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From Precision to Performance: How MicroBias Enables Compact Robotic Sensing

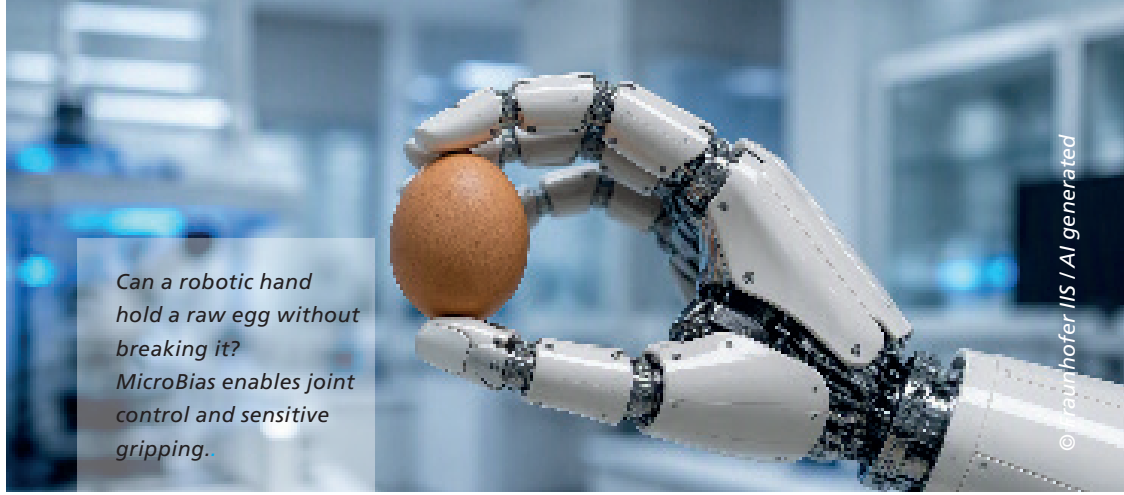
Robots are gripping and positioning with ever greater precision – yet at the moment of contact, they often still lack the sensing information needed for a controlled response. »MicroBias« integrates a permanent micromagnet into the sensor chip at wafer level and combines it with multidimensional Hall sensing. The result is a compact sensor-magnet architecture that can capture magnetic-field changes close to the application and convert them into motion-, contact- or load-related information.

Tactile sensing needs proximity

Whether a robot grips a component securely or squeezes too hard has to be decided within milliseconds, right at the point of contact. That is exactly where sensors need to be if they have to reliably detect touch, deformation, or even the smallest movements. In compact end effectors, lightweight grippers, or modular automation units, installation space is limited and complexity on system level can quickly become a constraining factor. With MicroBias, a unique technology has been developed that adds complexity to magnetic systems without requiring additional space.

Micromagnet and sensor as one integrated system

In demanding systems with limited installation space, MicroBias showcases its strengths: magnet, sensor, and signal processing are developed as a single measurement system. Using Fraunhofer ISIT's PowderMEMS® technology, the micromagnet is integrated into the sensor chip at wafer level, precisely defining its position relative to the sensing elements. The local bias field can be tailored to the mechanics of the application, while multidimensional Hall sensing based on the established HallinOne® technology makes it possible to evaluate all three magnetic field components. For developers, this opens up new degrees of design freedom: the magnetic measurement principle no longer has to be retrofitted into a tight design but can be aligned from the outset with motion, force transmission, and contact zones.



Can a robotic hand hold a raw egg without breaking it? MicroBias enables joint control and sensitive gripping.

© Fraunhofer IIS / AI generated

Compact integration and effective use of smaller magnets

The approach becomes particularly tangible in tactile robotic grippers. Motion and status information can be generated within mechanically demanding, space-constrained structures, such as gripper fingers, small actuators, or compact robot joints. When a suitable target or coupling element deforms upon contact, the local magnetic field changes. From that change, information about motion, touch, or load can be derived. Especially here, the integrated design can significantly reduce the sensor-magnet volume compared with conventional assemblies, use magnetic material more efficiently, and eliminate the separate placement and alignment of a package-level bias magnet. By enabling the use of much smaller magnets, it also reduces the amount of rare-earth materials significantly. The key lies in the co-design of the micromagnet, sensor elements, target mechanics, and algorithms, which work together so that even a smaller bias field can be used effectively.

From lab principle to customer-specific solution

This makes MicroBias compelling wherever standard solutions reach their limits: in very small installation spaces, moving components, demanding integration environments, or application-specific measurement tasks in robotics, automation, and sensing. Fraunhofer IIS supports the entire path from feasibility analysis and magnet and sensor design to prototypes, characterization, and pilot projects. The current focus is on combining MicroBias with Hall sensing, while adaptations to GMR or TMR technologies can be evaluated in joint development projects. In this way, the precise integration of a micromagnet becomes a building block for robotic systems that can derive contact- and load-related information close to the application and respond in a more controlled manner.

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Intelligent Edge AI: When Even Bolts Think for Themselves

Our infrastructure often ages faster than maintenance teams can respond. Bridges, wind turbines, and industrial plants consist of thousands of critical connecting elements, the condition of which has previously been checked manually. Neuromorphic computing opens up new possibilities here: With a NeuroQ-Bolt, an intelligent bolt with an integrated ADELIA AI chip, continuous self-monitoring directly on the component becomes a reality. This allows damage to be detected even before it becomes visible.

Bolts carry enormous loads and are crucial for the safety of large structures. However, the large number and inaccessibility of these locations make regular inspections costly. A NeuroQ-Bolt fundamentally changes this process. It combines sensor technology, AI processing, and energy-autonomous communication in a compact unit that remains permanently in the component.

Neuromorphic computing in the component

Neuromorphic computing refers to brain-inspired AI hardware that executes neural networks directly and extremely energy-efficiently in the hardware itself.

The neuromorphic AI chip ADELIA, a dedicated low-power processor for edge-based neural signal analysis, is built on precisely this principle and forms the heart of a NeuroQ-Bolt: Its analog in-memory computing enables the execution of complex neural networks with less than 1 mW of power consumption. This efficiency allows the complete analysis to be performed directly in the bolt – without the cloud, without external computers, and powered exclusively by energy harvesting. Even slight temperature differences or small ambient light levels are sufficient to power a whole NeuroQ-Bolt.

