Fraunhofer
ISIT

FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE ISIT

Achievements and Results Annual Report 2013

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REPRESENTATIVE RESULTS OF WORK

PREFACE

The new ISIT cleanroom building under construction in 2013

Prof. Wolfgang Benecke in discussion with members of State Government: Ministerpräsident Torsten Albig (left), Staatssekretärin Dr. Ingrid Nestle (right)

"The future we want needs to be invented; otherwise we will get one we don't want."

Joseph Beuys

Dear readers, dear business partners,

The year 2013 brought with it a great many challenges for Fraunhofer ISIT. We always put our customers' satisfaction at the heart of all we do and are delighted to be able to present you with this Annual Report as a further inspiring record of outstanding development results and innovations.

The stability of the economic climate also helped us bring this latest financial year to a positive close. Through trusted collaboration with our industrial customers, we were able to counterbalance the persistent downward trend in public-sector funding. The focal points we set in the fields of MEMS technology and power electronics have established themselves as solid pillars of our institute.

Overseeing construction of the new annex building as well as the restructuring of systematic aspects of the institute were both of vital and strategic importance to Fraunhofer ISIT in 2013.

Expansion of our location's potential by establishing a second cleanroom as a platform for micro-/nanosystems engineering went largely according to plan, keeping us on course for a 2014 launch. By continuously expanding systems expertise, the institute is able to keep pace with the growing importance of systems-led solutions and services. Local partnerships are helping to strengthen Fraunhofer ISIT's services portfolio and tailor it to market requirements. This makes the establishment of the Fraunhofer Innovation Cluster "Power Electronics for Renewable Energy Supply"

„Die Zukunft, die wir wollen, muss erfunden werden. Sonst bekommen wir eine, die wir nicht wollen."

Joseph Beuys

Liebe Leserinnen und Leser, liebe Geschäftspartner,

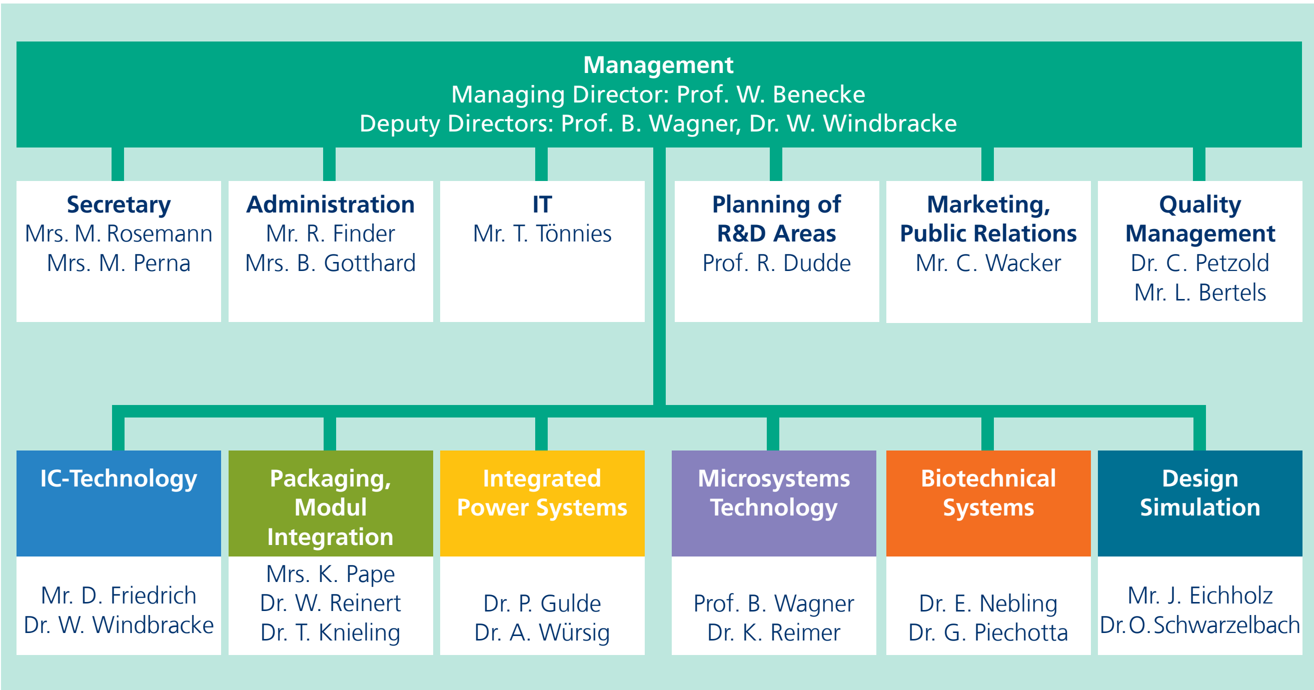
das Jahr 2013 hat für das Fraunhofer ISIT eine Vielzahl von Herausforderungen mit sich gebracht. Die Zufriedenheit unserer Auftraggeber haben wir dabei in den Mittelpunkt gestellt und wir freuen uns, Ihnen mit dem vorliegenden Jahresbericht wieder herausragende Entwicklungsergebnisse und Innovationen präsentieren und Impulse geben zu können.

Die stabile Wirtschaftslage hat es uns ermöglicht, auch das zurückliegende Geschäftsjahr wieder mit einer positiven Bilanz abschließen zu können. Die vertrauensvolle Zusammenarbeit mit unseren industriellen Kunden konnte dabei die stetig rückläufige Finanzierung aus dem öffentlichen Bereich ausgleichen. Als tragende Säulen des Instituts haben sich dabei die gesetzten Schwerpunkte im Bereich der MEMS-Technologien und der Leistungselektronik bewährt.

Für das Fraunhofer ISIT waren in 2013 die Betreuung des Erweiterungsbaues und die strukturelle Umgestaltung des Instituts in Richtung systemischer Aspekte von ganz besonderer und strategischer Bedeutung. Die Erweiterung der Möglichkeiten am Standort durch die Errichtung eines zweiten Reinraums als Plattform für die Mikro- und Nanosystemtechnik verlief weitgehend im Plan, so dass die Inbetriebnahme in 2014 erfolgen wird. Der wachsenden Bedeutung von systemgeprägten Lösungen und Angeboten wird im Institut durch den stetigen Aufbau von Systemkompetenz Rechnung getragen.

in Schleswig-Holstein all the more gratifying. Intensive talks and negotiations with the Land of Hamburg and with the Hamburg University of Applied Sciences (HAW) ultimately led to plans for the new Fraunhofer Application Center named "Power Electronics for Renewable Energy Systems." We expect to be in a position to launch this endeavor and set up the branch lab at HAW by mid-2014. Establishing

Durch Partnerschaften im Umfeld des ISIT wird unser Leistungsprofil zusätzlich gestärkt und den Erfordernissen des Marktes angepasst. In diesem Sinne ist es sehr erfreulich, dass das Fraunhofer-Innovationscluster »Leistungselektronik für Regenerative Energieversorgung« in Schleswig-Holstein eingerichtet werden konnte. Intensive Gespräche und Verhandlungen mit dem Bundesland Hamburg und der Hochschule für Angewandte Wissenschaften (HAW) haben schließlich zu einem Konzept für ein Fraunhofer-Anwendungszentrum »Leistungselektronik für Regenerative Energiesysteme« geführt. Den Start des Vorhabens und die Errichtung der Außenstelle an der HAW erwarten wir Mitte 2014.



