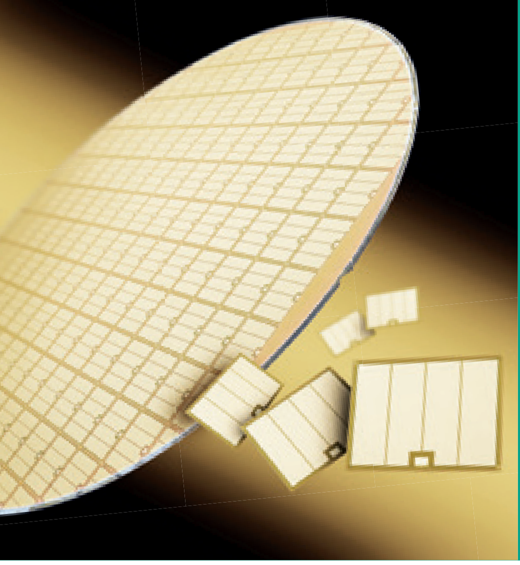
Fraunhofer
ISIT

FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE ISIT

INNOVATIONS FOR MICROSYSTEMS AND POWER ELECTRONICS

| RESEARCH & DEVELOPMENT | TECHNOLOGICAL SERVICE | NEW PRODUCTS | PRODUCTION |



RESEARCH AND PRODUCTION IN ONE LOCATION

Far left: 1200 V IGBTs with NiAu surfaces
Left: ISIT cleanroom
Bottom: Wafer with driving electrodes for high power scanning mirrors

Fraunhofer ISIT is headed by Dr. Axel Müller-Groeling

Fraunhofer ISIT in Itzehoe is one of Europe's most modern research facilities for microelectronics and microsystems technology. The institute in Itzehoe develops and manufactures customized components and systems for power electronics and microsystems technology. Important areas of application include energy technology, automotive and transport engineering, the consumer goods industry, medical technology, communications technology, and automation. Ultra-modern technological equipment based on 200 mm silicon wafer technology and expertise built up over decades put Fraunhofer ISIT and its customers at the forefront of the field worldwide.

Fraunhofer ISIT supports customers right the way from design and system simulation to the production of prototypes, samples, and preparation for series production.

The institute currently employs a staff of 160 persons with engineering and natural sciences backgrounds. Fraunhofer ISIT deals with all the important aspects of system integration, assembly and interconnection technology (packaging), and the reliability and quality of components, modules, and systems. The institute also provides manufacturing support for application-specific integrated circuits (ASICs) to operate sensors and actuators. Activities are rounded off by the development of electrical energy storage devices, with a focus on Li-polymer batteries. One thing that really sets Fraunhofer ISIT apart is the speed with which it can transfer innovative developments into industrial application and production. To this end, Fraunhofer ISIT operates a wafer production line in its cleanrooms in collaboration with the companies Vishay and X-FAB MEMS Foundry Itzehoe. There are longstanding collaborations with a variety of manufacturing companies local to Fraunhofer ISIT.

Fraunhofer ISIT runs an application center Power electronics for renewable energy systems at Hamburg University of Applied Sciences, a working group at the Christian-Albrechts-Universität, Kiel and maintains a close cooperation with the West Coast University of Applied Sciences in Heide.

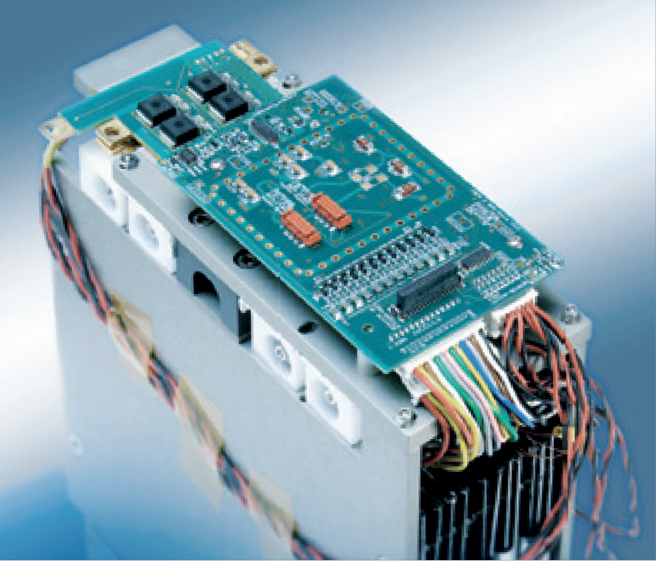
Cooperation with Fraunhofer ISIT

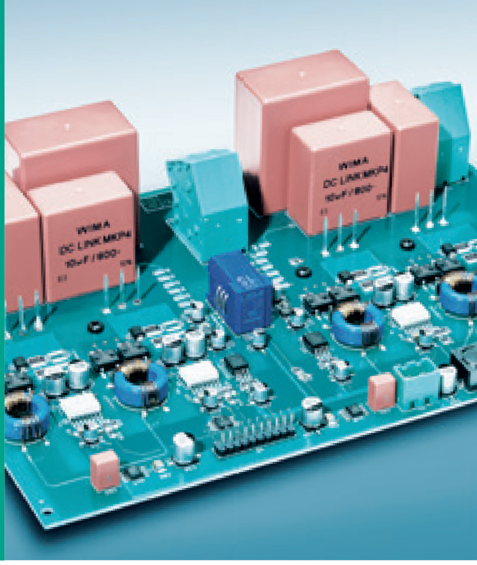
The institute's services assist companies and users in a wide range of sectors. Components, systems, and production processes are developed, simulated, and implemented in close collaboration with customers. This process is aided by Fraunhofer ISIT's use of technology platforms (production process flows defined for whole groups of components) meaning they can be used in production unchanged or with simple modifications to the design parameters.

