in a bioreactor
Fraunhofer ENAS is developing a new localization method based on magnetic fields. The inductive system allows reliable localization even in non-homogeneous and opaque substances. We plan to use the inductive system to localize Sens-o-Spheres in bioreactors as a first application.

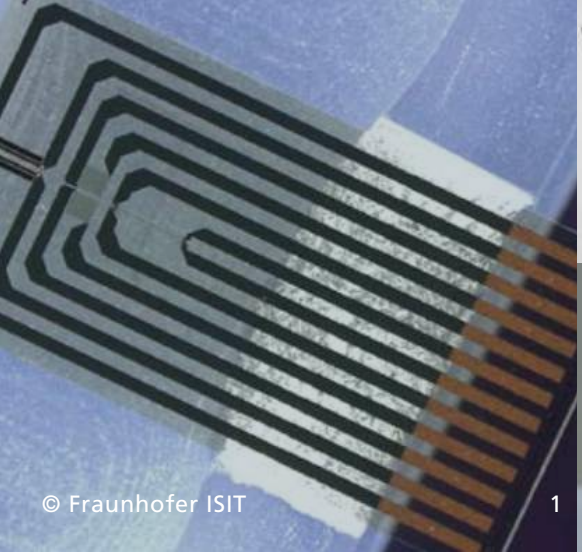
A new process for CNT integration
Carbon nanotubes (CNTs) are a promising functional material in nanoelectronics and sensor technology. Therefore, Fraunhofer ENAS has developed a modular process that overcomes previous hurdles in the integration of carbon nanotubes.

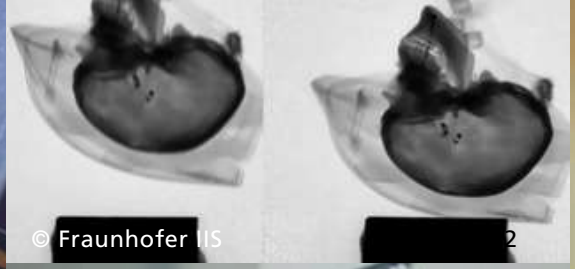
Wristband for personalized dementia therapy
In Germany alone, almost 1.6 million patients suffer from dementia, and the number of new diagnoses is on the increase. The health and care parameters indispensable to professional treatment are often not measured quickly enough or in a sufficiently structured manner. That is why Fraunhofer IZM is working with partners from industry and research on a wristband that automatically measures and processes this data.

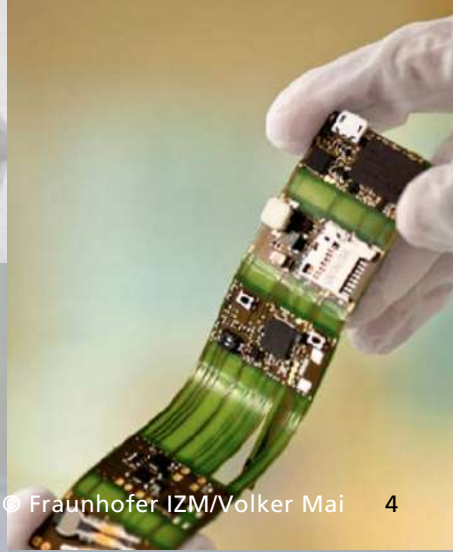
A monitoring system that can hear production errors
In industrial production, the testing of machines and products by means of acoustic signals still plays a niche role. Researchers at Fraunhofer IDMT have developed a cognitive system that can hear erroneous sounds more objectively than human hearing. The technology was proven in initial practical tests, in which it detected up to 99 percent of the errors.

Water disinfection with ozone
Together with partners from industry, Fraunhofer ISIT is developing an ozone generator for water disinfection. Ozone is an effective and environmentally friendly disinfectant. With the help of a boron-doped diamond layer, it can be generated electrolytically directly from water. This method is fast, safe, and allows for an exact dosage. Within the framework of the "MIKROOZON" project, funded by the state of SchleswigHolstein, a miniaturized ozone generator with integrated sensor technology and microprocessor-based control is being developed. It is to be used for the regular disinfection of small and household appliances, shower-toilets, and beverage dispensers. Device manufacturers can easily integrate the generator into their systems and thus develop individual hygiene solutions for their customers. Fraunhofer ISIT contributes the electrode substrates of the electrolysis cell and a sensor chip to the ozone generator. This chip monitors the parameters of mass flow, temperature, and conductivity.

1. Aluminium nitride crystal as semiconductor base material for power electronic devices.
2. The flexible implant with 324 electrodes and integrated electronics stimulates and records neuronal activity on the brain surface.
3. Phased array antenna of the GESTRA transmitter and receiver.
4. Sens-o-Spheres have a diameter of only 8 mm.
5. The Fraunhofer IDMT offers procedures for the end-of-line inspection of car parts, such as motors for seats, for the sake of automated quality analysis by means of airborne sound measurement.







A control unit processes the measured data and controls the ozone production of the MIKROOZON cell in order to optimize the operating conditions and extend the life of the cell. In addition to Fraunhofer ISIT, GO Systemelektronik GmbH and CONDIAS GmbH are involved in MIKROOZON.

Sensitive detection of cancer cells in lymph nodes
With the help of lymph node diagnostics, it is possible to determine whether a tumor has already spread in the body and formed regional metastases. An interdisciplinary team of researchers from the Fraunhofer Institutes IIS, IPA, and ITEM and the University Hospital Regensburg has now optimized and automated this diagnostic method. Up to now, the lymph node tissue removed has been hardened in the laboratory, cut into thin slices, and examined under the microscope. Tumor cells may remain undetected because only a small part of the tissue is naturally examined in this so-called sectional diagnosis. In the newly developed approach, the tissue is no longer cut up but broken down into individual cells. A team at Fraunhofer IPA has developed the necessary grinding device, the TissueGrinder. In the next step, the tumor cells are stained with methods based on Fraunhofer ITEM's findings. After that, a whole slide scanner automatically digitizes the entire slide. Fraunhofer IIS uses AI-based image analysis to detect individual tumor cells with high sensitivity and reliably distinguish them from other artifacts, such as color aggregates or unspecifically stained cells. Finally, tumor cells detected this way can be localized with micrometer precision, "isolated" from the slide, and, thanks to DNA amplification, subjected to individual molecular diagnostics (Fraunhofer ITEM). Researchers evaluated this workflow on patients diagnosed with both skin cancer and lung cancer. Thanks to automation, the new LyDia HD diagnostics are not only more accurate but also faster and more cost-effective than previous methods, providing important information about tumor cell characteristics. The new system thus creates an important prerequisite for the personalized medicine of the future. The project was successfully completed in 2019. Fraunhofer is currently evaluating additional samples to publish the results of this evaluation. Fraunhofer is looking for commercialization partners for the system. As part of the Fraunhofer spin-off program AHEAD, a start-up is currently being prepared with the aim of making the TissueGrinder subcomponent of this workflow commercially available from autumn 2020.