Organizational chart, ISIT

Prof. Wolfgang Benecke and Dr. Frank Osterwald, head of developement, Danfoss Silicon Power, present to Ministerpräsident Torsten Albig power components for windmill power plants

Prof. Ralf Dudde, ISIT (left) and Prof. Michael Berger, FH-Westküste, organizers of a joint project group

the Fraunhofer "Microsystems for new human-machine interfaces" project group at the West Coast University of Applied Sciences, Germany (FHW) in Heide complements our efforts in the field of MEMS. Plans have been set in motion to set up a permanent branch lab complete with lab space at Kiel University to step up long-term preliminary research activities and to recruit young scientific talent.
Our trusted and close collaborations with strategic partners VISHAY Siliconix and X-FAB MEMS Foundry Itzehoe serve to expand and strengthen Fraunhofer ISIT's core competences and our unique position in the field of semiconductor technologies for power electronics and MEMS. We expect these partnerships to yield ever more benefits and opportunities for our customers in the future, too.

On behalf of all of us at Fraunhofer ISIT, I would like to thank all our partners and customers for their trust and cooperation.

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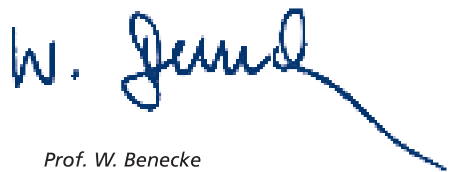
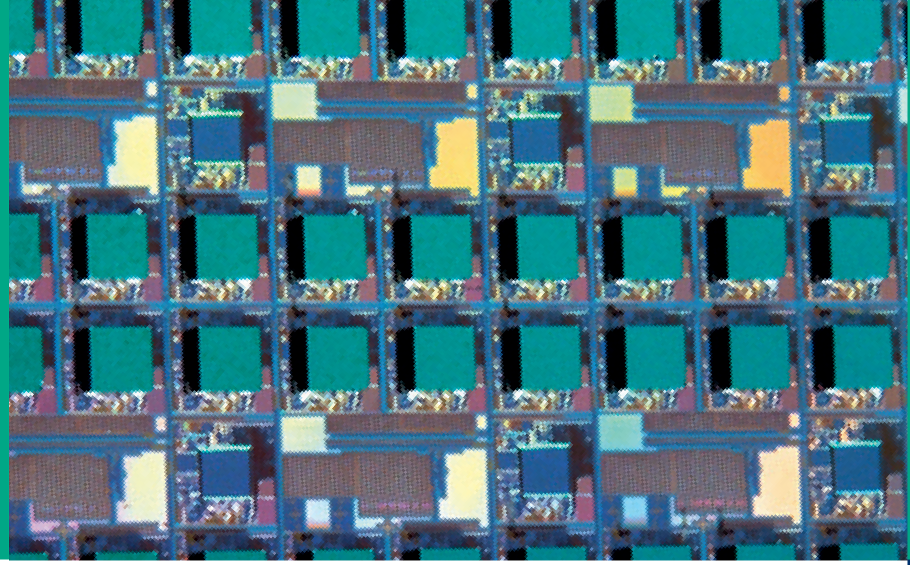
Die Arbeiten im Bereich der MEMS konnten durch die Einrichtung einer Fraunhofer-Projektgruppe »Mikrosysteme für neue Mensch-Maschine-Schnittstellen« an der Fachhochschule Westküste in Heide ergänzt werden. Zur Intensivierung der langfristigen Vorlaufforschung und zur Rekrutierung von Nachwuchswissenschaftlern wurde die Einrichtung einer dauerhaften Außenstelle mit Laborarbeitsplätzen an der CAU in Kiel vorbereitet.

Die Kernkompetenz und die Alleinstellung des ISIT auf dem Gebiet der Halbleitertechnologien für Leistungselektronik und MEMS konnten durch die vertrauensvolle und intensive Zusammenarbeit mit unseren strategischen Partnern VISHAY Siliconix und X-FAB MEMS Foundry Itzehoe weiter ausgebaut und gestärkt werden. Wir erwarten durch diese Partnerschaften auch für die Zukunft stetig wachsende Vorteile und Chancen für unsere Kunden und Auftraggeber.

Auch im Namen der Mitarbeiterinnen und Mitarbeiter des ISIT danke ich allen Partnern und Auftraggebern für die vertrauensvolle Zusammenarbeit.



Prof. W. Benecke



Vacuum capped absolute pressure sensors

FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE (ISIT)

Research and Production at one Location

The Fraunhofer Institute for Silicon Technology ISIT develops and produces power electronics and microsystems according to customers specifications. 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 round about 190 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.

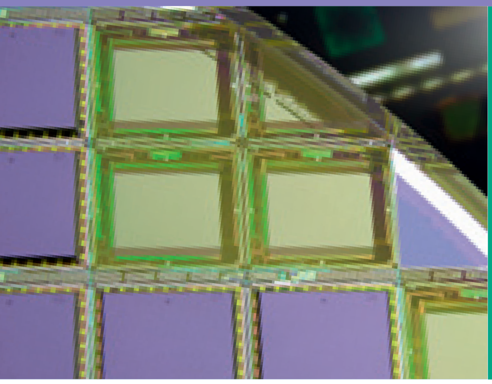
One thing that really sets Fraunhofer ISIT apart is the speed with which it can transfer innovative developments into industrial application and production. To this end, Fraunhofer ISIT operates a wafer production line in its cleanrooms in collaboration with the companies Vishay and X-FAB MEMS Foundry Itzehoe. There are longstanding collaborations with a variety of manufacturing companies local to Fraunhofer ISIT.

Fraunhofer ISIT runs an application center at Hamburg University of Applied Sciences, a project group at the University of Applied Sciences in Heide, and a working group at the Christian-Albrechts-Universität in Kiel.

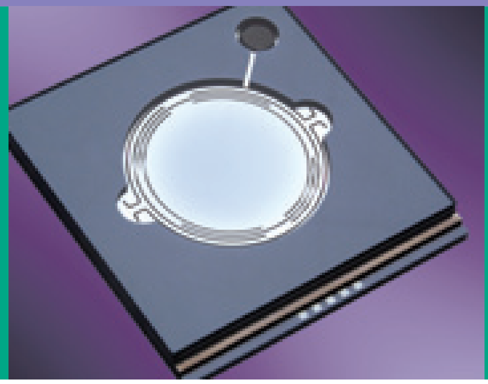
MAIN FIELDS OF ACTIVITY

Testructures for a new glass flow process

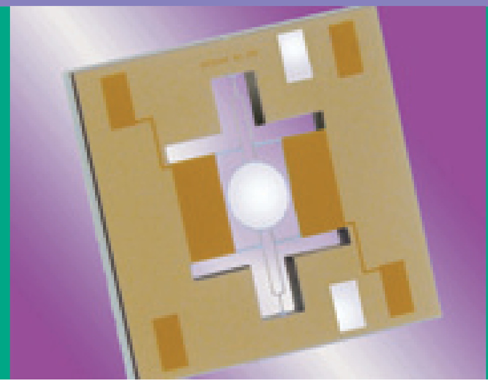
Gold covered 200 mm glass wafer with reflectors