Fraunhofer ISIT's expertise presents particularly exciting possibilities for small and medium-sized enterprises looking to realize their technological innovations.

Fraunhofer ISIT is Participant of Research Fab Microelectronics Germany

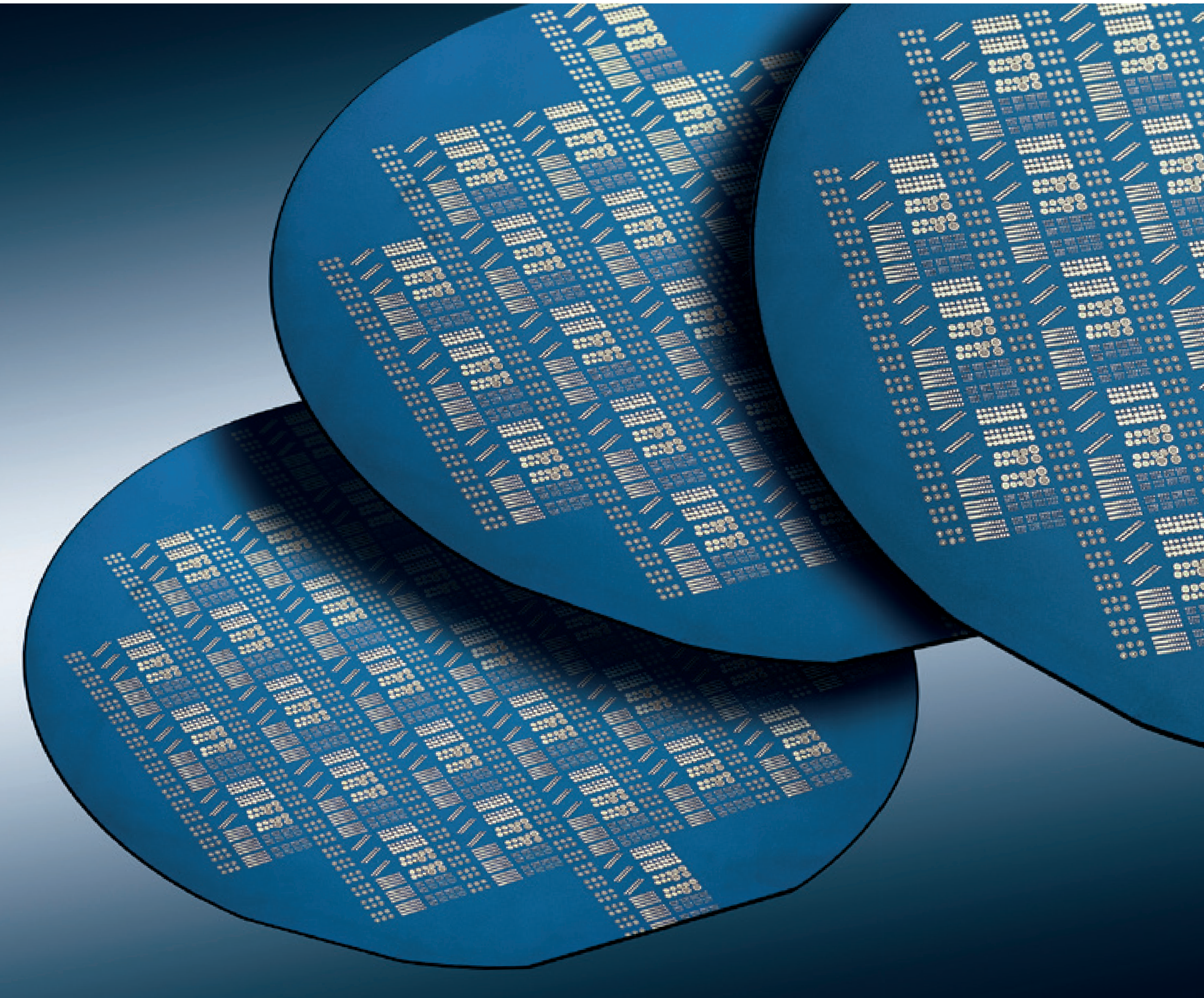
To reinforce the position of Europe's semiconductor and electronics industry within global competition, eleven institutes within the Fraunhofer Group for Microelectronics – including the Fraunhofer ISIT - have, together with the Leibniz Institute for Innovations for High Performance Microelectronics (IHP) and the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH), come up with a concept for a cross-location research factory for microelectronics and nanoelectronics. The new organization operates as a „Microelectronics Research Institute Germany", complements and modernizes the facilities and equipment of the institutes in order to adapt them to current technological developments and brings together the capabilities of the individual institutes in a common technology pool. With this new equipment park, ISIT can offer forward-looking manufacturing processes to the industry and is able to develop novel components and convert them into production.