ADELIA processes the signals from several integrated sensors: the piezoresistive DiaForce® thin-film system measures the preload force, while other sensors detect vibrations and acoustic events. Neuromorphic algorithms classify these signals in real time, detecting anomalies, incipient cracking, and atypical load curves, even in noisy or vibration-intensive environments.



A future scenario at sea: edge-AI driven predictive maintenance with self-monitoring bolts instead of manual inspections

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Self-sufficient monitor with a wide radio range

If the bolt detects any abnormalities, it sends an energy-efficient warning via the LPWAN system mioty®.
A base station can connect up to 30,000 bolts over distances of up to 10 km. Each message requires only 54 mWs – ideal for years of autonomous operation.

Greater efficiency and sustainability

With its local AI processing, a NeuroQ-Bolt enables true predictive maintenance. Inspections only occur where necessary, rather than at fixed intervals. This drastically reduces material, energy, travel, and costs. Areas that are particularly difficult to access, such as offshore wind farms, bolted motorway or railway bridges or large industrial plants, benefit greatly from this technology.

Pioneering for infrastructure and industry

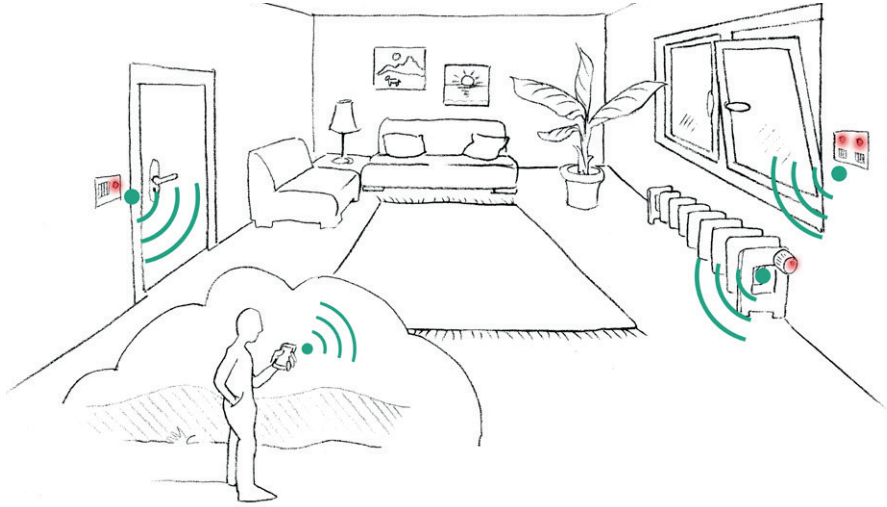
A NeuroQ-Bolt could be a solution for edge-AI driven predictive maintenance of critical infrastructure. Yet the underlying technologies – ADELIA, energy harvesting, mioty®, Q-Bo® and DiaForce® – already exist and can also be deployed as modular add-ons for existing bolts, for example. They impressively demonstrate how neuromorphic computing is making the leap from research to real-world applications. A bolt that thinks and reports for itself: small in size, big in potential for a more sustainable and secure infrastructure.

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Save Energy, Gain Control – That's how Smart a Home can be.

Modern buildings listen to their environment: temperature, humidity, and movement. To ensure that everything runs reliably, sensors must always be accessible and, if possible, maintenance-free. This requires wireless solutions that remain responsive at all times while consuming very little energy. One technology that addresses precisely these requirements is RFicient®.



© Fraunhofer IIS / Bianca Möller

Building automation scenario with RFicient®

Energy consumption reduced to a minimum

The RFicient® chip belongs to a new generation of wireless wake-up receivers that can continuously monitor radio signals without significantly draining the battery. This is achieved through power consumption in the microwatt range – so low that wireless sensors can be operated with particularly small energy sources. This opens up new possibilities in building automation, enabling sensors that require virtually no maintenance and can be installed in locations where battery replacement would otherwise be impractical.
The result: improved energy-efficient climate control, smarter access management, enhanced safety monitoring and more.

Ready when it counts

Despite its economical operation, RFicient® remains responsive at all times. The receiver recognizes a wake-up sequence within milliseconds and then activates the downstream system, such as a sensor and radio module, in a targeted manner. For smart home control centers, this means that sensor data can only be retrieved when it is really needed. This increases the efficiency of the overall system, for example when checking whether a window is still open before adjusting the room temperature..

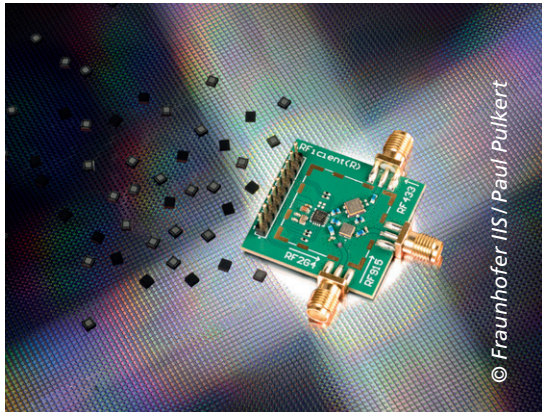
From idea to application – with the right tool

If developers want to integrate this technology into their own concepts, they need a simple and straightforward way to get started. That is exactly why new compact breakout boards were developed. They provide an integrated RFicient® chip on an extension board including all necessary RF filter components and are shipped with matching antennas.

This makes the transition from theory to practical implementation much easier, while keeping the option open to add external components like microcontrollers for advanced functionality. Such flexibility is especially appealing to experienced teams who prefer flexible architectures and are looking for cost-effective hardware for early development phases.

A building block for the next generation of connected buildings

RFicient® shows how the demand for wireless, low-maintenance sensor technology in the smart home can be met, enabling long-lasting radio nodes that integrate harmoniously into existing buildings.
In an infrastructure that is increasingly networked, RFicient® can make a significant contribution to reducing energy consumption and making automation systems more robust and efficient.



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RFicient® breakout board

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System-Technology Co-Optimization (STCO) for Advanced Heterogeneous Prototypes

The rising complexity and cost pressure of electronic systems demands new ways of heterogeneous design approaches and a chiplet-based ecosystem. System-Technology Co-Optimization (STCO) is a key enabler, orchestrating design choices throughout the entire system including the selection of optimal technologies and economic trade-offs. It supports decision-making across domains and hierarchies. In the APECS pilot line, our STCO approach captures and links requirements, data, and rules to inform decisions. This approach exposes trade-offs early on, speeds up cross-team iterations, reduces handover risks, and improves alignment. The result is faster, more cost-effective, high-performance solutions for next-generation semiconductor products.