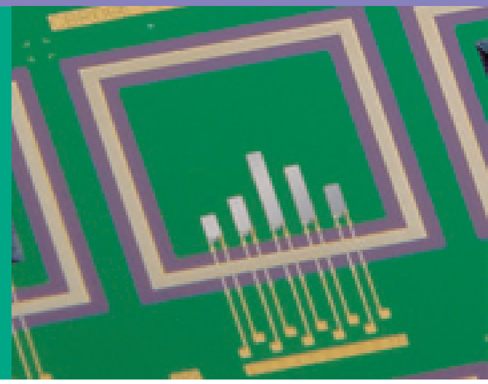
Vacuum capped IR imager



Micromirror for high power laser application



Piezoelectric micromirror



Magnetoelectric sensor

MICROSYSTEMS TECHNOLOGY, MEMS AND IC DESIGN

Research in microsystems technology is a major activity of Fraunhofer ISIT in different departments. For 30 years ISIT scientists are working on the development of micro electro mechanical systems (MEMS). This covers the complete development chain starting from simulation and design, technology and component development up to waferlevel probing, process qualification, and reliability tests. One of the core competences of the ISIT service offer is the development of integration technologies, like cost effective assembly of several chips in a common package, MEMS packaging on waferlevel (WLP) with defined cavity pressure or a system-on-chip approach. MEMS devices can be combined with suitable ASICs to miniaturized systems with high functionality.

ISIT has also the possibility to offer fabrication of prototypes and low volume pilot production. If high volume MEMS production is requested the on-site operating industrial partner X-FAB MEMS Foundry Itzehoe GmbH is able to meet this demand. All services are offered on a 200 mm wafer technology-platform.

ISIT is focussed on MEMS applications in the following areas: physical sensors and actuators, devices and technologies for high frequency application (RF-MEMS), passive and active optical MEMS as well as piezoelectric MEMS. In the field of sensor systems strong activities are put on multi-axis inertial sensors (accelerometer, gyroscopes), magnetometers and on flow sensors. MEMS for high frequency applications are primarily used in wireless reconfigurable communication networks. In particular developments for RF-MEMS switches, ohmic switches and waferlevel packaging (WLP) are ongoing. In the field of optical MEMS devices ISIT is active in the development of micromirrors for laser projection displays and optical measurement systems based on scanning micromirrors, e.g. LIDAR. Passive optical components based on borosilicate or quartz glass wafer processing are also in the portfolio of ISIT. Examples are glass lens arrays, aperture systems for laser beam forming and waferlevel packaging of optical MEMS.

The microsystems department has access to the standard front-end technologies for IC-processing and operates a separate new installed cleanroom with dedicated MEMS specific equipment and processes. The lithographic capabilities include a wide-field stepper, backside mask aligner, spray coating and thick resist processing. CVD, PVD and ALD tools for the deposition of poly-Si, SiGe, SiO_2, SiN, Ge, Au, Pt, Ir, Ag, Al, Cu, Ni, Cr, Mo, Ta, Ti, TiN, TiW, Al_2O_3, AlN, PZT and other thinfilms are available. The wet processing area comprises anisotropic etching of Si, automated tools for metal etching and electroplating of Au, Cu and Sn. 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 followed by critical point drying. A specific focus is given to hermetic waferlevel packaging of MEMS using metallic, anodic or glass frit waferbonding technology. Wafer grinding and temporary waferbonding are key process steps for thin wafer and 3D integrated products including through silicon vias. Of high importance for many MEMS, but also electronic products is the capability in chemical-mechanical polishing (CMP). The CMP application lab focusses on the development of polishing processes for Si, silicon oxides, W and Cu (damascene), and also on testing of slurries and polishing pads.

In addition to the single processes, ISIT has established a number of qualified technology platforms. Examples are the thick poly-Si surface micromachining platform for capacitive sensors/actuators and the piezoelectric MEMS platform. In the latter case sputtered thin PZT or AlN layers with suitable bottom and top electrodes are integrated in a complete process flow for piezoelectric MEMS transducers.

Beyond technology the microsystems department offers the design and realization of dedicated electronic circuits for driving/readout of the MEMS components, but also for MEMS testing and system demonstration. Moreover, an experienced ASIC design team is specialized in the design of analog/digital circuits to be integrated in smart systems. The designers also model micromechanical and micro optic elements and test their functionality in advance using FEM and behavioral modeling simulation tools. A final characterization on wafer level or module level allows the verification of the design as well as the used technology.