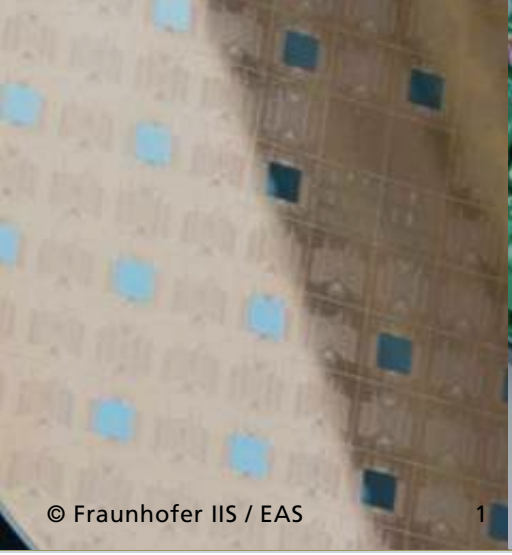
High-speed X-ray: New technology records dynamic processes
The Development Center X-ray Technology EZRT of the Fraunhofer IIS has developed a technology for the simultaneous recording of internal and external structures in dynamic processes.

The investigation of structures that are subject to unique dynamic changes—e.g., failure and deformation analyses, flow and mixing processes in fluids, or functional tests for airbags—is an important step in many product development and optimization processes. Imaging methods with high temporal resolution, which record more than 1000 images per second, are applied to capture processes that are otherwise too fast for the human eye. Until now, however, it has been necessary to decide whether to use high-speed cameras to observe the outer structures or X-ray technology to observe the inner structures. In addition, temporally high-resolution X-ray imaging is so far only possible under highly specialized laboratory conditions.

Technology allows for more precise analyses
With its new technology solution, the Development Center X-ray Technology EZRT makes it possible to record both structures in parallel. This enables precise nominal actual value comparisons and offers the potential to optimize product quality, especially in the pre-development phase of new products.

Development of optimized X-ray detectors
With a detector area of 40 × 40 cm², the measurement setup of the demonstrator covers an image section of 30 × 30 cm². In principle, however, the technology can be scaled to almost any size. The system has already proven its potential in various experiments and has, e.g., been tested on various helmets in cooperation with the sporting goods manufacturer Uvex Sports.

1. The sensor unit of the ozone generator is integrated on a glass chip. It monitors the water flow into the electrolysis cell.
2. Crash test of a bicycle helmet with an artificial skull. The impact can be followed in slow motion by means of X-ray technology. There are about 11 ms between the two images.
3. The TissueGrinder enables gentle tissue dissociation.
4. Sample view of a shape-adapted electronic layout in the wristband.



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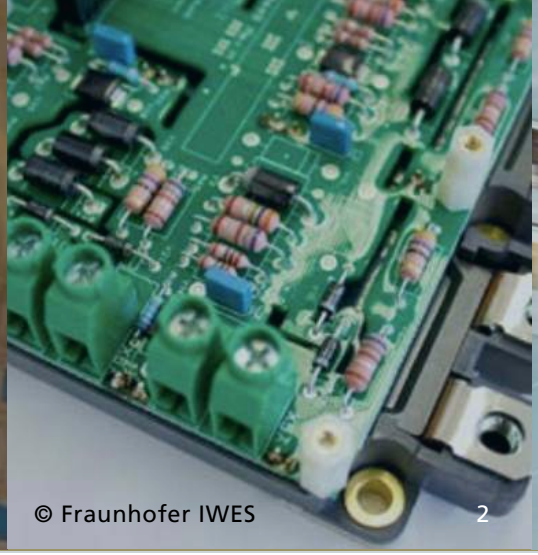

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© VVC 3

Robust converters for renewable energy plants
In the "power4re" project (Reliable converters for renewable energy supply), researchers are working on increasing the reliability and robustness of converters for wind power and photovoltaic plants.

Converters are a key technology for the energy transition. Converters enable the electricity generated by wind power and photovoltaic plants to be fed into the electricity grid. However, they are exposed to harsh environmental and operating conditions and are thus among the most failure-prone system components. High losses accompany failures. Therefore, more durable converters have great economic potential.

The aim of the power4re project is to use a converter. © Fraunhofer IWES field data and damage analyses to investigate application-specific weak points and failure mechanisms. Thus, the project aims to develop a concept for more reliable and robust converters and establish a procedure for testing the components. The findings can also be transferred to other applications, such as rail transport, aviation, or electromobility. The Fraunhofer Institutes IISB, IMWS, ISE, IWES, and IZM, as well as partners from industry, are involved in power4re.

Manufacturing technologies for 3 nm semiconductors
The next generation of highly integrated microelectronics requires the development of new manufacturing technologies. To this end, the European "PIN3S" project is working on processes for the production of ICs with lead spacing of only 3 nm.

These integrated circuits come close to the limits of what is physically possible. They will significantly exceed the performance of today's circuits and thus enable applications with particularly high computing power. In autonomous driving, machine learning, or large data centers, they can contribute to leaps in development. In all aspects of manufacturing and the associated measurement technology, innovations are needed to reliably produce such structures for high-performance computer chips.

The pilot production line in PIN3S brings together and evaluates novel technologies for the first time. Furthermore, we are actively developing the infrastructure to ensure defect-free production of highly precise masks for wafer production, which serve as templates for the structures to be manufactured.

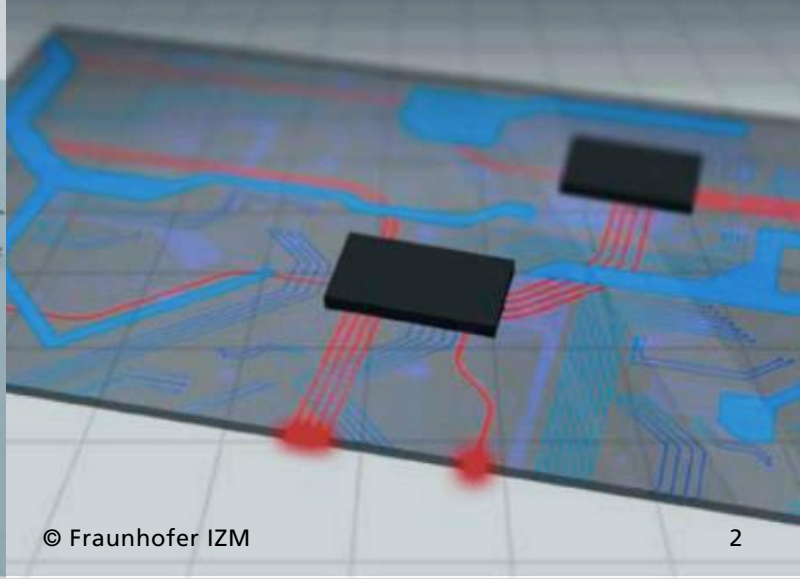
Fraunhofer IIS/EAS will develop a sensor module for measuring data capture for wafer exposure with extreme ultraviolet lithography (EUVL).