Far left: High performance battery storage system with energy management and singel cell monitoring
Left: DC / DC converter
Bottom: GaN wafers with test structures for power devices

BUSINESS UNIT POWER ELECTRONICS



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 supporting applications in a wide voltage range from a few 10 V up to 1200 V. The development portfolio ranges from silicon-based IGBTs, diodes and MOSFETs to diodes and transistors for highest switching frequencies in the MHZ range based on gallium nitride, using modern 8" manufacturing environment. A particular R&D focus are the application-specific design of the components and the development of new device architectures. Another important research topic is the development of new processes for advanced power device designs on wafer-level. For gallium nitride devices, ISIT is developing also front- and backside contacting methods for bulk-GaN wafer and GaN-on-Si wafers. The Fraunhofer ISIT develops customer-oriented device structures with special pad configurations and for improved integration concepts. For the wafer handling and wafer processing of thin Si substrates, the ISIT developed and applied new carrier wafer concepts together with laser annealing processing. The laser annealing enables the dedicated doping activation allowing customer-specific optimizations of static and dynamic losses while improving the robustness of the components. These activities are supported by numerous simulations, design and test tools. Additionally, the Fraunhofer ISIT has many years of R&D experience in the design and manufacturing of CMOS circuits.

The development of passive electronic components focuses primarily on chip capacitors, precision resistors and inductors as well as corresponding chip-level circuit networks. This involves the evaluation of new materials as well as their implementation in existing process flows.

On system level, the ISIT offers the development of novel circuit topologies and integration concepts for highly efficiency DC/DC and DC/AC power converters using application-specific power semiconductors targeting an optimized overall system performance and long-term reliability. By using resonant circuit topologies and control techniques, peak efficiencies larger than 99% are realized and a soft-switching operation is achieved over nearly the entire output power range.
For the increase usage of renewable energies, the ISIT develops solutions for increased flexibility for the overall grid stability by using the specific possibilities of battery systems. Furthermore, the ISIT is investigating how new control methods can be used to provide important system-stabilizing services and supports the overall system simulation. The main areas of application for these services of ISIT are in the field of renewable energies, e-mobility and electric aviation.

The topic of energy storage has been for a long time one of the key research areas at Fraunhofer ISIT. The ISIT develops batteries and battery systems for a wide variety of applications with its specific requirements, e.g. a particularly high energy density for a long range in electric vehicles or a high power density to charge and discharge batteries quickly. The latter is of high importance in the storage of wind energy for grid stabilization. By this, the ISIT has the opportunity to realize battery systems for special applications, where for instance stability at high temperatures or a particularly high power density is necessary. In the activities, the Fraunhofer ISIT pays special attention to a production-related development. At the ISIT, a complete process chain is available from paste processing up to the assembly and characterization for single cells up to high-power storage systems. The complete process chain from material preparation and electrode production to packaging and electrical and thermomechanical characterization of cells regarding different chemistries and design is available. A current focus is on the development of special high-performance batteries that can be charged in less than four minutes and deliver all their energy when needed in one minute. In addition, the Fraunhofer ISIT takes research on next generation energy storage systems, e.g. the lithium-sulfur battery, which can be expected in the future, facilitating a significant increase in energy density and allowing at the same time a significant cost reduction.

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This business unit focuses on the processes, procedures, and services that constitute essential prerequisites for research and development in the Business Unit MEMS Applications on the one hand and, on the other hand, also services offered by ISIT directly in the market.

Important offerings at ISIT are wafer-level packaging (WLP) and various individual processes at the wafer level. Here the focus is on the packaging of microsystems on the wafer, but also the further processing of pre-structured wafers and the development of problem-specific technology solutions at the individual process level. The wafer technologies that are developed make it a functional part of a microsystem. Outstanding successes were achieved in the vacuum capping of MEMS sensors by means of eutectic wafer bonding. The technology basis at ISIT is excellent: Front-end processes of the power-MOS cleanroom line and the own back-end clean room line with equipment for MEMS-specific manufacturing processes can be used.

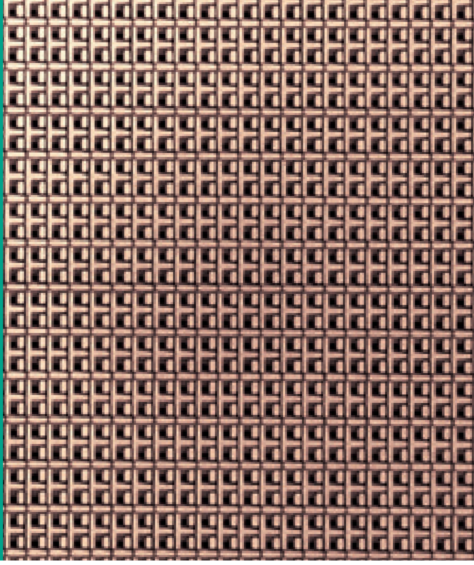
The lithographic capabilities include a wide-field stepper, backside mask aligner, spray coating and spin coating, and thick resist processing. CVD, PVD, ALD and special tools for thin films are available. The wet processing area comprises anisotropic etching of Si, automated tools for metal etching, and electroplating. In case of dry etching, equipment for DRIE of Si and RIE of oxidic compounds is available. MEMS release etching can be performed using HF and XeF2 gas phase etching or wet etching. A specific focus is given to hermetic wafer level packaging of MEMS using metallic, anodic, or glass frit wafer bonding technology. Wafer grinding and temporary wafer bonding are key process steps for thin wafer and 3D integrated products. In addition to the individual processes, ISIT has established a number of qualified technology platforms.