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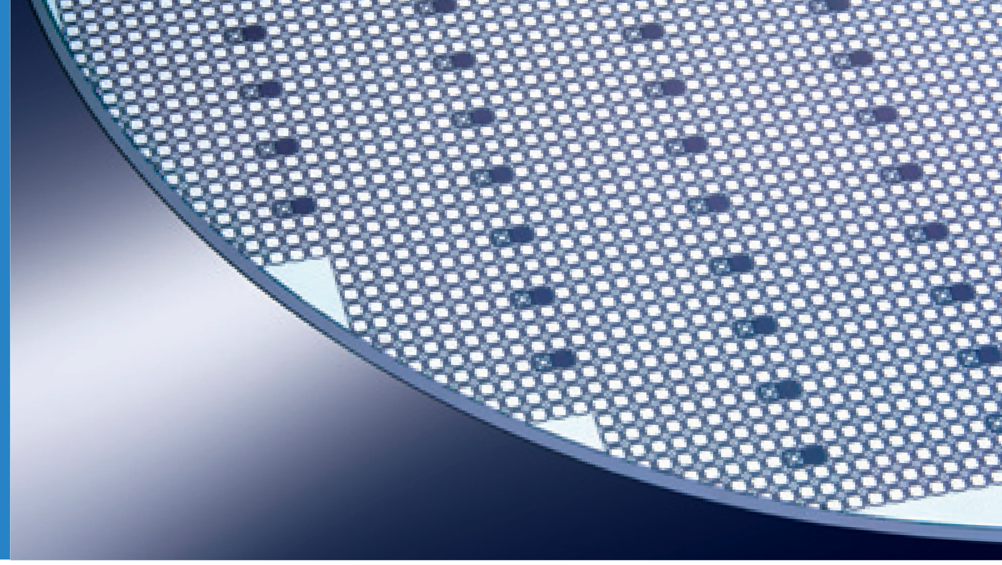
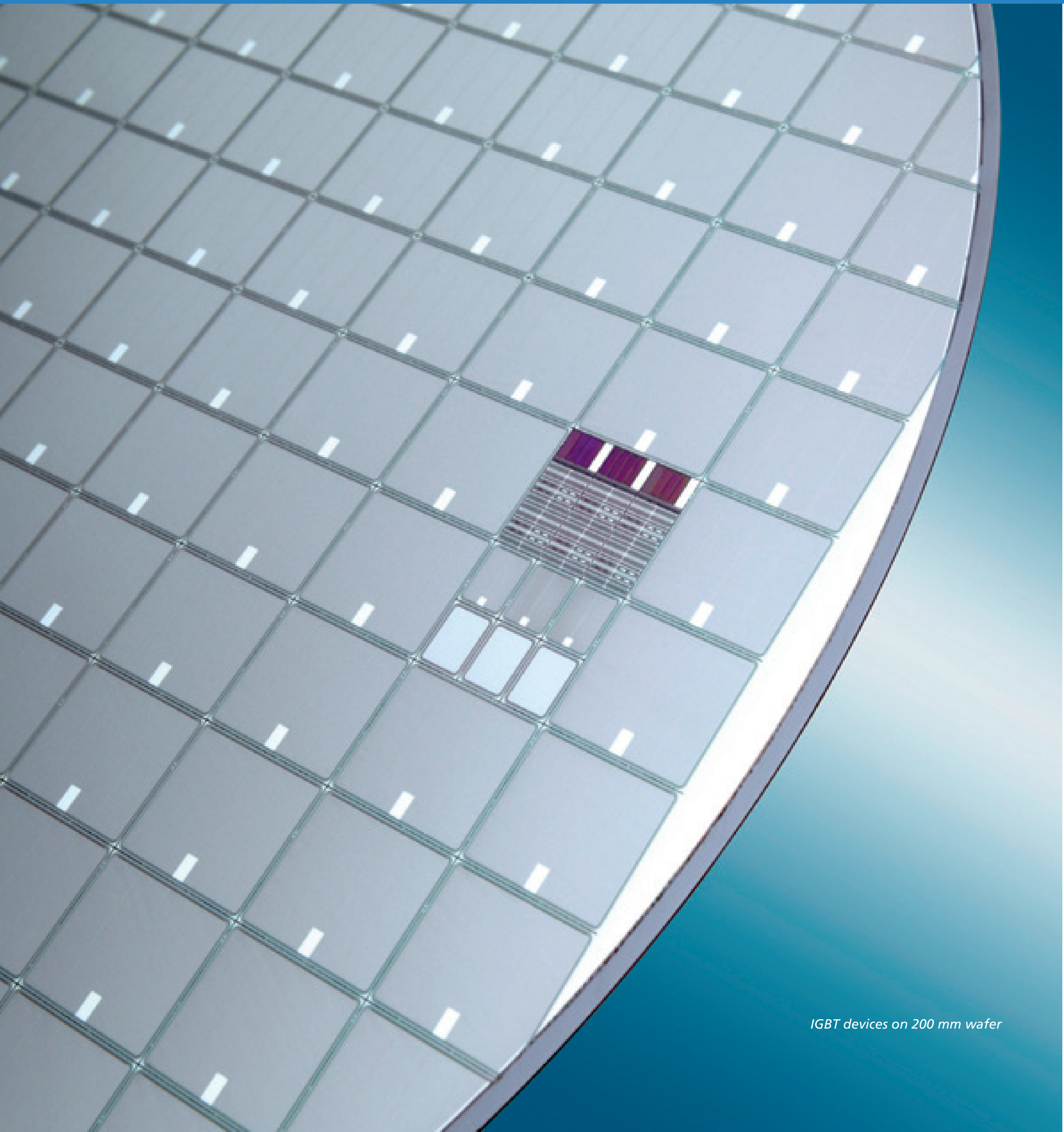


Wafer with fast recovery diodes



IGBT devices on 200 mm wafer

IC TECHNOLOGY AND POWER ELECTRONICS

The power electronics and IC technology group develops and manufactures active integrated circuits as well as discrete passive components.

Among the active components the emphasis lies on Silicon power devices such as smart power chips, IGBTs, PowerMOS circuits and diodes. In this context application specific power devices and new device architectures are special R&D areas. The development of new processes for advanced power device assembly on wafer level is a further important research topic. Application specific semiconductor devices with non standard metallization layers and adapted layouts for chip geometry and pad configurations are offered for new assembly techniques.

Novel techniques for handling and backside processing of ultra thin Silicon substrates based on carrier wafer concepts and laser annealing processes are being used for power device development. Customized trade-off adjustment of static-dynamic losses and robustness are prerequisite for power electronic system optimization and can be developed according to customer requirements.

Additional support is provided by a number of tools for simulation, design and testing. ISIT also benefits from years of experience in the design and manufacturing of CMOS circuits.

Passive components developed and fabricated at ISIT are primarily chip capacitors, precision resistors and inductors. Implementation of new materials and alloys into existing manufacturing processes is an important feature in the development process.

ISIT develops individual processes, process modules and complete process flows for diverse applications. The institute also offers processing of customer specific silicon components in small to medium sized quantities on the basis of a qualified semiconductor process technology.

A special R&D group with focus on power electronic systems works on application specific topics covering the interface to system end users. New circuit topologies based on system specific semiconductor power devices are special R&D topics for system optimization.

In the field of power electronics ISIT coordinates an Innovation Cluster dealing with power electronics for renewable energies. This cluster was founded in close cooperation with companies and universities of the federal state of Schleswig-Holstein.

IC Technology and Power Electronics

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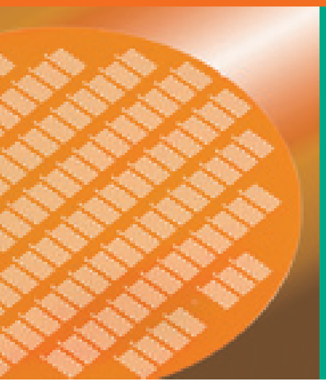

Wafer with micro liquid chromatography chips

Point of care diagnostic system

Disposable cartridge for sample collection

BIOTECHNICAL MICROSYSTEMS

The department BTMS develops and produces silicon based microsystems for high sophisticated biosensors used in miniaturized and mobile analysis platforms. The research focus addresses especially the topic "microsystems for health". Electrical micro-electrode array based tests are a main research field of the department. Position-specific applications are realized by immobilization of biomolecules and highly sensitive, highly selective measurement methods such as the „redox cycling". These very robust sensor systems are useful for the simultaneous detection of a variety of analytes within one sample.
In combination with micro-fluidic components and integrated electronics, these electrical microarrays represent the basis of rapid and cost-effective analysis systems. They can be used to identify and quantify DNA, RNA, proteins and haptens.

In a further field of activity biosensors for the continuous monitoring, e.g. of metabolites as glucose or lactate are developed. The monitoring and quantification of these substances is realized by enzymatic conversion and electrochemical detection.

These sensors are also used in combination with pH-measurement and -control in bioreactors. In the BMBF-funded project „Cell-free bioproduction" ISIT integrates microelectrodes on pore membranes and also in microreactor systems for example (www.zellfreie-bioproduktion.fraunhofer.de). For a wider range of mobile analytics, ISIT develops microsystems based on a liquid chromatographic separation process. Various materials, process technologies and system integration technologies are investigated. The aim of this development is an integrated microsystem for detection of contaminants and residues for a sustainable environment, food and health management.