New video codec H.266/VVC (Versatile Video Coding)
Fraunhofer HHI was involved in the development of the new video codec, H.266/VVC (Versatile Video Coding). Due to significantly improved compression, VVC requires 50% lower data rates than its predecessor codec, H.265/HEVC, while maintaining the same perceived picture quality. This enables more efficient transmission and storage of all video formats, from SD to 8K, and thus streaming applications with much lower bandwidth.

The standard was developed specifically with a focus on ultra-high-resolution video content (4K and 8K) and also supports special applications such as high-dynamic range and omnidirectional 360-degree video. The reduction of required data rates also benefits mobile video applications, which typically have limited data capacity. Overall, VVC improves the accessibility of video formats in general and, at the same time, expands the range of possible applications.

VVC-compatible chips are currently under development. Fraunhofer HHI has already published suitable software for both encoders and decoders.

1. The aim of the PIN3S project is the defect-free production of highly precise masks for wafer production.
2. IGBT module of a wind turbine converter.
3. The new video codec H.266/VVC (Versatile Video Coding) improves the storage and streaming of video files.



New RFID technology for metallic environments
Fraunhofer IMS has developed a new RFID technology for use in and on metal. RFID (Radio-Frequency Identification) technology is established in numerous areas of application, from theft protection to monitoring company sizes. Depending on the application, the frequency standards of low, high, or ultra-high frequency are used.

However, the application in metallic environments or on metallic surfaces is problematic. These can lead to standing waves or impact the performance of the RFID transponder (tag). In addition, many use cases are subject to size restrictions in order not to endanger the usability of RFID-tagged tools, for example.

Fraunhofer IMS addresses these challenges with RFID technologies in the super-high frequency (SHF) range. Fraunhofer FHR and other partners support the researchers. The RFID-in/on-metal technology improves performance in metallic environments or on metallic surfaces and also enables the tags to be further reduced in size. In order to establish an SHF standard on the market, the Fraunhofer IMS also developed communication protocols for this frequency range.

Therefore, the technology solution of Fraunhofer IMS contains a complete RFID system from reader to tag. The technology can adapt to individual requirements and environments. The technology is already used for the management of tools and surgical instruments, i.e., their unique identification, tracking, and life cycle management.

Thin glass – multifunctional substrate
With the increasing processing of ever higher data rates, the quality of signal transmission must also improve. While optical signal transmission currently dominates for long transmission distances, a large part of signal transmission at circuit board level is still electrical.

This is where electro-optical circuit boards (EOCBs) come in. A promising material for such circuit boards is thin glass. For this purpose, optical waveguides are generated in the glass, and electrical layers are applied to both sides of the glass.

The Fraunhofer IZM has created a way to combine single-mode waveguides with very low loss (< 0.06 dB/cm) into large-format (440 mm × 330 mm) thin glass boards. The requirements of the display industry have also greatly improved the mechanical properties of the glass substrates, which benefits the production of glass EOCBs. These glass materials will also enable the realization of flexible EOCBs in the future.

Researchers at Fraunhofer IZM are currently working on connector concepts. These should enable broadband coupling with low coupling losses between the printed circuit boards and fibers, as well as between the printed circuit boards and the optical chips located on them. In addition, the scientists are opening up the research fields of sensor technology in connection with the microfluidic structuring of glass and photonic quantum technology. Scientists are developing novel approaches to meet the demand for more compact and cost-effective system integration technologies. The combination of low-cost PCB technology, optical functionalization of thin glass, and expertise in microsystems technology opens up innovative and design-oriented approaches.

1. With RFID-in/on-Metal technology, RFID tags can also be integrated into surgical instruments.
2. Schematic diagram of an electrooptical printed circuit board (EOCB) made of thin glass.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Info on Fraunhofer's tender platform + German Supply Chain Acts

Introducing **https://vergabe.fraunhofer.de**: The Gateway to Procurement Opportunities with the Fraunhofer-Gesellschaft.

In the dynamic landscape of research and technology, collaborating with renowned organizations can open up a world of opportunities for businesses. One such organization is the Fraunhofer-Gesellschaft, a global leader in application-oriented research. With its focus on cutting-edge technology for businesses and industries, the Fraunhofer-Gesellschaft has established itself as a hub of innovation and collaboration since its founding in 1949.

The organization operates an impressive network of 76 institutes and research facilities across Germany. These institutes are strategically located throughout the country, enabling collaboration with industry partners and facilitating the transfer of research findings into practical applications. Each institute specializes in specific research areas, covering various fields such as engineering, materials science, information technology, life sciences, health, defence and more.

The Fraunhofer Model, which the organization follows, is a unique approach to applied research. It combines scientific excellence with practical relevance and focuses on the direct transfer of knowledge and technology to industry. This model ensures that the research conducted by the Fraunhofer-Gesellschaft addresses real-world challenges and contributes to developing innovative solutions for businesses and business partners.

Through the Fraunhofer-Gesellschaft, businesses have the opportunity to collaborate with experts in various fields and leverage their expertise to drive innovation, improve products and processes, and gain a competitive edge. The organization's broad spectrum of research areas allows for interdisciplinary collaborations, fostering the exchange of ideas and the creation of synergies between different scientific disciplines.

One of the key strengths of the Fraunhofer-Gesellschaft is its ability to bridge the gap between academic research and industry. By actively engaging with industry businesses, the organization ensures that its research findings are relevant and applicable to real-world scenarios. This approach has made the Fraunhofer-Gesellschaft a trusted partner for companies seeking to enhance their competitiveness through technological advancements.

In addition to its strong presence in Germany, the Fraunhofer-Gesellschaft has also expanded its international collaborations and operations. With approximately 30,000 employees worldwide, it has established partnerships with research institutions, universities, and businesses across the globe. This global reach not only enhances the organization's ability to address global challenges but also provides opportunities for international businesses to engage in collaborative projects and benefit from the expertise offered by the Fraunhofer-Gesellschaft.

To meet its extensive procurement needs, the Fraunhofer-Gesellschaft has developed a user-friendly bilingual procurement platform called https://vergabe.fraunhofer.de. This platform serves as a gateway for businesses to become suppliers to the organization and provides access to a wide range of procurement opportunities.

Vergabe.fraunhofer.de offers several key features that make it an essential tool for businesses looking to engage with the Fraunhofer-Gesellschaft:

Free Registration: The platform allows suppliers to register at no cost, making it accessible to businesses of all sizes. This registration process is straightforward and enables suppliers to create a profile and showcase their capabilities to the Fraunhofer-Gesellschaft.

Procurement Opportunities: Once registered, suppliers gain access to a diverse range of procurement opportunities within the Fraunhofer-Gesellschaft. These opportunities span various industries and product groups, providing a chance for businesses to align their offerings with the organization's specific needs.