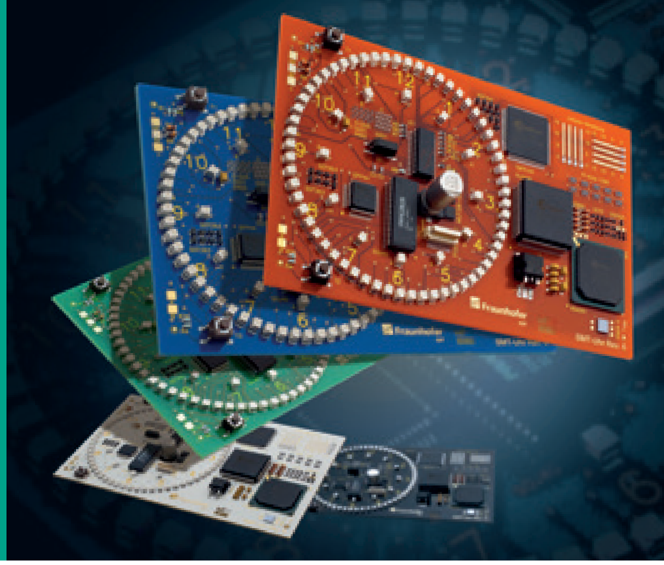
ISIT can also offer the developed components and systems to customers as prototypes or in small series from pilot production. Not only does this require proving that certain manufacturing steps and functional principles are feasible in principle, for example using demonstrators, but also taking all development steps to series readiness – an effort that must not be underestimated. High volume series production can be supported in particular through cooperation with the local company X-FAB MEMS Foundry Itzehoe GmbH, so that the industrial production of larger quantities is also possible in many cases.

After all, ISIT offers a number of services at the module level to internal and external customers as module services. In assembly and interconnection technology, ISIT specializes in the implementation of innovative processes and technologies in direct cooperation with manufacturers of assemblies, equipment, and materials. The automatic assembly of ultra-thin chips on flexible PCBs has already been tested successfully several years ago. ISIT has all basic technologies for the automated or manual handling of microchips and MEMS as well as their electrical contacting using wire bonding and flip-chip technologies. For power electronics assemblies with improved power cycle performance, ISIT has highly developed thick wire/ribbon bonding technology, both for aluminum and for copper bonding material.