Modern semiconductor components are becoming more and more complex and cost sensitive. To master technological and economic challenges, new chiplet approaches and heterogeneous integration technologies are becoming increasingly relevant.

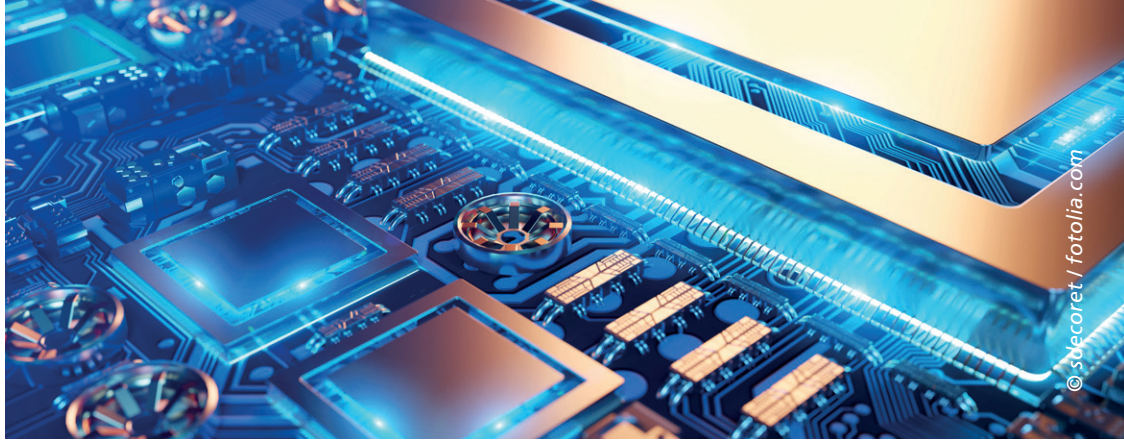
Heterogeneous design approaches make it possible to combine different design domains across technological options while satisfying economic and performance demands of the application.

However, a broad spectrum of information must be considered and optimized altogether. Handling this range of both technological and design choices while targeting cost figures requires a new and extended design approach: the System-Technology Co-Optimization design methodology – or STCO for short.

System-Technology Co-Optimization

This new approach addresses overall system optimization across different fields of expertise, across abstraction levels or hierarchies, and across different domains of KPI measures.

This sheer complexity is what makes support from cross-domain tools a critical contribution to decision-making in the design process of heterogeneous systems.



Chiplet system

Such tooling must help capture, aggregate, and connect requirements, data, rules, etc. to enable the monitoring and control of economic, technological, and design implications stemming from the components, packages, and chiplets that altogether form complex heterogeneous systems for challenging target applications.

STCO in the context of the European APECS pilot line

In the context of the European Pilot Line for Advanced Packaging and Heterogeneous Integration for Electronic Components and Systems (APECS), we are utilizing, extending, and developing design tool solutions for the STCO approach.

It provides a representation of the many details and makes it available to various experts across the development teams and in the value chain.

This will bring enormous value: Problems at handover points will be identified earlier, iteration across teams will be accelerated, and the alignments across expertise fields and domains will be improved.

Establishing the STCO philosophy and respective tools will push the semiconductor ecosystem ever further forward into the new and exciting chiplet era.

Part of Forschungsfabrik Mikroelektronik Deutschland

APECS

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VerGaN: GaN as a key technology for the next generation of power electronics

Until now, power electronic systems have been predominantly based on silicon semiconductors. In recent years, materials such as gallium nitride have increasingly gained importance. GaN is characterized by excellent electrical properties, enabling higher switching speeds and lower switching losses. However, so far mainly so-called lateral devices are available, whose performance is limited.
With VerGaN, we combine scientific expertise with industrial application prospects and develop the vertical GaN devices and packaging for modern power converters. This collaborative research leads to innovation that can pave the way for the microelectronics of tomorrow.

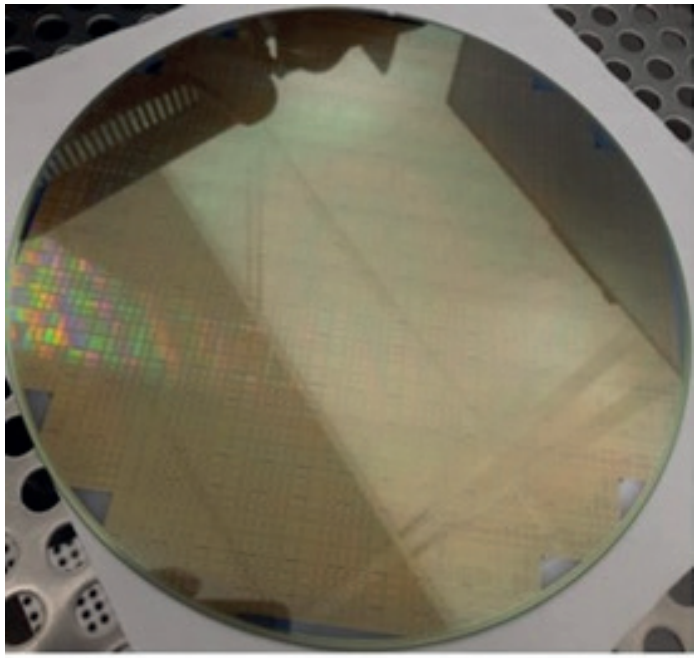
Why vertical GaN sets new standards:

By developing vertical power transistors based on the innovative GaN-on-QST technology (Qromis Substrate Technology), the project aims to achieve a breakthrough in efficiency and sustainability.
These novel components significantly reduce both on-state and switching losses, while simultaneously providing access to higher voltage classes in the range of 650 to 1200 volts and beyond compared to lateral GaN devices. Of note is the ability to significantly minimize losses through extremely fast switching operations, which represents a decisive advantage over existing technologies.

To fully exploit this potential, the project examines not only the semiconductors themselves but also their embedding into modules and systems. The high switching speeds of GaN require an exceptionally close integration between the driver and the power semiconductor, which is why new integration concepts are being developed within the project. Effects such as stray inductance and stray capacitance also play a central role, as they significantly influence performance.

Shaping the Future.