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Tender Alerts: To ensure suppliers stay informed about relevant future tenders, vergabe.fraunhofer.de offers a free Tender Alert service. By opting for this service, suppliers receive timely notifications about upcoming tenders that match their commodities via push mail. This feature allows suppliers to proactively prepare and submit their bids, maximizing their chances of securing contracts with the Fraunhofer-Gesellschaft.

Global Reach: The Fraunhofer-Gesellschaft operates not only within Germany but also has a global presence. This global reach provides suppliers with the opportunity to expand their customer base and explore new business prospects in emerging markets. By becoming a supplier to the Fraunhofer-Gesellschaft, businesses can tap into these international opportunities and generate significant sales.

Getting started with **vergabe.fraunhofer.de** is a simple and effective process. Interested businesses can visit the official website of the procurement platform at https://vergabe.fraunhofer.de to learn more. The website offers detailed information on how to register, technical support, access procurement opportunities, and utilize the Tender Alert service.

Don't miss out on the chance to become a supplier to the Fraunhofer-Gesellschaft and visit **https://vergabe.fraunhofer.de** today to embark on an exciting journey of collaboration and innovation.

WHAT INDIAN COMPANIES SHOULD KNOW ABOUT THE GERMAN SUPPLY CHAIN ACT

Dr. Andreas Kannt, Head of Strategy Supply Chain Management, Fraunhofer-Gesellschaft; Ass. jur. Sophia Heckmann, Strategy Officer, Fraunhofer-Gesellschaft; Ms. Anandi Iyer, Director, Fraunhofer Office India

On January 1, 2023, the German Corporate Due Diligence Act for the Prevention of Human Rights Violations in Supply Chains – "LkSG" or Supply Chain Act for short - came into force. The German federal law governs the economic activities of companies based in Germany with more than 1,000 employees by imposing due diligence obligations to minimize human rights and environmental risks in their supply chains.
The law has far-reaching implications for how German companies organize their supply chains. Germany is thus taking on a trailblazer role within the European Union. At the European level, the adoption of a supply chain act – the Corporate Sustainability Due Diligence Directive (CSDDD) – is currently in negotiations.

Even before the German Supply Chain Act came into force, the Fraunhofer-Gesellschaft, which is based in Germany, had already dealt intensively with the due diligence obligations and adapted its purchasing processes to the new requirements. As the world's leading organization for applied research, the Fraunhofer-Gesellschaft plays a significant role in the innovation process of the global economy. Fraunhofer Corporate Purchasing is responsible for the purchasing activities of the 76 institutes and headquarters with an annual purchasing volume of 1 billion euros and procures via its **tender portal** (https://vergabe.fraunhofer.de/NetServer/). Because of the high volume of contracts awarded, the dynamic and complex requirements and the heterogeneous supplier base, the demand for a structured approach is increasing to adequately fulfil the due diligence obligations of the Supply Chain Act.

How do the requirements of the Supply Chain Act affect companies based in India?
German companies must ensure that human rights and environmental risks are minimized along their supply chains. In order to fulfil this obligation, they need to cooperate with their national and especially international suppliers. Since the introduction of the Supply Chain Act, German companies have placed ever greater emphasis on social and environmental criteria when selecting their suppliers. A good performance in these areas can be decisive for Indian companies when it comes to winning future orders from German customers.

To better prepare for these requirements, Indian companies should familiarize themselves with the provisions of the German Supply Chain Act. This includes understanding the specific obligations and expectations placed on companies operating in Germany. A comprehensive risk analysis of their supply chains, particularly in relation to the areas of protection set out in the German Supply Chain Act, is also crucial. Indian companies should clearly position themselves in favour of human rights protection and take proactive steps to ensure that their suppliers also follow these principles. In the event of violations, corrective action should be taken immediately to address the issues and prevent recurrence.

International standards, such as the Sustainable Development Goals of the United Nations, the ILO core labour standards and internationally recognized certificates can also provide assistance in the further development of a company's own business activities and make Indian suppliers more attractive to German customers. Registration on an ESG rating platform may also be advisable, as many German companies already check the ratings of their suppliers on these portals.

Overall, the German Supply Chain Act presents both challenges and opportunities for Indian companies supplying goods and services to Germany. By implementing these requirements, Indian companies can strengthen their reputation, and improve their relationships with German customers and help promote responsible business practices around the globe.

RECENT ACTIVITIES, EVENTS CALENDAR, AND MEDIA COVERAGE

Recent Activities @ Fraunhofer in India

JANUARY 2023

16-20 Jan 2023: Visit of Dr Marius Mohr, Head of Innovation Field Water Technologies & Resource Recovery, Fraunhofer IGB to India (Kochi and Chennai)
Dr Marius Mohr visited Kochi on 16 Jan 2023 to examine the progress of the Sustainable Neighbourhood project; which will be launched in June 2023. Dr Mohr then participated in the 13th IWA International Conference on Water Reclamation & Reuse in Chennai on 17 and 18 Jan 2023 organized by International Water Reuse. Several high-level industry meetings were organized with L&T, Murugappa Water Technology Solutions Ltd. and VA Tech Wabag Ltd on 19 and 20 Jan 2023.

19 Jan 2023: Strategic Cooperation with the State Govt. of Tamil Nadu - Conference on "Building Advanced Manufacturing Ecosystems for Sustainable Growth" at Tamil Nadu Pavilion in Davos
Fraunhofer Office India has coordinated a long-term strategic cooperation between Fraunhofer IPT and the State Govt. of Tamil Nadu to develop an innovation ecosystem with a core focus on strengthening the industry-academia collaboration in Advanced Manufacturing in Tamil Nadu. Ms. Anandi Iyer, Director, Fraunhofer Office India, oriented the discussions between Fraunhofer and Govt. of Tamil Nadu in Davos. She also met with Mrs Smriti Irani, Union Minister of Women and Child Development, Govt. of India at Davos.

23-24 Jan 2023: Greendustrial Dialogues India 2023
Mr. Aditya Fuke, Senior Manager – Strategic Projects, Smart Cities & IoT represented Fraunhofer IGB and delivered a presentation on "Fostering Indo-German Collaboration on Water Management through Water Innovation Hubs" in this conference, organized by Indo-German Chamber of Commerce (IGCC) and German Water Partnership (GWP).

27 Jan 2023: International Seminar on "Hydrogen - The fuel of the future is here"
Dr. Carsten Cremers, Group Leader 'Fuel Cells' - Department for Applied Electrochemistry from Fraunhofer ICT delivered a presentation on "Emerging Technologies developed by Fraunhofer addressing current issues of the Hydrogen Economy" in the technical session of this seminar.