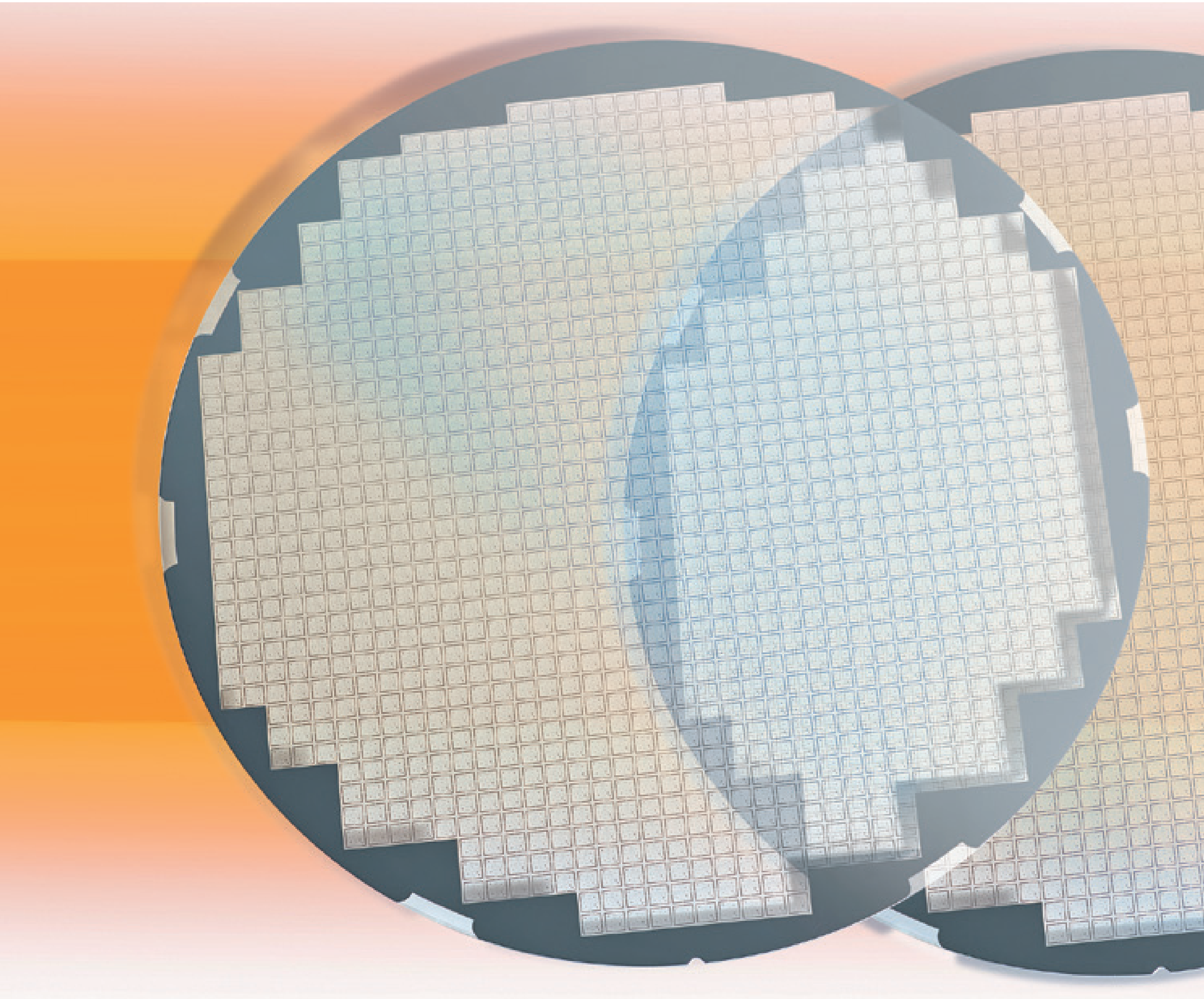
ISIT has more than 20 years of experience with the assessment of quality, reliability, and robustness. Focal points are on the assessment of manufacturing quality, reliability testing, lifetime prediction and failure analysis, and the development of electronics as well as assembly and inter-connect concepts, from the chip to the system. Beyond that, ISIT evaluates the aging behavior of assembly and interconnect techniques like chip-on-chip, chip-on-system, chip-on-board, and chip-on-polymer as well as bonding and soldering connections. The scientists create prognostics by means of model calculations, analyses under different environmental conditions, and accelerated aging tests. They also conduct extensive assessments of failure analyses in the prognostics.

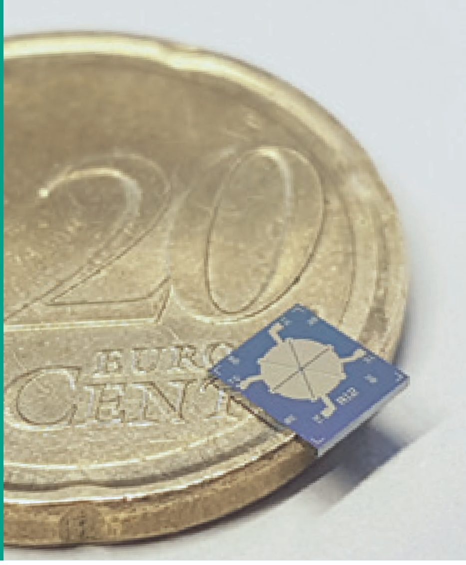
Right: *Galvanic gold structures on CMOS wafer*
Far right: SMT test boards
Bottom: Glass substrate test wafer for calibration support