As part of the "Research for New Microelectronics" (ForMikro 2.0) program, we are combining our expertise with Kiel University of Applied Sciences (HAW Kiel), Volkswagen AG, and Semikron Danfoss GmbH.



© Fraunhofer ISIT / HAW-Kiel

The first vertical GaN wafers with 200 V com-ponents are in the final stages of transistor assembly on the front side of the wafers. This will be followed by back-side processing of the wafer for the back-side contact.

On top of this, the VerGaN project is receiving a total of 1.2 million euros in funding from the Federal Ministry of Education and Research (BMBF).
This funding highlights the importance of innovative microelectronics for technological competitiveness and the development of forward-looking applications.

Project duration:
February 1, 2024 – January 31, 2028

Funding:
1.2 million euros from the BMFTR

Project partners:
Fraunhofer ISIT, HAW Kiel, Volkswagen AG, and Semikron Danfoss GmbH

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Making Integrated Microchips Possible: How the Design Enablement Team Accelerates Innovation

Having a good idea for a new electronic product is one thing, but turning it into a technically and economically viable solution is quite another. Small and medium-sized companies in particular face major hurdles: complex development processes, expensive design tools, limited access to manufacturing. This is exactly where the Design Enablement Team (DET) at Fraunhofer IIS comes in.

Challenges on the way to your own chip

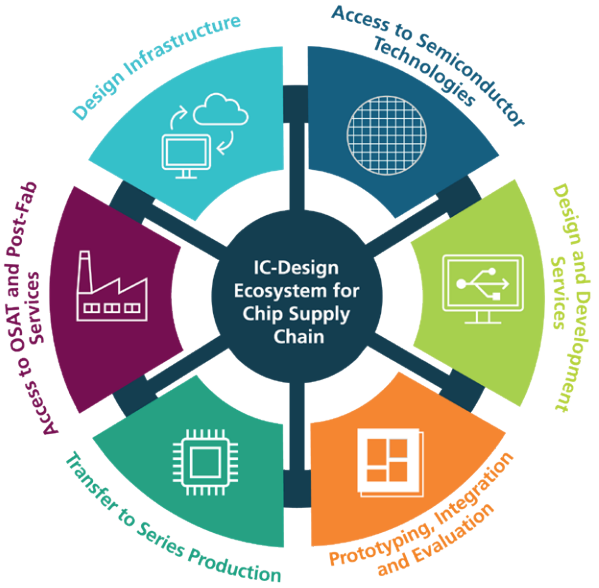
Anyone who wants to develop a chip has to make fundamental decisions early on: Should the functionality be implemented through a system or software-based solution? Or does an ASIC offer decisive advantages in terms of performance, energy efficiency, size and scalability? Which technology is suitable? Which IP blocks are needed? What is the optimal packaging approach? And last but not least: Can all this be realized economically?

For many start-ups and SMEs, these questions are difficult to answer on their own, especially since any mistake in the early design process can lead to enormous costs later on.

Design Enablement that lowers barriers

From the initial technical evaluation through architecture, simulation, and verification, followed by post-fabrication bring-up, testing and transition to series production, the DET ensures that designs are set up for scalability from the outset. The team provides proven design flows, models, and tools within a secure, user-friendly, and scalable EDA infrastructure, enabling easy access to industry-standard EDA tools and PDKs. This approach keeps initial design flow costs low and shortens development times, especially for small and resource-constrained companies.

The MPW (Multi Project Wafer) offering plays a central role. It enables cost-effective prototype production by allowing multiple projects to share a wafer. This is often the first opportunity for start-ups and SMEs to bring their idea »into silicon«.



Lowering the barriers to silicon: The Design Enablement Team's IC service ecosystem.
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A modular ecosystem that opens doors from research to market

In collaboration with research and technology partners from academia and industry – spanning IC design and development, fabrication, and post-fab processes such as packaging, testing, and related activities – the DET has access to an established ecosystem that significantly simplifies access. This modular approach comprises foundry access, cloud- and on-premises-based EDA and PDK environments, design support and expertise, and fabrication services, closing critical gaps in resources and know-how for start-ups and SMEs. They benefit not only from technical expertise, but also from the fact that scientific innovations become usable at an early stage: from energy-efficient edge AI chips to robust sensor designs.

The Design Enablement Team from Fraunhofer IIS sees itself as an enabler. It sets up ideas from the very beginning for scalability and makes microelectronics accessible to those who have strong product ideas but do not have the infrastructure of a semiconductor company, thus helping to bring innovations into application faster and at scale.

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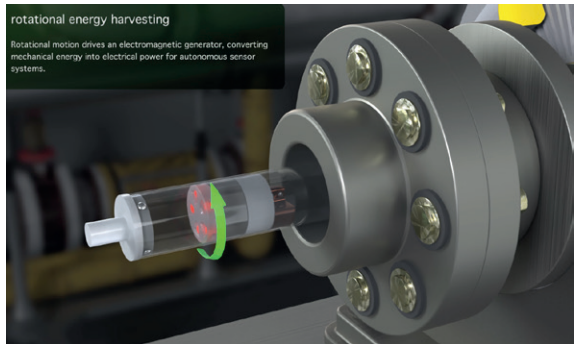
Do your IoT sensors still need external power by batteries or power cords?

Autonomous condition monitoring – powered for the long run:

The essential parts of high-performance IoT applications depend on the number of sensors that can send reliable information whenever it is needed. Concentrating on condition monitoring and predictive maintenance services based on sensors – two essential questions are still not sufficiently answered – from where do they get their power to be convincing also during the long run of their use and how much are the maintenance costs for batteries and manpower to exchange them over the years? Tiny but powerful energy harvesting systems can be the game changer for these applications.

The power supply bottleneck at the sensing edge

Most of the processes where IoT sensors deliver meaningful information about the condition of devices, structures, buildings, motors or industrial processes are providing an energy source by themselves – with smallest temperature differences, (micro-) vibrations and other kinetic or even electromagnetic field energy. With energy harvesting systems – based on energy converters that can be integrated directly into the device or structure – you realize a powerful, sustainable solution which minimizes maintenance and run time costs.



Autonomous power for IoT sensors that are resilient and robust

The application areas for condition monitoring of buildings, bridges, infrastructures or industrial environments that work 24/7 where sensors send information via radio connection grow extensively. Especially areas that today still depend on manual maintenance work or on fixed routines that take place and cause costs even when they are not necessary would benefit hugely from autonomous wireless sensors. Offshore wind turbines, conveyer belts, pumps and turbines or motorway and railway bridges could be monitored more safely with self-powered sensors and guarantee higher resilience even in emergency situations.