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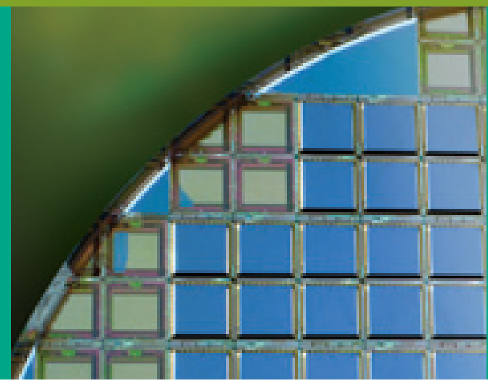
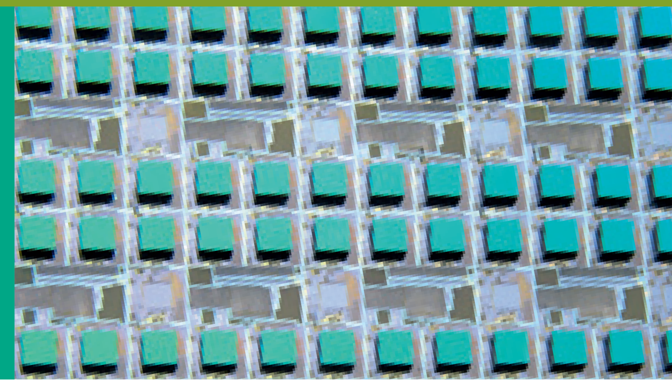


Eutectic AuSn hermetic sealed µ-bolometer



AuSn transient liquid phase bonded pressure sensors

PACKAGING TECHNOLOGY FOR MICROELECTRONICS AND MICROSYSTEMS

The „Advanced Packaging" group is specialized in the identification and the promotion of new trends and technologies in electronics packaging. The industrial challenges of tomorrow are addressed in direct collaboration with suppliers of materials, components, modules, and equipment. As an example, the automatic pick-and-place assembly of ultra-thin dies on flexible substrates was already developed several years ago. For the encapsulation of MEMS components, the glass frit bonding and metallic bonding was developed. ISIT also participates in the development of organic electronics (functional printing) and RFID technologies.
The Fraunhofer ISIT is equipped with all the basic technologies for automatic or manual handling of microchips and MEMS-devices, as well as electrical interconnect methods like wire bonding and flip chip technologies. Power electronic assemblies with improved power-cycle performance can be developed and connected by thick wire and ribbon bonding technology based on aluminum and copper wire/ribbon up to 200 µm x 2000µm cross section.
Through the close relationship between MEMS technology and packaging under the roof of ISIT, the institute has become a leading R&D service provider in the domain of waferlevel-packaging. A cross-disciplinary technology portfolio is now available that allows to reduce cost and size of a system. Even more, the packaging itself can become a functional part of the microsystem in many cases, e.g. by integrating optical elements or directly interconnecting MEMS and ASIC dies. Outstanding success was achieved in the vacuum encapsulation of micromechanical sensors by eutectic wafer bonding, which paved the way towards the industrialization of an automotive yaw-rate sensor product family.

ISIT continuously expands their assortment of test chips and -substrates that facilitate the ramp up and calibration of production lines for securing quality on a high level.

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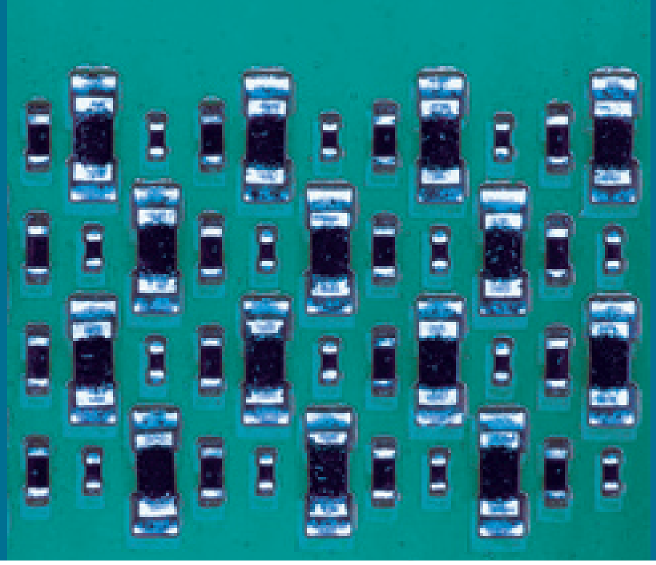
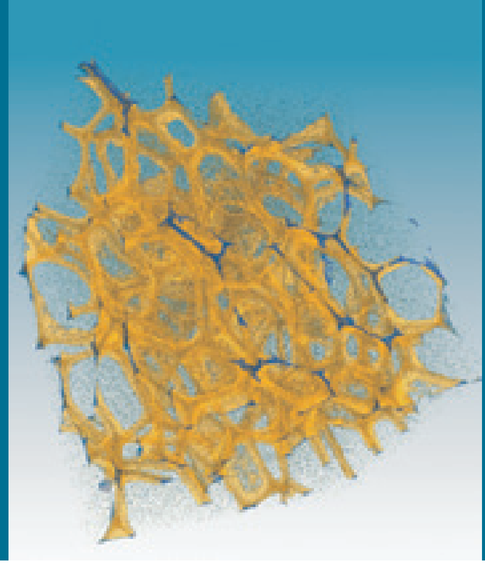


Different Resistors (200 µm x 400 µm to 1000 µm x 500 µm on ISIT testboard



CT of a foam structure

Traversing contact-free coating thickness control (yellow) at the coater in the pilot plant

QUALITY AND RELIABILITY OF ELECTRONIC ASSEMBLIES

Quality evaluation – in particular for the soldering work done in pre-production, pilot and main series lots – represents a continuous challenge for ISIT, as for example whenever new technologies such as lead-free soldering are introduced, or when increased error rates are discovered, or if a customer desires to achieve competitive advantages through continual product improvement. To reveal potential weak points, ISIT employs both destructive and non-destructive analysis methods, such as X-ray transmission radiography, computer tomography, laser profilometry and scanning acoustic microscopy. Working from a requirements matrix, ISIT scientists also evaluate long-term behavior of lead-free and lead-containing assemblies alike. They then formulate prognoses on the basis of model calculations, environmental and time-lapse load tests, and failure analysis.

In anticipation of a conversion to lead-free electronics manufacturing, Fraunhofer ISIT is undertaking design, material selection and process modification projects for industrial partners. To effect a further optimization of manufacturing processes, the institute applies process models and produces samples on industry-compatible equipment. The group also addresses issues related to thermal management and reliability for customer-specific power modules.

In addition to these technological activities, the group regularly holds training sessions, including multi-day classes, at the institute or at company site.

Quality and Reliability of Electronic Assemblies
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INTEGRATED POWER SYSTEMS

Secondary Lithium batteries as a powerful storage medium for electrical energy are rapidly capturing new fields of application outside of the market of portable electronic equipment.

These new fields include automobiles, medical devices, stationary electric storage units, aerospace, etc. Therefore, this type of rechargeable batteries has to meet a variety of new requirements. This covers not only electrical performance but also design and safety features. The Lithium polymer technology developed at ISIT is characterized by an extensive adaptability to specific application profiles like extended temperature range, high power rating, long shelf and/or cycle life, extended safety requirements, etc (tailor-made, energy storage solutions). Also included is the development of application-specific housings.

In the Lithium polymer technology all components of the cell from electrodes to housing are made from tapes. At ISIT the complete process chain starting with the slurry preparation over the tape casting process and the assembly and packaging of complete cells in customized designs is available including also the electrical and thermo-mechanical characterization. This allows access to all relevant parameters necessary for an optimization process. The electrode and the electrolyte composition up to the cell design can be modified.