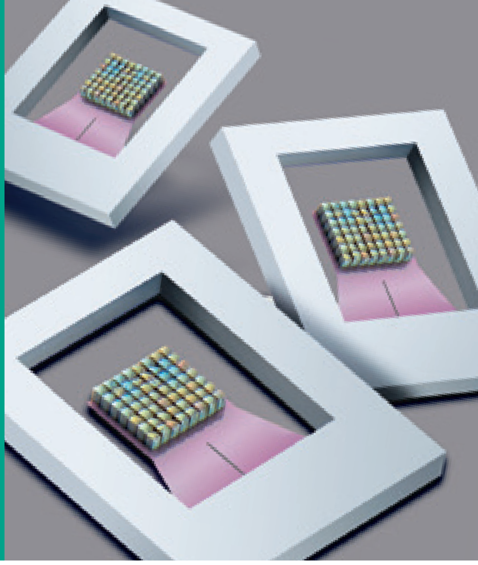




BUSINESS UNIT MICRO-MANUFACTURING PROCESSES

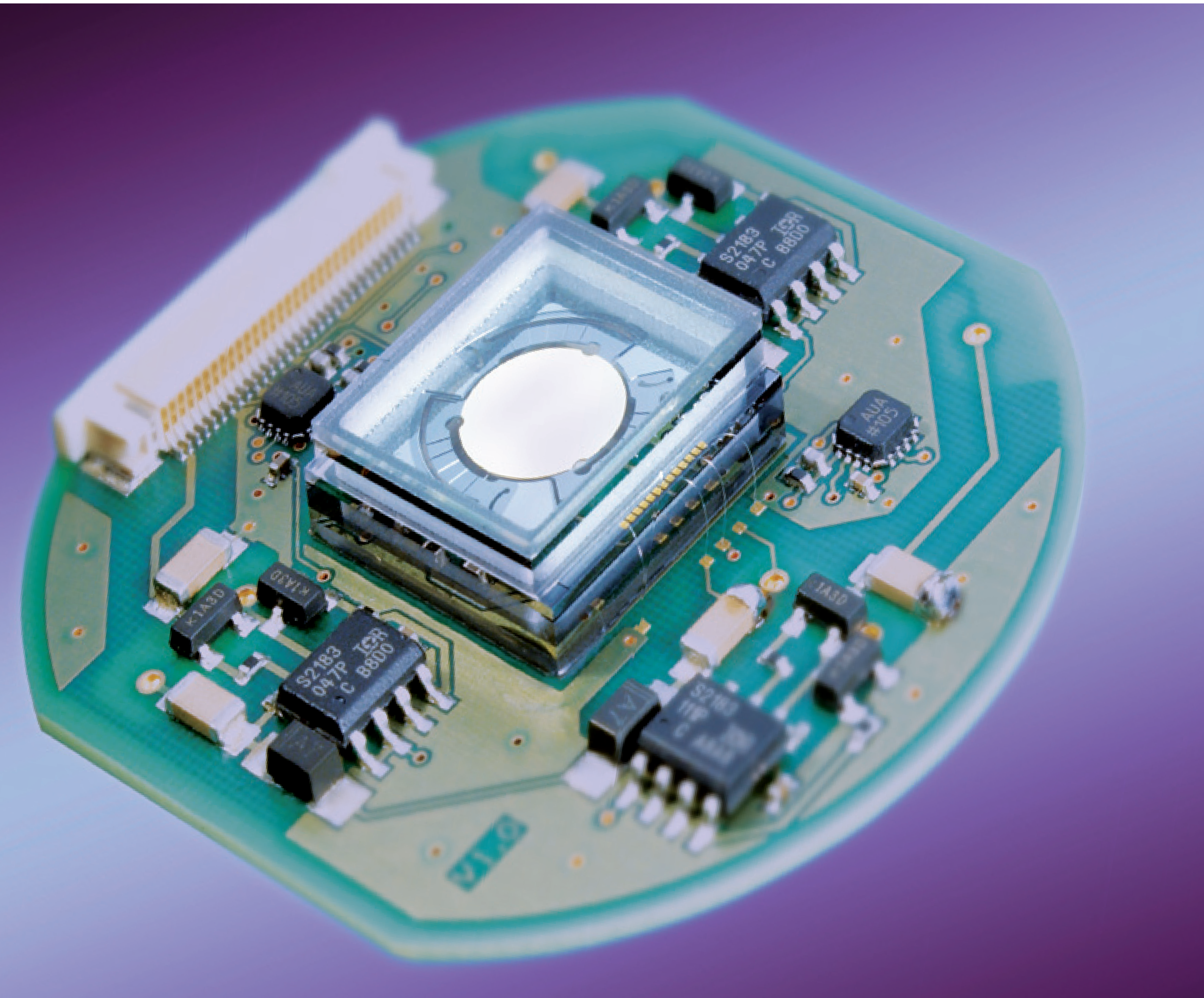






Far left: MEMS-Speaker
Left: Magneto-sensitive piezoelectric energy harvesters
Bottom: Electrically mounted micro mirror

BUSINESS UNIT MEMS-APPLICATIONS



ISIT scientists have been working on the development of micro electro mechanical systems (MEMS) for more than 30 years. In the Business Unit MEMS Applications, ISIT focuses on the design, development, and production of MEMS components and MEMS systems.

Optical microsystems are a key focal point in this business unit. Here ISIT develops MEMS scanners, that is to say scanning micromirrors including control and read electronics for different kinds of laser projection displays, for optical measuring and detection systems (such as LIDAR), and power applications in the fields of laser material processing and generative manufacturing. Based on a patented fabrication process, ISIT is currently the world's only manufacturer of wafer-level vacuum packaged dual-axis MEMS scanners. Operating these scanning micromirrors in a vacuum environment offers significant advantages. Damping by the gas molecules is reduced to a minimum, enabling high-frequency scanning with unrivaled scan angles even at low electrostatic driving voltages. Hermetic encapsulation at the wafer level also results in the cost-effective and permanent protection of the scanning micromirrors against all kinds of contamination. This for example makes the steam sterilization of these MEMS scanners in an autoclave for endoscopy applications possible without causing damage.

ISIT has also realized a 3D camera with a depth resolution of just a few millimeters and a detectable object distance of 2 meters on the basis of 2D MEMS scanners. Novel scanning micromirrors with apertures of up to 2 centimeters and highly reflective coatings even permit highly dynamic dual-axis laser beam deflection for CW laser outputs of up to 500 watts.

In addition to capacitively driven scanning micromirrors, piezoelectrically driven scanning micromirrors are currently a research focal point at ISIT. This drive concept is particularly attractive due to its high force with simultaneous low energy consumption. Deflections of up to 1600 µm have already been realized on individual scanning micromirrors of this type for resonant, translatory lifting movements.