FEBRUARY 2023

11 Feb 2023: G20 EMPOWER Inception Meeting
India had assumed the G20 Presidency with effect from 01 Dec 2022 up to 30 Nov 2023. Ms. Anandi Iyer, Director, Fraunhofer Office India, Co-Chair Science, Technology and Innovation Committee, FICCI & Chairperson, Women in Science and Entrepreneurship (WISE) Council was invited to moderate the panel discussion on "Achieving Universal High Quality Skilling for Adolescent Girls and Women in Tech and Innovation" at G20 EMPOWER Inception Meeting held in Agra.

15 Feb 2023: Visit of DAAD and GIZ delegation to Fraunhofer Office India
The delegation from DAAD and GIZ visited Fraunhofer Office India on 15 Feb 2023 to understand the activities of Applied Research in India. There were around 20 delegates from Germany, India and other countries with a background in Urban Sustainability, Green and Smart Cities and Urban Planning.



MARCH 2023

14 Mar 2023: Launch of FICCI WISE - BML Partnership on Women in Leadership
The Women in Science and Entrepreneurship (WISE) Council is an initiative of the FICCI Science, Technology, and Innovation Committee. The WISE council is chaired by Ms. Anandi Iyer, Director, Fraunhofer Office India and Member, FICCI ST&I Committee and has eminent members from Industry, Government and Academia. The launch of FICCI WISE and BML Munjal University on Women in Leadership programme took place on 14th March 2023.

23 Mar 2023: Indo-German Forum: Sustainable Urban Mobility
Dr Daniel Stetter, Institute Director and Head of Smart Energy and Mobility Solutions Research Unit, Fraunhofer IAO participated in this forum as a speaker in the panel discussion on "Adaptation and diffusion of innovative technologies", organized by the German Centre for Research and Innovation (DWIH) New Delhi.

APRIL 2023

19 April 2023: Visit of BHEL senior management to Fraunhofer ISE
Mr Sanmati Naik, Senior Manager - Energy (RE), Fraunhofer Office India coordinated a visit of a high-level delegation of Bharat Heavy Electricals Ltd. (BHEL), led by its CMD to Fraunhofer ISE in Freiburg, with a focus on establishing a Center of Excellence (CoE) for Hydrogen Technology. The delegation also had the privilege of visiting the Electrolysis Lab, Test Bench, Power-to-Liquid facilities, and the H2 Refueling Station.

27 April 2023: Medical India Fair 2023 - Future for Health Conference
Mr Aditya Fuke represented Fraunhofer as a speaker in the panel discussion on "NRW Germany - Innovative Region for MedTech", organized by NRW. Global Business GmbH, Trade & Investment Agency of the German State of North Rhine-Westphalia (NRW).

27 April 2023: Celebration of Nürnberg Messe India's 10th anniversary
Ms Anandi Iyer along with other esteemed members participated in the panel discussion on "Sustainable Supply Chains" as part of the Nürnberg Messe India's 10th anniversary celebration.

29 April 2023: FICCI National Executive Committee Meeting
FICCI's National Executive Committee meeting was held in Chennai, featuring a session on "Public Digital Infrastructure - Private Sector Opportunities." Ms. Anandi Iyer was invited to moderate this session. Additionally, a special session was held in the presence of Thiru M. K. Stalin, Hon'ble Chief Minister of Tamil Nadu, further adding to the success of the event.

MAY 2023

03 May 2023: UNIDO Workshop on Industry 4.0
As Fraunhofer is one of the key stakeholders within Govt. of Tamil Nadu on Industry 4.0, UNIDO had invited Fraunhofer to share its strategy, expertise, experiences, opportunities and challenges, for the participants of the workshop to gain a sense of real-time firm-level Industry 4.0 applications and implementation requirements. Ms. Anandi Iyer and Mr. Aditya Fuke represented Fraunhofer in this workshop. Ms. Anandi Iyer delivered a presentation on the "Role of industry-academic cooperation for uptake of Industry 4.0" in this workshop.

18 May 2023
Ms Anandi Iyer and Mr Aditya Fuke met with Dr R. Mashelkar, Chairman of Reliance Innovation Leadership Centre to discuss cooperation between Fraunhofer and Reliance Industries on bringing in industry-specific solutions from Fraunhofer which are at higher TRLs and relevant for Indian market.

JUNE 2023

01 June 2023: Planning Workshop with Bangalore International Airport Ltd. (BIAL)

Fraunhofer Office India coordinated the first planning workshop between Fraunhofer UMSICHT, ICT, IPA, ISE and BIAL virtually to present the key competencies of Fraunhofer in (i) Circular Economy and Resource Efficiency in airports (ii) Battery Storage and circularity in disposal of batteries (iii) Green Hydrogen Infrastructure from an Airport perspective, and discuss with BIAL the key technology asks and identify opportunities for collaboration.

01 June 2023: The 2nd meeting of the India Global Innovation Connect (IGIC)
Ms Anandi Iyer was invited as a speaker in the panel discussion on "Innovation partnerships: Creating an innovation dynamic through ecosystems collaboration" in the 2nd meeting of IGIC , organized by Smadja & Smadja in Bangalore.

08 June 2023: Launch of Pilot Project - Sustainable Neighbourhood Kochi
The project "Sustainable Neighbourhood Kochi" was launched by H.E. Dr Philipp Ackermann, German Ambassador to India on 08 June 2023 at the Government Higher Secondary School (GHSS) in Elamakkara Ward, Kochi in the presence of Adv. M. Anil Kumar, Mayor of Kochi Municipal Corporation, Dr. Rajan C, Director, C-HED, Ms. Anandi Iyer, Director, Fraunhofer Office India, Dr. Debjani Ghosh, Associate Professor at NIUA, and other key dignitaries from the city and state administration. This innovative project showcases the implementation of nature-based sewage treatment, green and cool roofs, and rooftop solar photovoltaics. This project is jointly coordinated by Fraunhofer and the University of Stuttgart. Centre for Heritage, Environment and Development (C-HED), an institution under Kochi Municipal Corporation (KMC) and the National Institute of Urban Affairs (NIUA), Govt. of India are the local partners.

12 June 2023: Asia Berlin Summit
Ms Anandi Iyer was invited to moderate a panel discussion on "The Battle for Innovation" at the Asia Berlin Summit 2023 organized by Asia Berlin Forum e.V. and attended the IGCC Traditional Meeting 2023. She also had a brief meeting with Ms Franziska Giffey, Deputy Mayor of Berlin and Senator for Economy, Energy and Enterprise.

27–29 June 2023: Visit of Dr Jens Neugebauer, Head of International Representations and Senior Advisors and Ms Andrea Mandalka, International Business Development Regional Business Development - Latin America from Fraunhofer Headquarters to India
Dr. Jens Neugebauer and Ms. Andrea Mandalka visited Bangalore from 27-29 June 2023. They met with the entire team of Fraunhofer Office India to discuss important points and the vision of Fraunhofer HQ for its international offices, as well as the strategy for the future. During their visit, Fraunhofer Office India also coordinated some strategic meetings for them with the German Consulate Bangalore, State of Bavaria India Office – Invest in Bavaria, VDMA, NRW Global Business GmbH/ India and Indo-German Chamber of Commerce (IGCC) to discuss the experiences of these German organizations and their activities in India and explore potential collaboration in R&D and Innovation.