In addition to the development of prototypes, limited-lot manufacturing of optimized cells on a pilot production line at ISIT with storage capacities of up to several ampere-hours is possible. Specific consideration in process development is addressed to the transferability of development results in a subsequent industrial production.
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ISIT offers a wide portfolio of services in the field of secondary Lithium batteries:

- Manufacturing and characterization of battery raw materials by half cell as well as full cell testing
- Selection of appropriate combinations of materials and design of cells to fulfil customer requirements
- Application driven housing development
- Test panel
- Prototyping and limited-lot manufacturing of cells

Additional services are:

- Preparation of studies
- Failure analysis
- Testing (electrical, mechanical, reliability etc.)
- Technical consultation

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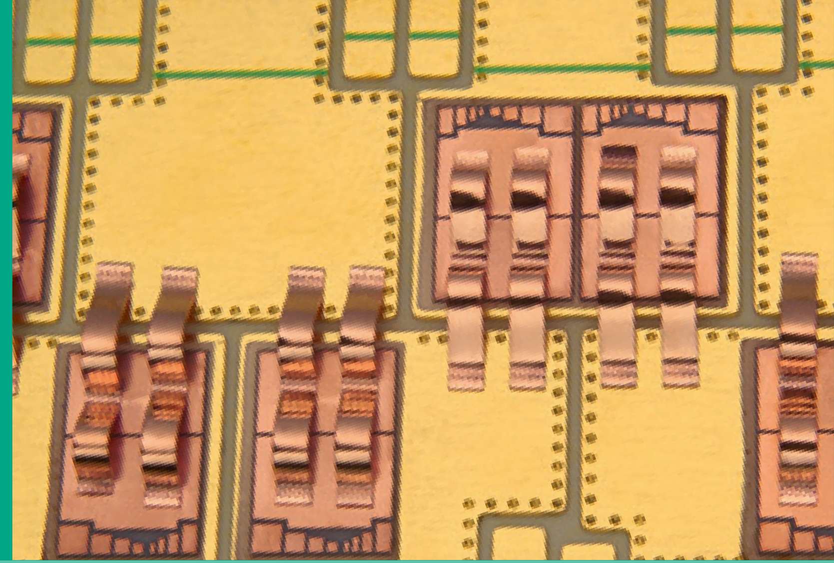

Cu ribbon bonded power module

OFFERS FOR RESEARCH AND SERVICE

RANGE OF SERVICES

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.

FACILITIES AND EQUIPMENT

Fraunhofer ISIT has access to a 200 mm Silicon technology line (2500 m²) for front-end processes (MOS and PowerMOS). Specific processes for MEMS and NEMS as well as for packaging are implemented in a special newly built cleanroom (1000 m²). This includes wet etching, dry etching, DRIE, deposition of non-IC-compatible materials, lithography with thick-resist layers, gray-scale lithography, 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 1500 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.

Coating facility for Lithium accumulators

OFFERS FOR RESEARCH AND SERVICE

CUSTOMERS

ISIT cooperates with companies of different sectors and sizes.
In the following, some companies are presented as a reference:

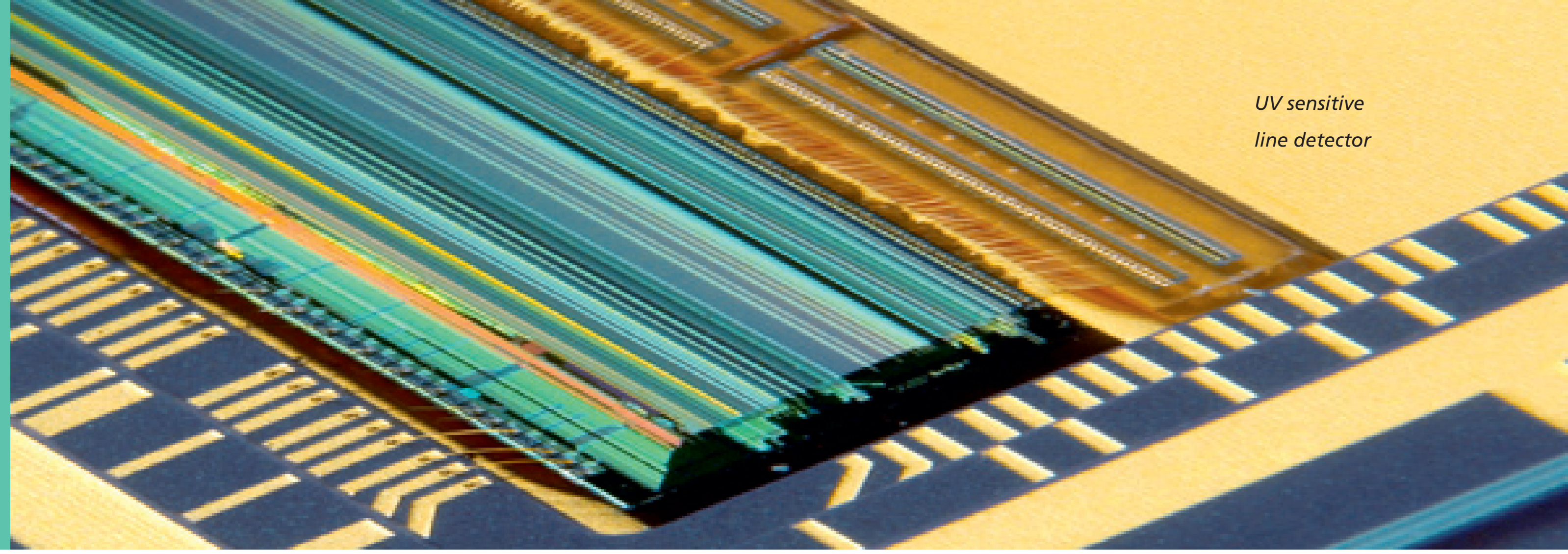
UV sensitive line detector

ABB AG, *Ladenburg*

Advaplan, *Espoo, Finland*

Airbus-Systeme, *Buxtehude*

aixACCT Systems GmbH, *Aachen*

Analytik Jena AG, *Jena*

Andus electronic GmbH, *Berlin*

Atotech Deutschland GmbH, *Berlin*

austrianmicrosystems, *Unterpremstätten, Austria*

Avisaro AG, *Hannover*

BASF SE, *Ludwigshafen*

Basler Vision Technologies, *Ahrensburg*

Bosch Sensortec GmbH, *Reutlingen*

B. Braun, *Melsungen*

Brückner, *Siegsdorf*

H. Brockstedt GmbH, *Kiel*

CAPRES A/S, *Kongens Lyngby, Denmark*

CarboFibretec GmbH, *88046 Friedrichshafen*

Cassidian Electronics, *Ulm*

Condias GmbH, *Itzehoe*

Conti Temic, *Karben*

Conti Temic microelectronic GmbH, *Nürnberg*

Continental, *Nürnberg*

Danfoss Drives, *Graasten, Denmark*

Danfoss Silicon Power GmbH, *Schleswig*

Datacon Technology AG, *Radfeld/Tirol, Austria*

davengo GmbH, *Berlin*

Delphi Deutschland GmbH, *Nürnberg*

Deutsches Elektronen Synchrotron DESY, *Hamburg*

Diehl Avionik Systeme GmbH, *Überlingen*

Dispatch Energy Innovations *GmbH, Itzehoe*

Dow Chemical Company, *Lausanne, Switzerland*

Dräger Systemtechnik, *Lübeck*

E.G.O. Elektro-Gerätebau GmbH, *Oberderdingen*

EADS Deutschland GmbH, Corporate Research Germany, *München and Ulm*

EN Electronic Network, *Bad Hersfeld*

Endress+HauserGmbHCo.KG, *Maulburg*

Engineering Center for Power Electronics GmbH, *Nürnberg*

EPCOS, *Nijmegen, Netherlands*

EPCOS AG, *München*

Eppendorf Instrumente GmbH, *Hamburg*

ESCD, *Brunsbüttel*

ESPROS Photonics AG, *Schweiz*

ESW-Extel Systems GmbH, *Wedel*

EVGroup, *Schärding, Austria*

Evonik Degussa GmbH, *Hanau*

Foxboro Eckardt GmbH, *Stuttgart*

Freudenberg & Co. KG, *Weinheim*

GEMALTO, *Meudon, France*

GÖPEL electronic *GmbH, Jena*

Hako-Werke, *Bad Oldesloe*

Hannusch Industrieelektronik, *Laichingen*

Harman & Becker, *Karlsbad*

Hella KG, *Lippstadt*

Heraus Materials Technology GmbH Co. KG, *Hanau*

Honeywell Deutschland AG, *Offenbach*

HSG-IMIT, *Villingen-Schwenningen*

ifm ecomatic gmbh, *Kressbronn*

Ifm electronic GmbH, *Essen*

IMS Nanofabrication AG, *Wien, Austria*

Innovavent GmbH, *Göttingen*

Institute of Electron Technology, *Warsaw, Poland*

Isola GmbH, *Düren*

Jenoptik Automatisierungstechnik GmbH, *Jena*

Jenoptik ESW GmbH, *Essen*

Jungheinrich AG, *Norderstedt*

Kristronics GmbH, *Harrislee-Flensburg*

Kuhnke GmbH, *Malente*

Lenze Drive Systems GmbH, *Hameln*

Limedion GmbH, *Mannheim*

Liebherr Elektronik, *Lindau*

Mair Elektronik GmbH, *Neufahrn*

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Marquardt, *Rietheim-Weilheim*

Maxim Integrated GmbH, *Lebring, Austria*

Meder eletronic AG, *Engen-Welschingen*

Melexis Ieper N.V., *Belgium*

Miele, *Lippstadt*

MKS, *München*

NXP Semiconductors, *Hamburg*

Oerlikon AG, *Liechtenstein*

Okmetic Oyj, *Vantaa, Finland*

Opel, *Rüsselsheim am Main*

Osram GmbH, *München*

Osram Opto Semiconductors GmbH, *Regensburg*

Otto Bock Health-Care GmbH, *Duderstadt*

PAC Tech, Packaging Technologies, *Nauen*

Panasonic, *Neumünster*

PAV Card GmbH, *Lütjensee*

Peter Wolters GmbH, *Rendsburg*

Picosun Oy, *Espoo, Finland*

PlanOptik AG, *Elsoff*

Plath Eft GmbH, *Norderstedt*

POCDIA GmbH, *Itzehoe*

Prettl Elektronik Lübeck GmbH, *Lübeck*

Raytheon *Anschütz GmbH, Kiel*

Reese und Thies, *Itzehoe*

RefuSol GmbH, *Metzingen*

Rehm Anlagenbau GmbH, *Blaubeuren-Seissen*

Robert Bosch GmbH, *Reutlingen*

Robert Bosch GmbH, *Salzgitter*

Robert Bosch GmbH, *Stuttgart*

ROFIN-BAASEL Lasertech GmbH Co. KG, *Starnberg*

SAES Getters S.p.A., *Lainate/Milan, Italy*

Saint Gobain, *Cavaillon Cedex, France*

Schlötter GmbH &co. KG, *Geislingen*

Senvion SE, *Osterröhnfeld*

Silex Microsystems AG, *Järfälla, Sweden*

SINTEF ICT, *Oslo, Norway*

SMA Regelsysteme GmbH, *Niestetal*

Smyczek, *Verl*

St. Mauritius Therapieklinik, *Meerbusch*

STABILO International GmbH, *Heroldsberg*

Sterling Industry Consult GmbH, *Itzehoe*

Still GmbH, *Hamburg*

Stolle Sanitätshaus GmbH, *Hamburg*

tagitron GmbH, *Salzkotten*

Technolas, *München*

TESAT SPACECOM GmbH, *Backnang*

Theon, *Athens, Greece*

Trainalytics GmbH, *Lippstadt*

Treichel Elektronik GmbH, *Springe*

Trinamic, *Hamburg*

Umicore AG & Co., *Hanau*

Vectron International GmbH & Co. KG, *Neckarbischofsheim*

Vishay BCcomponents Beyschlag GmbH, *Heide*

Vishay Siliconix Itzehoe GmbH, *Itzehoe*

Vishay Siliconix, *Santa Clara, USA*

Vistec, *Jena*

Volkswagen AG, *Wolfsburg*

Wabco Fahrzeugbremsen, *Hannover*

Würth Elektronik GmbH, *Schopfheim*

X-FAB MEMS Foundry Itzehoe GmbH, *Itzehoe*

X-FAB Semiconductor Foundries AG, *Erfurt*

Carl Zeiss SMT GmbH, *Oberkochen*

INNOVATION CATALOGUE

ISIT offers its customers various products and services already developed for market introduction. The following table presents a summary of the essential products and services. Beyond that the utilisation of patents and licences is included in the service.

Product / Service	Market	Contact Person
Chemical-mechanical polishing (CMP), planarization	*Semiconductor device manufacturers*	**Dr. Gerfried Zwicker** *+ 49 (0) 4821/17-4309* *gerfried.zwicker@isit.fraunhofer.de*
Wafer polishing	*Si substrates for device manufacturers*	**Dr. Gerfried Zwicker** *+ 49 (0) 4821/17-4309* *gerfried.zwicker@isit.fraunhofer.de*
IC processes and power devices CMOS, PowerMOS, IGBTs Diods	*Semiconductor industry IC-users*	**Detlef Friedrich** *+ 49 (0) 4821/17-4301* *detlef.friedrich@isit.fraunhofer.de*
Single processes and process module development	*Semiconductor industry semiconductor equipment manufacturers*	**Detlef Friedrich** *+ 49 (0) 4821/17-4301* *detlef.friedrich@isit.fraunhofer.de*
Customer specific processing	*Semiconductor industry semiconductor equipment manufacturers*	**Detlef Friedrich** *+ 49 (0) 4821/17-4301* *detlef.friedrich@isit.fraunhofer.de*
Microsystem products	*Electronic industry*	**Prof. Ralf Dudde** *+ 49 (0) 4821/17-4212* *ralf.dudde@isit.fraunhofer.de*
MEMS process Development and Integration	*Electronic industry*	**Björn Jensen** *+ 49 (0) 4821/17-1434* *bjoern.jensen@isit.fraunhofer.de*
Inertial sensors	*Motorvehicle technology, navigation systems, measurements*	**Dr. Klaus Reimer** *+ 49 (0) 4821/17-4213* *bernd.wagner@isit.fraunhofer.de*
Piezoelectric microsystems	*Sensors and actuators*	**Hans-Joachim Quenzer** *+ 49 (0) 4821/17-4643* *hans-joachim.quenzer@isit.fraunhofer.de*
Microoptical scanners and projectors	*Biomedical technology, optical measurement industry, telecommunication*	**Ulrich Hofmann** *+ 49 (0) 4821/17-4553* *ulrich.hofmann@isit.fraunhofer.de*
Flow sensors	*Automotive, fuel cells*	**Dr. Peter Lange** *+49 (0) 4821/17-4506* *peter.lange@isit.fraunhofer.de*
Microoptical components	*Optical measurement,*	**Hans-Joachim Quenzer** *+ 49 (0) 4821/17-4643* *hans-joachim.quenzer@isit.fraunhofer.de*
RF-MEMS	*Telecommunication*	**Dr. Thomas Lisec** *+ 49 (0) 4821/17-4512* *thomas.lisec@isit.fraunhofer.de*
Beam deflection components for maskless nanolithography	*Semiconductor equipment manufacturers*	**Dr. Klaus Reimer** *+ 49 (0) 4821/17-4233* *klaus.raimer@isit.fraunhofer.de*
Design and test of analogue and mixed-signal ASICs	*Measurement, automatic control industry*	**Jörg Eichholz** *+ 49 (0) 4821/17-4253* *joerg.eichholz@isit.fraunhofer.de*