Another focal point of this business unit is acoustic systems and the corresponding powerful microactuators. Here a focus is on the development of MEMS speakers. These can be produced much more cost effectively and more miniaturized in at least the same acoustic quality as their conventional electrodynamic equivalents. Further advantages are the high energy efficiency and the high acoustic bandwidth (20 Hz–20 kHz) of these components. This makes the ISIT chip speakers especially attractive for mobile communication devices such as tablets, smartphones, headphones, and hearing aids that require high acoustic quality and low energy consumption while the component size has to keep shrinking.

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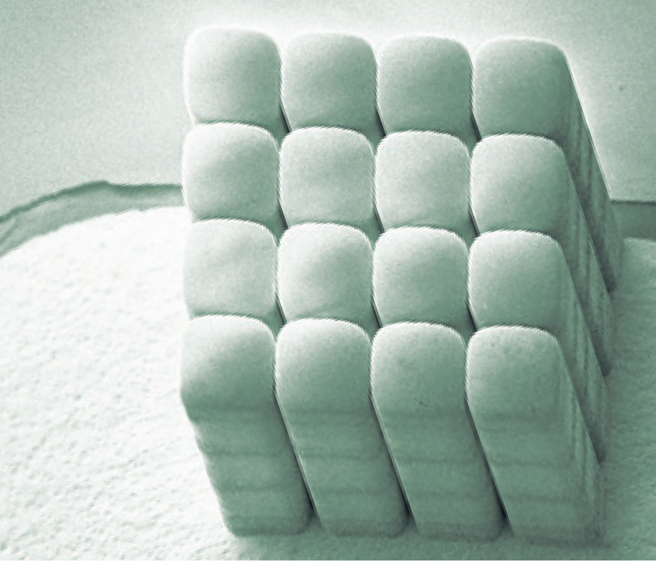
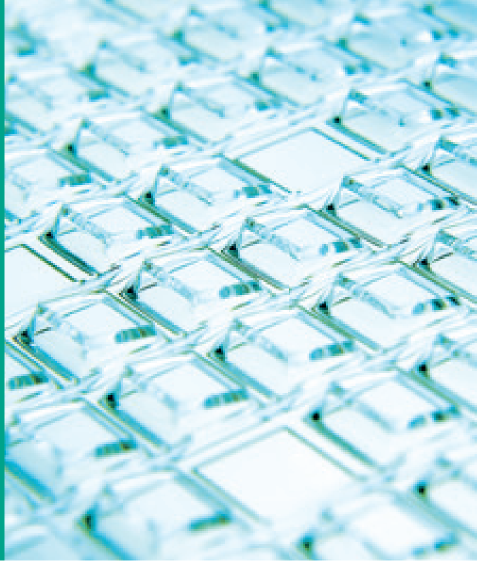
Aside from the MEMS speakers miniaturized ultrasonic transducers are a focal point. Depending on the frequency range, the transducers at ISIT are usually designed as thickness-mode or membrane transducers with AlN, AlScN, or PZT as drive materials. Efficient ultrasound transducers with center frequencies of a few kHz to several hundred MHz can be realized this way. The developed components include ultrasound arrays for medical technology, non-destructive testing, and gesture recognition.

The business unit is also involved in sensor applications with a focus on high energy efficiency. The increasing number of mobile applications in combination with an increasing demand for flexibility requires for more and more wireless solutions. Here, often only a few milliwatts decides if a particular sensor is suitable for an application or not, especially if the sensor systems have to operate for 10 years or more without maintenance. Our work at ISIT focuses on passive sensors based on piezoelectric and pyroelectric materials, which generate their voltage signal solely from the environmental stimulus to be measured. The focus here is on the development of a pyroelectric infrared sensor. Since this sensor only detects temperature changes, it is particularly suitable for use as a motion detector, as a people counter or for gesture recognition. Its main advantages are low energy consumption and a comparatively easy miniaturization. The latter, especially in combination with a functionalized wafer-level package as developed in the Business Unit Microfabrication. The long-term target of these activities is to integrate sensors into stand-alone sensor nodes for Industry 4.0, Wearables, IoT or home automation.





Far left: Magnetic micro-array manufactured by of powder technology
Left: Opto-packages made with glass micromachining
Right: ISIT cleanroom

TECHNOLOGY PLATFORMS

Fraunhofer ISIT is running to a 200 mm Silicon technology line (2.500 m²) for front-end processes (MOS and PowerMOS). Specific processes for MEMS and NEMS as well as for packaging are implemented in a special and newly built cleanroom (1.000 m²). This includes wet etching, dry etching, DRIE, deposition of non-IC-compatible materials, lithography with thick-resist layers, electroplating, microshaping, and wafer bonding. Further cleanroom laboratories are set up for chemical-mechanical polishing (CMP) and post-CMP processing.

Extra laboratories covering an area of 1.500 m² are dedicated to electrical and mechanical characterization of devices, assembly and interconnection technology, and reliability testing. Fraunhofer ISIT also operates a pilot production line for Li-polymer batteries. The institute's facilities have been certified to ISO 9001:2008 for many years.

Fraunhofer ISIT has a wide portfolio of qualified single process technologies available, which were combined to five specific technology process platforms. They form a kind of tool box to realize various applications. In addition, the institute has further technology offers, e.g. for metal surface micromachining or for the technical realization of various accumulator concepts. Therefore, there is a complete manufacturing line from the electrodes to the accumulator cells. In addition, complete systems can also be manufactured.