28 June 2023: Launch of German Innovation and R&D Forum
The Fraunhofer Office India team coordinated a launch meeting of the German Innovation & R&D Forum. The objective was to introduce and delve into the framework development of the German R&D and Innovation Forum and seek suggestions from the industry for enabling a consolidation of German industries' technologies, competencies, and experiences, and leverage the value proposition for opportunities for Innovation in India. The German Innovation and R&D Forum comprises the following German companies: Continental, Bosch Global Software Technologies Ltd. (BGSW), SAP Labs, Siemens, Siemens Healthineers, Infineon, Festo, Mercedes-Benz Research & Development India, and supported by German Consulate Bangalore.




JULY 2023

13 July 2023: Zinnov Confluence on "Technology by design: Unlocking India's collective genius"
Ms Anandi Iyer was invited by Zinnov as a speaker in the panel discussion on 'The Techade Manifesto: Building Next-Gen Technologies from India' at this conference which thematically focussed on 'Technology by design: Unlocking India's collective genius'.

21 July 2023: IGMTP Networking event: "Forming long-term partnerships"
Mr Aditya Fuke was invited by GIZ as a speaker in the panel discussion on "Green transition - Opportunities and Challenges for SMEs" to give an expression on (i) Scientific perspective and challenges for companies to adopt green transition considering climate change, (ii) possible changes in the production processes and new trends, and (iii) recommendations from Fraunhofer's point of view.

26 July 2023: Green Hydrogen Roundtable
Mr Sanmati Naik represented Fraunhofer at the Green Hydrogen Roundtable organised by the Indo-German Chamber of Commerce (IGCC) and the Indo-German Energy Forum Support Office (IGEF) on the occasion of the visit of Mr Stefan Wenzel, Secretary, German Ministry for Economic Affairs and Climate Action (BMWK) to India.

31 July 2023: G20 EMPOWER Summit
Ms Anandi Iyer is the Chair of the G20 EMPOWER Working Group on Women in STEM. She represented Fraunhofer in the G20 EMPOWER Summit on Women-Led Development: Ensuring sustainable, inclusive and equitable global economic growth in Gujarat.

AUGUST 2023

01 Aug 2023: G20 EMPOWER Summit
Ms. Anandi Iyer is the Chair of the G20 EMPOWER Working Group on STEM. The working group under the leadership of Ms. Anandi Iyer works on the need for substantial changes to enable more women to pursue and excel in STEM careers. The vision involves a collective effort from all stakeholders to bring about positive change. G20 EMPOWER summit celebrated key outcomes to accelerate women-led development in Gandhinagar on 01 Aug 2023.

04 Aug 2023: First Meeting of CII Council on Urban Development and Smart Cities 2023-24
Ms Anandi Iyer represented Fraunhofer in the CII Council on Urban Development and Smart Cities. The first meeting of the council was held virtually and was chaired by Mr Sunil Mathur, MD & CEO, Siemens India Ltd. Ms Iyer spoke on the recently launched pilot project in Kochi, "Sustainable Neighbourhood", coordinated by Fraunhofer and gave a brief representation on how this project has addressed the challenges of climate change by means of circular processes and innovations at pilot scale, and the need for industry participation for further scaling up of this project.

21 Aug 2023: Second Meeting of the German Innovation and R&D Forum
The second meeting of the German Innovation and R&D Forum was held at SAP Labs in the form of a design thinking workshop on the theme "Building synergies to drive co-innovation". The objective of this meeting was to discuss the vision, mission statements, action themes and operating principles of the forum.


SEPTEMBER 2023

06-09 Sept 2023: Fraunhofer's Exclusive Conference on Hydrogen Technologies & 6th Fraunhofer Innovation and Technology (FIT) Platform 2023, followed by high-level industry meetings

September was a very eventful and gratifying month for Fraunhofer Office India. On the occasion of 15 years of Fraunhofer's existence in India, a series of events were held in Bangalore. Fraunhofer's Exclusive Conference on Hydrogen Technologies on 06 Sept 2023 - this conference aimed at demonstrating Fraunhofer's expertise in the hydrogen ecosystem and innovative breakthroughs, fostering a robust framework for Indo-German collaboration. The Fraunhofer Innovation and Technology (FIT) Platform on 07 Sept 2023 - The FIT Platform is the biennial flagship event of Fraunhofer in India, and this year was the 6th edition. The 6th FIT Platform featured 'Circular Economy- Creating a Sustainable Environment' as a theme focused on showcasing technology needs/solutions for smart technology intervention in India. The specific target audience for both events was invited delegates from Industry, Academia, Research, Government, and the Media. As a precursor to these events, a briefing session was organized in the afternoon of 06 Sept 2023 for German delegates to brief them on the Growth Story of India, the geopolitical paradigm of Indo -German Relations, the Circular Economy Scenario in India and the journey of Fraunhofer in India.

Snapshots

- Shri Priyank Kharge, Hon'ble State Minister of Karnataka for IT&BT as Chief Guest
- Keynote speech by the Shri. Suman Bery, Vice Chairman of NITI Aayog, India Premier Policy Think Tank chaired by the Hon'ble Prime Minister and Mr. Friedrich Birgelen, Deputy Consul General, German Consulate Bangalore
- Marquee speakers from India and Germany, Delegation consisting of over 17 Fraunhofer Institute Colleagues and 1 German SME
- 14 Indian Speakers, including top leadership from Government, Industry and Research
- Release of a Knowledge Paper on Circular Economy and Sustainability in (i) Manufacturing (ii) Mobility (iii) Wastewater treatment focussing on the Water-Energy-Food Nexus (iv) Plastic waste management and recycling
- Declaration of three significant collaborations with (i) Dept. of Science & Technology, Govt. of India (ii) Bharat Heavy Electricals Ltd. (BHEL) (iii) Tamil Nadu Industrial Development Corporation (TIDCO)
- Over 15 media meetings, and excellent coverage in print and visual media.
- Nearly 400 participants in both events
- A series of on-site meetings with clients including German Industry.
- Fraunhofer Wall of Fame illustrating the journey of Fraunhofer in India since 2008 and celebrating the 15-year Jubilee
- Exhibition of technologies and prototypes around the Circular Economy, developed by Fraunhofer Institutes
- 3rd Meeting of the German Innovation and R&D Forum

14 Sept 2023: Visit of Confederation of Indian Industry (CII) to Fraunhofer IKS
Fraunhofer Office India had coordinated a visit of a high-level delegation of CII – Institute of Quality to Fraunhofer IKS on the theme "Emerging Quality frameworks encompassing Digital & ESG compliances in EU". The agenda of the visit was to understand the implementation of advanced digital and sustainable practices like manufacturing facilities, and industry clusters especially related to advanced digital healthcare, AI, next-gen computing, the energy sector and advances in hydrogen infrastructure.