Powered by rotations

At electronica the energy harvesting experts of the Fraunhofer-Institute for Integrated Circuits IIS introduce their latest achievement where the condition monitoring of a turbine can be powered by a small energy harvesting system that uses rotation from the turbine itself. Several milli-watts of power are generated in a small generator and are processed to directly supply a couple of sensors and a wireless module on the turbine.

At a Glance:

- Energy Harvesting Systems using thermal gradients, vibrations, rotations, EM fields and even sound waves
- Self-powered radio sensors with energy harvesting power supply

Delivering the perfect fit for your use case

is our core competence. Every process calls for its tailored energy harvesting system to deliver the optimum of energy and enable unlimited operating time of wireless (condition monitoring) sensors!

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Novel glass-packaging approach bringing photonic and quantum chips towards mass production

Photonic chips are entering applications ranging from high-speed communications and medical diagnostics to sensing, quantum technologies and artificial intelligence. Their wider use, however, depends not only on chip performance. The components also need packages that can be produced efficiently and integrated reliably into larger systems. Conventional photonic integrated circuit (PIC) technologies and testing processes are difficult to automate and account for a large share of module manufacturing costs.packages. LTCC in combination with a new, high resolution structuring technology allow unique low loss characteristics above 100 GHz.

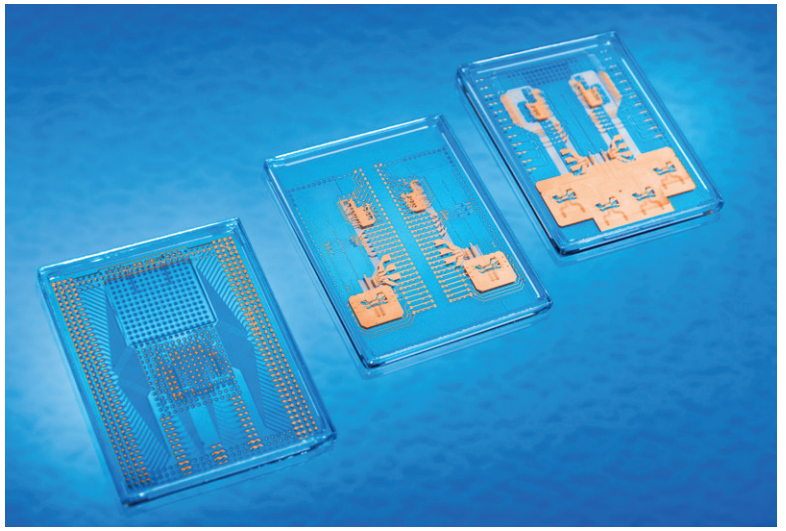
Creating a thin, hermetic and solderable machine-placable package

To address this challenge, disruptive wafer-level PIC module integration, packaging, and test technologies have been developed that can significantly reduce PIC packaging costs. A thin-glass interposer offers a compact way to connect photonic and electronic components. Through-glass vias provide thermal and electrical paths, while fine-pitch redistribution layers route the connections across the surface. Because the material is transparent, the top of the package can also serve as an optical interface for either emitting free space beams or coupling to optical fibers.
Fraunhofer IZM realized the interposers on laser-structured glass wafers, metallized the vias and created the redistribution layers.

Once the photonic and electronic components are placed, the package is closed by laser-sealing a glass frame and lid. The resulting flat, hermetic and solderable package, allowing them to be placed like thin surface-mount technology devices.

Designed for scalable manufacturing

Laser processing makes the glass structure adaptable, while wafer-level production provides a route to larger manufacturing volumes. Standardized ball-grid contacts on the underside provide thermal and electrical connections. The upper surface remains available for free-space beams or coupling to optical fibers. The technology makes photonic modules easier to manufacture, connect and integrate.



Thin glass interposer with structured metallization created using wafer-level processes – before assembly with photonic components (and package closure)

© Fraunhofer IZM / Volker Mai

Standardized design rules and a process design kit could also make the packaging approach accessible through established design tools.

Applications from communications to medical diagnostics

This approach represents a cost-effective alternative to Si interposers, is easily scalable thanks to production on wafers thus enabling new applications in the fields of telecommunications, biomedicine, AI-oriented optical processing, quantum photonics and optical chiplet platforms. Fraunhofer IZM is expanding its glass-processing capabilities toward larger formats, including 300 mm wafers and 500 mm × 500 mm panels. This creates a foundation for transferring the packaging concept from individual demonstrators to scalable manufacturing environments.

The project behind the technology

These developments are part of PhotonicLEAP (2021-2025), a joint European project focused on wafer-level integration, packaging and testing technologies for photonic integrated circuit modules. Within the project, Fraunhofer IZM was responsible for key elements of the glass package, including through-glass vias, redistribution layers and laser sealing. PhotonicLEAP also focused on developing standardized packaging design rules and a process design kit to support future use of the technology.

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LTCC Technologies for Millimeter-Wave Frequency Applications

LTCC (low-temperature co-fired ceramics) materials offer outstanding high-frequency characteristics such as a very low loss angle and a comparable low permittivity over a measured temperature range from -50 °C to 150 °C. Due to their glassceramic composition, they also offer a high degree of reliability, for example under harsh environmental conditions. With its multilayer-ability to become 3D-structured, it is possible to integrate electrical circuits or to realize ceramic packages. LTCC in combination with a new, high resolution structuring technology allow unique low loss characteristics above 100 GHz.