Poly Silicon MEMS Technology Platform (PSM-X2)

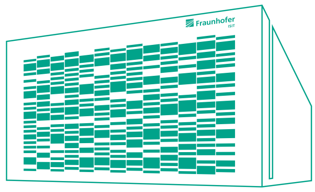
The technology platform PSM-X2 features a low stress 10–30 µm thick poly silicon layer for the realisation of mechanical active and passive MEMS structures. The use of high resolution lithography allows minimal structure dimension down to 0.5 µm. For the wafer scale bonding of the sensor device and the protective encapsulation a dedicated multi pressure wafer level packaging process is applied using e.g. a gold silicon eutectic process at about 400 °C. The metallic bond frame induces a hermetic encapsulation of the cavity. Integrated getter films allow cavity pressure levels down to 10–6 bar and a pressure ratio within adjacent cavities of up to 1:400.

Glass Micromachining

Fraunhofer ISIT developed a process based on hot temperature viscous glass micromachining. It is mainly used for the production of micro-lenses and glass packages with inclined window surfaces. Using this process, it is possible to structure glass wafers with high aspect ratios on wafer level. Depending on the application, the glass may now be further processed by grinding and polishing.

Piezo MEMS Technology Platform

Fraunhofer ISIT has been working on the deposition of thin films of the piezoelectric materials aluminum nitride (AlN) and lead zirconium titanate (PZT). Currently, sputtering processes with film thicknesses of up to 4 µm for AlN and up to 3 µm for PZT are available. The integration into MEMS structures is typically realised via unimorphs consisting of a piezoelectric layer embedded between two metal electrodes on top of a passive support layer made from mono- or polycrystalline silicon. PZT is mainly used for actuator applications, as its high piezoelectric coefficients enable particularly large deflections



and high forces with only low drive voltages. The PZT actuators are integrated for their utilization in MEMS scanners and loudspeakers. For sensory applications, AlN is preferred due to its considerably better signal-to-noise ratio. At ISIT it is currently used in ultrasonic transducers, MEMS microphones and vibrational energy harvesters.

Powder MEMS Technology Platform

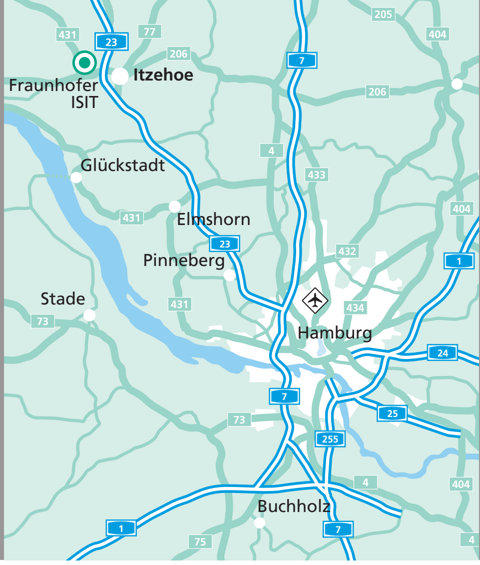
At Fraunhofer ISIT a novel technology has been developed which allows the integration of nearly any material onto planar substrates. It is based on the agglomeration of micron-sized powder (particles) by atomic layer deposition (ALD). Like for the fabrication of ceramics, firstly a mold, in this particular case a silicon substrate with dry etched micromold pattern, is filled with loose powder. However instead of sintering the particles together with high pressure at 800 °C to 1.400 °C, the silicon substrate is subjected to an ALD process at much lower temperatures. Thanks to the outstanding coating capability of ALD the loose particles in the micromolds are fixated to porous 3D structures over the whole mold depth (up to 700 µm) by a layer with a thickness of only 75 nm. These porous 3D structures are shrinkage-free and stable mechanically as well as thermally. Lateral dimensions between 50 µm and several mm can be realized with high precision. The nearly perfect envelopment of each particle by the ALD layer ensures an excellent protection against environmental influences. Substrates with embedded porous 3D structures can be post-processed in a cleanroom using standard processes of IC and MEMS fabrication at up to 400 °C. That opens up a unique range of applications. One of the evaluated ones is the fabrication of integrated permanent micromagnets from NdFeB powder. Strong magnetic fields on small scale are of interest for many MEMS sensors and actuators.

GaN Technology

In addition to the research of new high voltage silicon devices the ISIT is developing power semiconductor components with gallium nitride (GaN) substrates. This material is used to replace silicon because of higher electric strength and higher possible working temperature. These benefits lead to a higher efficiency with smaller device capacities and faster switching speeds.

The research objectives of the ISIT are vertical transistors on 8″ wafers allowing higher power density compared to lateral components. The source material is 8″-GaN-on-Si wafers with epitaxially grown GaN layers as well as bulk GaN wafers with smaller diameters.

To achieve the goal, the equipment and know-how of the newly built MEMS cleanroom is used. The technology portfolio is and has been adapted to meet the requirements of the new material.



ISIT is located about 40 km north of Hamburg in Schleswig-Holstein directly at the highway Autobahn 23 in sight of the exit Itzehoe Nord

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