22 Sept 2023: Gender-based Violence - Policy Maker's Perspective
A panel discussion was scheduled on the topic of "Gender-based Violence" at the School of Innovation and Management in Hyderabad. The objective was to foster mutual learning and understanding of gender and diversity, policies, and practices in the context of higher education and research in India and Germany. Ms. Anandi Iyer was invited as a moderator for the session.

27 Sept 2023: European Research Day 2023 - Sharing Experiences in H2020 Project
On behalf of the European Union (EU) Delegation to India, EURAXESS India organized the European Research Day 2023 (ERD) 2023 in Bangalore. Ms Anandi Iyer was invited as a leading Indian Principal Investigator to be a speaker at this conference. She delivered a short presentation on the significance of international cooperation in multilateral/bilateral projects and the opportunities and challenges that arise during such collaborations as well as shared some best practices.

OCTOBER 2023

04 Oct 2023: CII Karnataka Agri & Food Processing Conclave 2023
Fraunhofer was invited as a speaker in the session on 'Technology Innovations in Agri & Food Security' in this conclave. Mr. Aditya Fuke represented Fraunhofer and delivered a presentation on "RE and Agri-Integrated and Sustainable Solutions" in this session.

10 Oct 2023: DWIH Annual Roundtable
Fraunhofer is one of the supporters of DWIH in India. Ms Anandi Iyer represented Fraunhofer in the annual roundtable of The German House for Innovation and Research (DWIH) in Delhi.

13 Oct 2023: 3rd Annual Conference of the Indo-German Centre for Business Excellence
The Indo-German Centre for Business Excellence organized its Annual conference in collaboration with Mahindra University at Hyderabad, which thematically focussed on "Emerging Technologies and Inclusive Innovation". Ms Anandi Iyer was invited as a speaker in the panel on "Inclusive Innovation" where she spoke on the Indian scenario of affordable and scalable solutions for the development of innovative manufacturing processes that can cater to diverse demographics.

13 Oct 2023: 12th VDMA Mechanical Engineering Summit
The 12th VDMA Mechanical Engineering Summit, organized by VDMA India was held in Bangalore to showcase India's dynamic manufacturing sector and its close ties with Germany. The event concluded with VDMA's 6th Manufacturing Excellence Awards, which recognized companies for their outstanding contributions in areas such as Corporate Social Responsibility, Energy Efficiency and Conservation, and Work conditions and Work Safety. Ms. Anandi Iyer was one of the jury members to finalize the awards in these areas and was invited to present these awards to the winning companies.

17-19 Oct 2023: IFAT 2023
IFAT India is a leading trade fair for environmental technologies and sustainable solutions in India. Fraunhofer held a booth in the German Pavilion at IFAT 2023, representing the entire Fraunhofer Water Systems Alliance, which comprises 11 Fraunhofer Institutes working in the various fields of water, waste and environmental technologies. Mr Marc Beckett from Fraunhofer IGB and Mr Aditya Fuke from Fraunhofer Office India represented the Fraunhofer Water Systems Alliance at IFAT 2023. Alongside the exhibition, parallel conferences namely 'Innovative Water Forum' and 'Innovative Waste Forum' were also organized. Mr Marc Beckett was invited as a speaker at the Innovative Water Forum.

25 Oct 2023: 4th meeting of the German Innovation and R&D Forum
The German Innovation and R&D Forum, conceptualized and driven by Fraunhofer Office India brought thought leaders and experts to discuss and brainstorm on avenues for building a sustainable future by leveraging joint innovation capabilities of German companies in India. The forum was launched at Fraunhofer Office India in June 2023, followed by two design thinking workshops at SAP Labs India and Bosch Global Software Technologies in Aug and Sept 2023 respectively. The fourth meeting of the forum was held at Continental India Ltd. on 25 Oct 2023. The forum members delved deep into a wide spectrum of industry topics identified in the earlier workshops, and a final list of topics was identified for project development.


NOVEMBER 2023

02 Nov 2023: Micelio Mobility Awards 2023
Micelio Mobility organized India's first clean mobility summit on 02 Nov 2023 in Bangalore. On this occasion, Micelio also organized a Micelio Mobility Awards for innovators, pathbreakers, and visionaries working towards emission-free transportation. Ms Anandi Iyer was invited as one of the jury members along with other industry pioneers to decide the winner in each of the categories.

03 Nov 2023: SAP TechEd
The annual SAP Developer event, SAP TechEd, is an initiative driven by SAP developers, architects and enthusiasts to bring forward revolutionary innovations to the ERP giant's platforms. Ms Anandi Iyer represented Fraunhofer in SAP TechEd 2023. During the event, an exclusive Women Leadership Forum was also organized, where she met with Mr Juergen Mueller, CTO, SAP Global to opportunities between Fraunhofer and SAP in Generative AI.

21 Nov 2023: Hamburg - India Business Day 2024
Hamburg Chamber of Commerce organized Hamburg - India Business Day in Hamburg and invited Ms Anandi Iyer as a speaker in the panel discussion on "India as a partner in the value chain" to discuss the critical success factors for identifying and utilizing India's potential for firm-internal value creation activities. In the evening, Ms Iyer was also invited by the Indian Consulate in Hamburg for a high-level networking event, where she was one of the speakers in the panel discussion on "Research cooperation in Sustainable Technologies".

DECEMBER 2023

01 - 02 Dec 2023: AMTech 2023
AMTech is India's largest and only dedicated tradeshow on Additive Manufacturing and 3D Printing. Fraunhofer held a booth in the German Pavilion and showcased three interesting exhibits on the topic. Fraunhofer IWU and Fraunhofer Office India represented the Fraunhofer Competence Field Additive Manufacturing, spanning its research activities in the various topics of Additive Manufacturing from Materials, Technology, Engineering, and Quality, to Software and Simulation. Dr Bernhard Müller, Spokesman of the Fraunhofer Competence Field Additive Manufacturing and Group Leader at Fraunhofer IWU, Mr Aditya Fuke, Senior Manager – Strategic Projects, Smart Cities & IoT from Fraunhofer Office India and Ms Mythili Shrivarathri, Student Coordinator, represented Fraunhofer in AMTech 2023. Alongside the exhibition, a conference on 'Innovations in Additive Manufacturing' was also organized. Dr Bernhard Müller was invited as a distinguished guest speaker in this conference.