Additional Benefits of LTCC Technologys

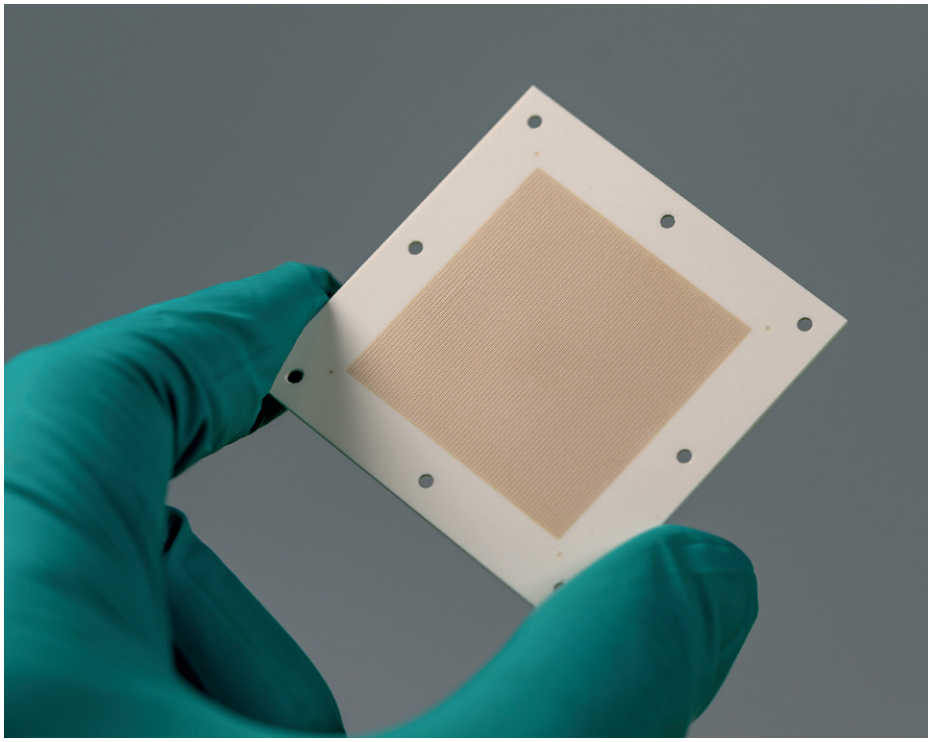
Beyond its outstanding high-frequency properties, LTCC technology is particularly suitable for demanding applications requiring long-term reliability. Its high-temperature stability at temperatures of 300 °C and above enables dependable operation in challenging environments. At the same time, the excellent thermo-mechanical compatibility with semiconductor components helps to minimise mechanical stress during temperature changes.

Hermetically sealed LTCC packages provide effective protection against moisture, gases and other external influences, ensuring stable performance even in aggressive atmospheres.

In addition, the technology enables the development of highly integrated hybrid components combining conductive, dielectric, magnetic, piezoelectric and sensor materials within a single ceramic structure.

Development and Manufacturing Services

Fraunhofer IKTS supports customers throughout the development of multilayer ceramic high-frequency components tailored to specific requirements. Services include the selection and characterisation of suitable materials, the development and qualification of reliable manufacturing processes, and the production of samples in small to medium quantities.



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30-dBi gain LTCC-based transmittarray with embedded anisotropic printed cells.

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Printed, Flexible AMR Sensors for Detecting Weak Magnetic Fields

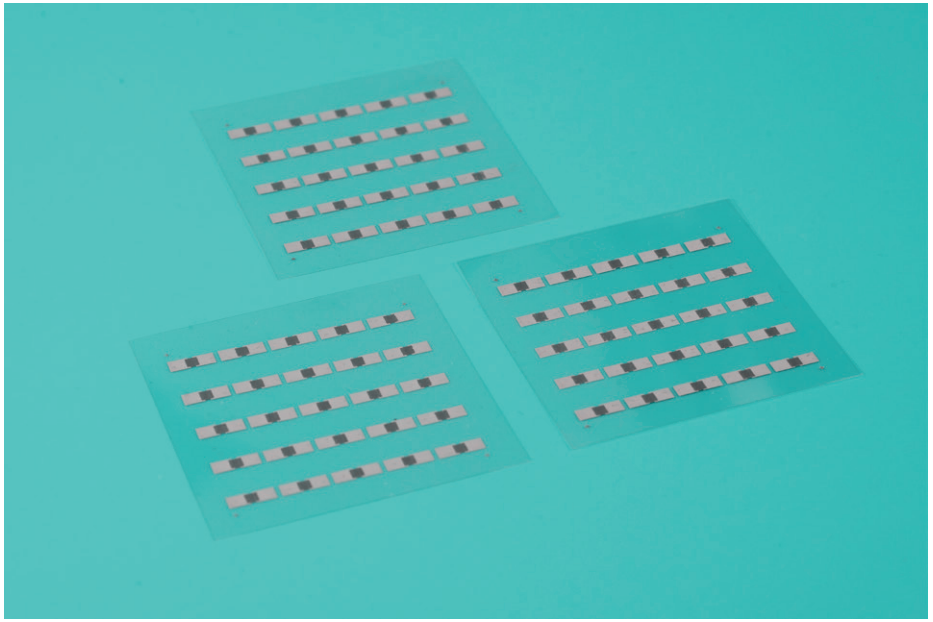
Weak magnetic fields in the range of approximately 0.1 to 5 mT can be detected very effectively using anisotropic magnetoresistive (AMR) sensors – ohmic electrical resistors that respond to an applied magnetic field with a defined change in electrical resistance. These consist of ferromagnetic materials, such as a nickel-iron alloy (permalloy) with very good magnetizability. The anisotropic magnetoresistive effect (AMR) that occurs depends on the orientation of the current flow in the sensor resistor relative to the external magnetic field. For this reason, AMR sensors are used as position and rotation sensors in encoders to detect the motion of mechanical components in machines.

In the current state of the art, microelectronic AMR sensors are implemented as surface-mount devices (SMDs). These sensors have several disadvantages, however: a lack of mechanical flexibility, high costs for the fabrication of sensor arrays, and limited temperature stability up to 150 °C due to the packaging technology used.
These disadvantages of SMD sensors can be avoided by printed AMR sensors fabricated using microprinting processes such as screen printing or inkjet printing.

To this end, Fraunhofer IKTS develops magnetic material pastes and inks that can be precisely deposited on a wide range of substrates, including polymer and ceramic tapes.

The printed layers are sintered within milliseconds using a diode laser array operating in continuous-wave mode and generating a line-shaped laser beam in the near-infrared range.

This enables energy-efficient sensor production, including at industrial scale. Results demonstrate that AMR sensors printed on polymer tapes exhibit very good mechanical flexibility and durability (tested up to 30,000 bending cycles). Printed AMR sensors on polyimide tapes show significantly enhanced temperature stability compared with the state of the art, with resistance up to 300 °C.



AMR sensor arrays on PET polymer tape, produced by screen printing and laser sintering.

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Diode Laser Sintering

The structure prepared by wet chemical deposition methods require specific post-processing in order to remove the organic components and sinter metallic/ceramic particles. Fraunhofer IKTS for this purpose uses an innovative method based on a microoptically optimized high-power diode laser (HPDL) line.

This technology enables a selective and extremely fast funtionalization of the printed materials and allows using of thermally sensitive polymer- and paper substrates potentially also in roll-to-roll applications.

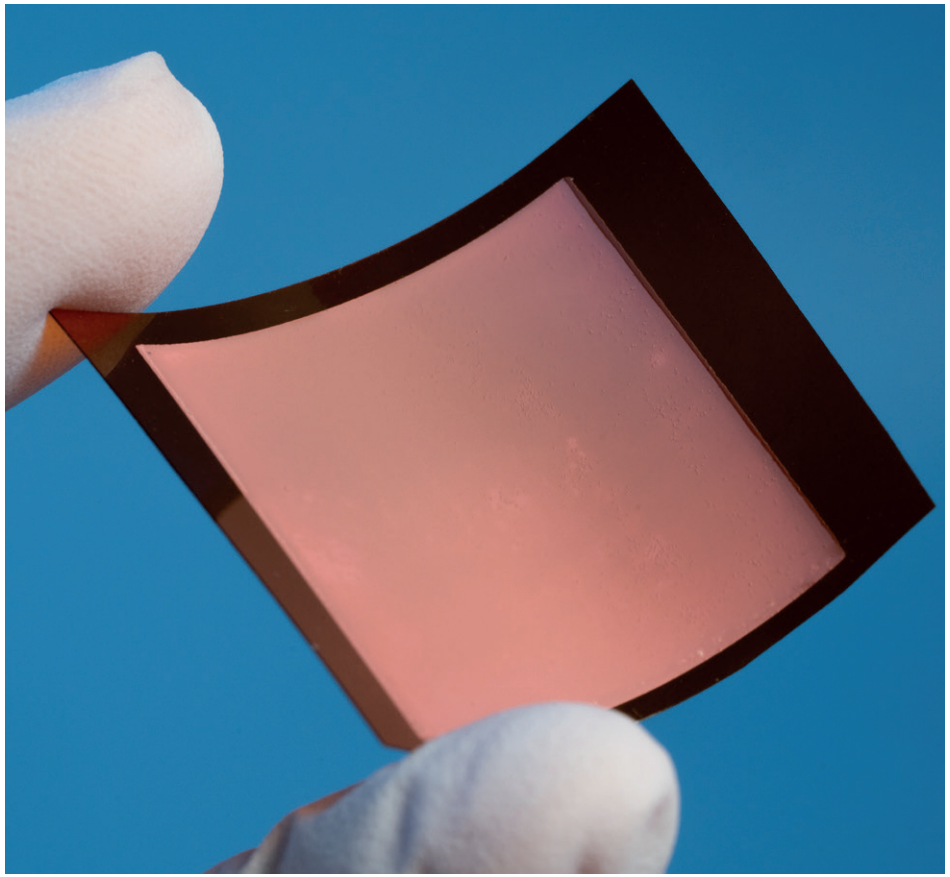
Moreover, the short processing time allows sintering of non-noble metal particles in air without their oxidation. With this technology, Fraunhofer IKTS supports industrial partners as well as research institutions in the development of printed electronics products and sensor technology. The portfolio of the processable materials covers nickel and molybdenum on alumina as well as silver, gold, copper, and platinum which are suitable for polymer, paper, glass, and Al_2O_3 substrates.

Services offered

- Functionalization of printed metallic and ceramic structures
- Realization of unique combinations of materials and properties using fast heating/cooling as well as melting/solidification
- Feasibility studies and demonstration on lab scale

Diode Laser System

The Fraunhofer IKTS diode laser system can process substrates up to 250 mm x 300 mm in size. The maximum optical power is 900 W (near-infrared diodes), while the diode array length is 30 mm.
The system operates at a processing speed of 0.01–60 m/min.



Screen printed copper layers on polyimide foil sintered by diode laser arrays with sheet resistance in mOhm range.

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Cold Sintering of Materials for Solid-State Battery Applications

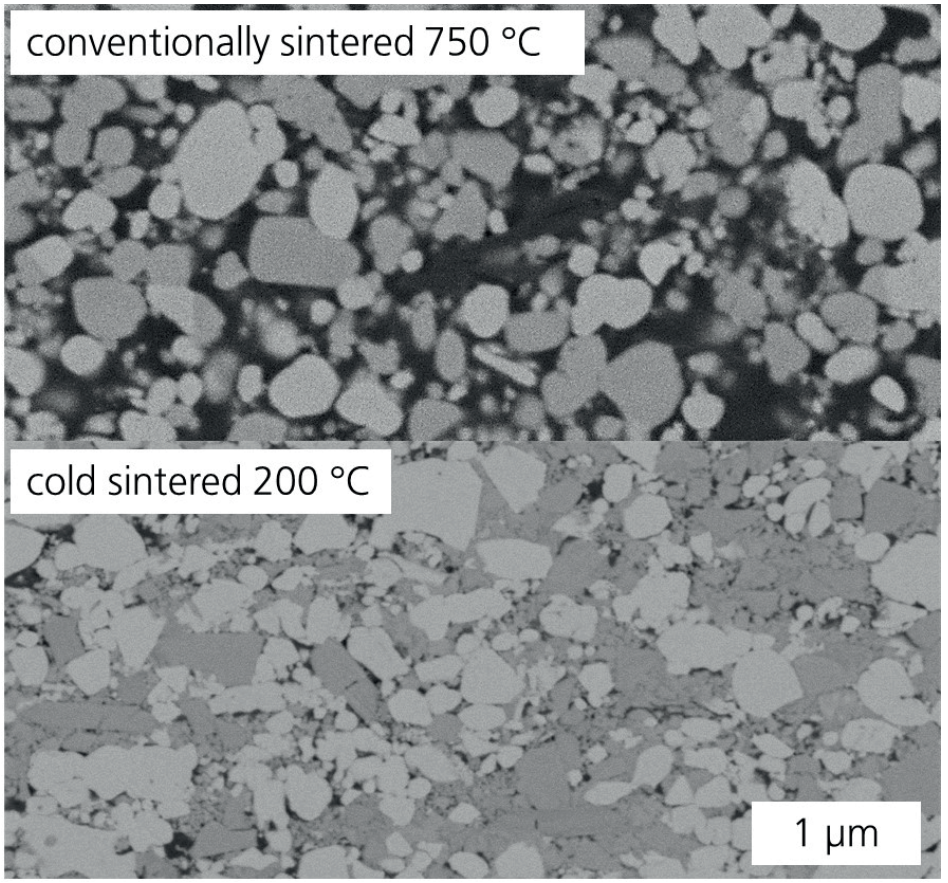
The energy transition and electromobility are leading to a steadily increasing demand for power storage units with high energy and power densities. Currently, lithium-ion batteries with liquid electrolytes are mainly used for this purpose. Solid-state batteries are a promising alternative as they are also particularly safe. Fraunhofer IKTS is investigating innovative approaches, such as cold sintering for the production of components for lithium and sodium solid-state batteries.