Events/Activities in 2024 (illustrative and tentative)

Date	Events	Place
09.01.2024	5th Meeting of German Innovation Forum	Bangalore
06.02.2024 – 09.02.2024	India Energy Week	Goa
20.02.2024	6th Meeting of German Innovation Forum	Bangalore
21.02.2024 – 23.02.2024	The smarter E India	Gandhinagar
26.02.2024 – 01.03.2024	Incubators Connect 2.0: Innovation and Internationalisation Visit of Fraunhofer Venture to India	Delhi, Bangalore
11.03.2024	Workshop on Sensor Systems with Ministry of Electronics & Information Technology, Govt. of India and Centre for Materials for Electronics Technology	Hyderabad
12.04.2024	7th Meeting of German Innovation Forum	Bangalore
22.04.2024 – 24.04.2024	Hannover Messe 2024	Hannover
16.05.2024 – 18.05.2024	Electronics for You Expo 2024	Pune
21.05.2024 – 22.05.2024	Celebration of 50 years of Indo-German Science and Technology Cooperation	Frankfurt
19.06.2024 – 21.06.2024	Intersolar Europe 2024	Munich
01.07.2024 – 05.07.2024	India Energy Storage Week (IESW) International Conference & Exhibition	Delhi
12.07.2024*	German Innovation Forum launch event on “Sustainability: The Technology Imperative for our Future” Networking Reception with German Ambassador and Key decision makers from Govt. of India	Delhi

Date	Events	Place
11.09.2023 – 13.09.2023	electronica India 2024, Productronica India 2024 and SEMICON 2024 Participation of Fraunhofer EMFT as an exhibitor in Productronica India 2024	Noida
20.09.2024	Women in STEM: Indo-German Women's Event The event will be supported by Prof. Dr. Kristina Sinemus, Hessian Minister for Digitalization and Innovation	Frankfurt
03.10.2024 – 05.10.2024	REI Expo	Noida
25/26.10.2024	18th Asia-Pacific Conference of German Business 2024	Delhi
Dec 2024*	ALUCAST 2024	Chennai
Dec 2024*	AMTech 2024	Hyderabad/ Pune*

*signifies either the event/activity or the date or the speaker is to be confirmed

Fraunhofer in India: Recent Media Coverage

Sustainable neighbourhood project to be launched in Kochi

June 07, 2023 09:03 pm | Updated 09:56 pm IST - KOCHI

THE HINDU BUREAU

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The nature-based sewage treatment plant set up at the Government Higher Secondary School, Puthukkalavattom. | Photo Credit: THULASI KAKKAT

What PM Modi Has Done to Amplify Contribution of Women in Science is Commendable: Anandi Iyer

• Reported By: Sidhant Mishra • Edited By: Nitya Thirumalai • CNN-News18 • Last Updated: AUGUST 31, 2023, 14:43 IST • New Delhi, India

Under PM Modi's leadership, women in science have actually been included into the mainstream, says Fraunhofer Institute's India Office director Anandi Iyer. (PTI/File)

In an exclusive interview to News18, Fraunhofer Institute's India Office director Anandi Iyer talked about India's position in global research and innovation, and lauded Prime Minister Narendra Modi's push for women-led development during India's presidency of the G20

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The Fraunhofer Institute has been a long-time trusted innovation partner in India, collaborating with some of the major players in the field of material science, energy, environment, automotive, electro-mobility, production technology, microsystems and smart cities, working with industry, government and public sector. The Fraunhofer-Gesellschaft based in Germany is the world's leading applied research organisation, prioritising key future-relevant technologies and commercialising its findings in business and industry.

Large RE Market A Boon For India: Anadi Iyer, India Director, Fraunhofer

By Manish Kumar / Updated On Fri, Sep 15th, 2023

Highlights :

Anandi Iyer is the India Director for Fraunhofer, Europe's largest application-oriented research organization. The organization has a presence in 82 countries globally. The German government also helps Fraunhofer financially for their research outreach. It has been working in India on several renewable energy projects. In an exclusive interview with Saur Energy, she speaks about the operations of the research entity in India, her views on the clean tech policies in India, the bottlenecks and the future plans. Excerpts:

Large RE Market A Boon For India: Anadi Iyer, India Director, Fraunhofer

How is Fraunhofer's helping the renewable energy sector in India?

Fraunhofer works around science and engineering, whether it is renewable energy, production technologies, material science, smart cities, smart manufacturing, and artificial intelligence, etc. We can make solar cell battery storage systems of high quality. We are also working on several technologies simultaneously, like thins cells. We possess capabilities far ahead of other companies. That is why the world's

Germany's Fraunhofer to boost India's start-up ecosystem with Innovation

The recently introduced policy document on G20 devotes a significant portion to innovation, technology, and R&D, including Germany-led Industry 4.0, Artificial Intelligence, and the promotion of 5G/6G technologies and start-up ecosystems.

Written by **Huma Siddiqui**

September 1, 2023 08:51 IST

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India well-placed to be hydrogen exporter to decarbonizing economies: Fraunhofer Society

On Fraunhofer's collaboration in the Hydrogen Valley project, Fraunhofer India's head Anandi Iyer said," Fraunhofer has one of the largest capabilities around hydrogen with more than 36 institutes working on various technologies."

By: Express News Service
Bengaluru | Updated: September 8, 2023 19:31 IST

NewsGuard

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Dr. Hebling (third from left) was speaking at a discussion on India's potential and challenges in developing a hydrogen economy and its collaboration with Fraunhofer Society on the Hydrogen Valley project. (Express photo)

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00:00 1x 1.5x 1.8x

In line with its ambitious renewable energy targets, India could produce surplus

Germany's Fraunhofer Society stresses need for countries to chalk out sustainability plan

Experts in Fraunhofer Society aired views on sustainability and clean energy in India and Eur during a media conference in Bengaluru.

By: Express News Service
Bengaluru | September 7, 2023 13:53 IST

NewsGuard

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Dr Markus Wolperdinger of Germany's Fraunhofer's Institute of Interfacial Engineering and Biotechnology (Facebook/ Fraunhofer IGB)

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00:00 1x 1.5x 1.8x

Dr Markus Wolperdinger of Germany's Fraunhofer's Institute of Interfacial Engineering and Biotechnology has voiced concern over the cheap availability of fossil fuels, or "rather fuels that appear to be cheap" due to subsidy.

"Irrespective of whether it is Germany, Europe or India, do we have the will to go for the sustainable methods or the cheapest?" he asked on Wednesday during a

Germany's Fraunhofer unveils major ties on hydrogen technologies, innovation clusters with India

Fraunhofer is a valued partner of the Indian government and is actively part of many government projects in several states.

Shubham 12 September, 2023

Delegates release a document at the 6th Fraunhofer Innovation & Technology Platform at the Taj hotel in the southern Indian city of Bengaluru on September 7, 2023. (L-R) Anandi Iyer, director, Fraunhofer India; Dr Markus Wolperdinger, director, Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB; prof Prasad Modak, managing director, Environmental Management Centre Pvt Ltd; Priyanka Kharge, information technology and biotechnology minister of the southern Indian state of Karnataka; Friedrich Birgelen, deputy consul general of Germany in Bengaluru and Torsten Nyncke, head foreign Fraunhofer Affiliates and Representations, Fraunhofer-Gesellschaft (Picture: Fraunhofer)

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