Cold sintering

The cold sintering process has been attracting increasing attention in recent years as an energy-efficient sintering technique. In this process, materials are mixed with a liquid phase (water or solvent) and pressed at temperatures below 300 °C and pressures up to 700 MPa. The liquid phase causes dissolution and reprecipitation processes to take place in the microstructure. In this way, materials with densities comparable to those of conventionally sintered materials can be realized at a fraction of the conventional sintering temperature.

Composite cathodes

Since solid-state batteries do not use liquid electrolytes, cathode composites of active and electrolyte materials have to be used for this purpose. At sintering temperatures such as those required for conventional sintering, the materials used react with each other and lose their electrochemical activity. Composite cathode tapes, developed at Fraunhofer IKTS, show reduced signs of these decomposition reactions after cold sintering at a maximum temperature of 200 °C. In addition, cold-sintered composites have significantly denser microstructures than conventional composites sintered at 750 °C (bottom image). Thus, cold sintering enables completely novel material combinations for the production of high-performance solid-state batteries.



FESEM images of conventionally and cold-sintered composite cathode tapes (dark = LATP; light = active material).

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Multilayer Ceramic Components for Electrocaloric Cooling

Solid-state cooling based on caloric effects represents a promising approach for alternative, environmentally friendly and energy-efficient cooling systems and heat pumps. Electrocaloric materials show a sudden increase in temperature when an electric field is applied. After releasing the generated heat via a heat sink, the electric field can be removed, whereby the material cools down to a value below the initial temperature. It can now absorb thermal energy from a heat source. This effect is highly reversible and can be used in an electrocaloric cycle.

Ceramic Components for High Electrocaloric Effects

In addition to selecting a suitable material that exhibits a phase transformation close to the application temperature, the right component design is of great importance.

Ceramic multilayer components are particularly advantageous because of their higher cooling volume compared to thin films and their higher dielectric strength compared to bulk materials. For this purpose, Fraunhofer IKTS is developing highly efficient materials and components that show high electrocaloric temperature changes and low dielectric losses. Due to the small individual layer thickness of the ceramic layers, only low driving voltages are required to operate the electrocaloric components.

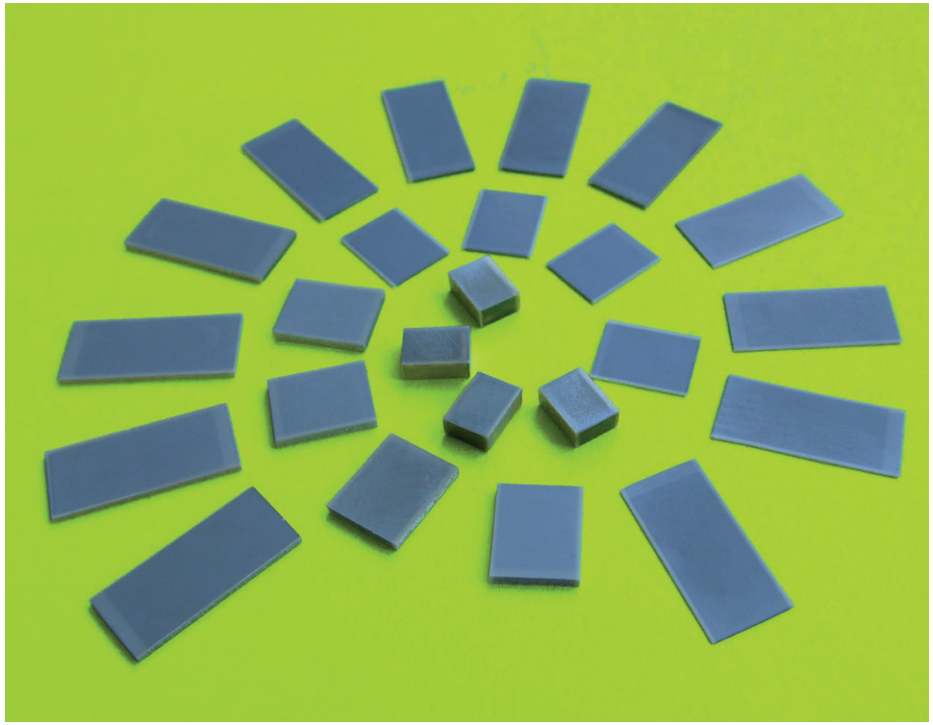
Electrocaloric materials can also be used as fillers in polymer-based films to enhance their electrocaloric performance. For this, particle size and shape are optimized.

Revolutionizing Heat Pump Technology

Electrocaloric heat pumps offer a highly efficient, compact, and environmentally friendly alternative to conventional vapor-compression systems. They do not require greenhouse-gas refrigerants and enable silent and scalable operation.

Fraunhofer IKTS develops materials and components that meet the system requirements for high electrocaloric effect and increased operating frequency.

In addition, characterization of dielectric and electrocaloric properties as well as life prediction studies are offered.



Electrocaloric multilayer components. *© Fraunhofer IKTS*

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Bavarian Chip-Design-Center's Focus Areas

The Bavarian Chip-Design-Center focuses on the following topics:

IC – Design Ecosystem

- Versatile Edge-AI Processor
- RF Sensor Systems
- Ultrasonic Sensors
- Wake-up Receiver
- Secure System-on-Chip (SSoC)
- Application Specific Multi-Chip-Modules
- Heterointegrated Sensor Systems

IC – Supply Chain

- Small Volume Manufacturing
- Foundry Services

IC – Design Talents

- Trainee Program
- Course Programs



Bavarian Chip-Design-Center

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