Product / Service	Market	Contact Person
Design Kits	*MST foundries*	**Jörg Eichholz** *+ 49 (0) 4821/17-4253* *joerg.eichholz@isit.fraunhofer.de*
MST design and behavioural modelling and wafer tests	*Measurement, automatic control industry*	**Jörg Eichholz** *+ 49 (0) 4821/17-4253* *joerg.eichholz@isit.fraunhofer.de*
Electrodeposition of microstructures	*Surface micromachining*	**Martin Witt** *+ 49 (0) 4821/17-4613* *martin.witt@isit.fraunhofer.de*
Electrical biochip technology (proteins, nucleic acids, haptens)	*Biotechnology, related electronics microfluidics, environmental analysis, Si-Chipprocessing, packaging, chip loading*	**Dr. Eric Nebling** *+ 49 (0) 4821/17-4312* *eric.nebling@isit.fraunhofer.de*
Microsystem production service	*MEMS fabless manufactorers*	**Dr. Peter Merz** *+ 49 (0) 4821/17-4221* *peter.merz@memsfoundry.de*
Secondary lithium batteries	*Mobile electronic equipment, medical applications, automotive, smart cards, labels, tags*	**Dr. Peter Gulde** *+49 (0) 4821/17-4219* *peter.gulde@isit.fraunhofer.de*
Battery test service, electrical parameters, climate impact, reliability, quality	*Mobile electronic equipment, medical applications, stationary storage solutions, automotive, smart cards, labels, tags*	**Dr. Peter Gulde** *+49 (0) 4821/17-4219* *peter.gulde@isit.fraunhofer.de*
Quality and reliability of electronic assemblies (http://www.isit.fraunhofer.de)	*Microelectronic and power electronic industry*	**Karin Pape** *+ 49 (0) 4821/17-4229* *karin.pape@isit.fraunhofer.de*
Material and damage analysis	*Microelectronic and power electronic industry*	**Dr. Thomas Knieling** *+ 49 (0) 4821/17-4605* *thomas.knieling@isit.fraunhofer.de*
Printed electronics	*Electronic industry*	**Dr. Thomas Knieling** *+ 49 (0) 4821/17-4605* *Thomas.knieling@isit.fraunhofer.de*
Thermal measurement and simulation	*Microelectronic and power electronic industry*	**Dr. M. H. Poech** *+ 49 (0) 4821/17-4607* *max.poech@isit.fraunhofer.de*
Application center for process technologies in manufacturing electronic assemblies	*Electronic industry*	**Helge Schimanski** *+49 (0) 4821/17-4639* *helge.schimanski@isit.fraunhofer.de*
Packaging for microsystems, sensors, multichip modules (http://www.isit.fraunhofer.de)	*Microelectronic, sensoric and medical industry*	**Karin Pape** *+ 49 (0) 4821/17-4229* *karin.pape@isit.fraunhofer.de*
Wafer level packaging, ultra thin Si packaging and direct chip attach techniques	*Microelectronic, sensoric and medical industry, automotive industry*	**Dr. Wolfgang Reinert** *+ 49 (0) 4821/17-4617* *wolfgang.reinert@isit.fraunhofer.de*
Vacuum wafer bonding technology	*Microelectronic, sensoric and medical industry, automotive industry*	**Dr. Wolfgang Reinert** *+ 49 (0) 4821/17-4617* *wolfgang.reinert@isit.fraunhofer.de*

REPRESENTATIVE FIGURES

EXPENDITURE

In 2013 the operating expenditure of Fraunhofer ISIT amounted to 23.943,8 T€.
Salaries and wages were 10.102,5 T€, material costs and different other running costs were 12.385,0 T€.
The institutional budget of capital investment and renovation was 1.456,3 T€.

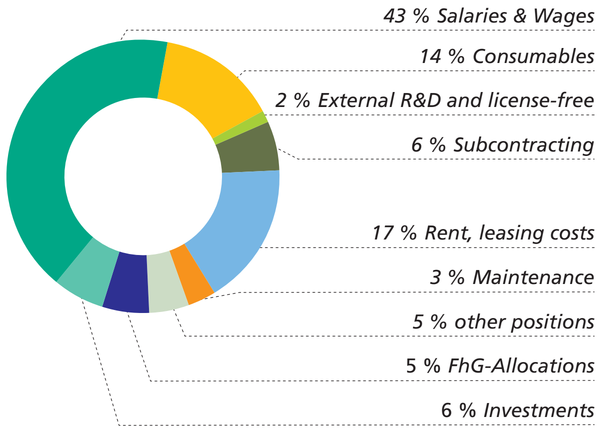
INCOME

The budget was financed by proceeds of projects of industry/industrial federations/small and medium sized companies amounting to 12.707,9 T€, of government/project sponsors/federal states amounting to 4.586,1 T€ and of European Union/others amounting to 674,5 T€.
Furthermore there were FhG-projects about 2.418,7 T€ and basic funding with 3.952,5 T€.

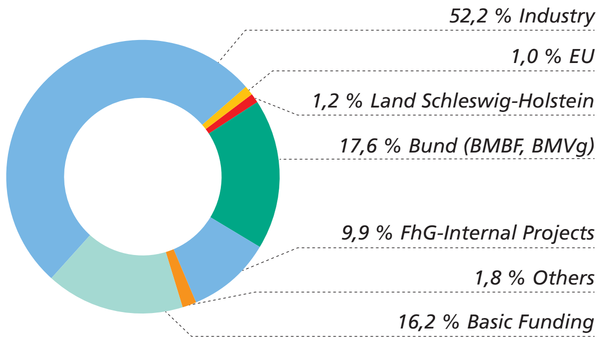
STAFF DEVELOPMENT

At the end of 2013 the staff consisted of 157 employees. 71 were employed as scientific personnel, 68 as graduated/technical personnel and 18 worked within organisation and administration.
The employees were assisted through 23 scientific assistants, 7 apprentices and 2 others.

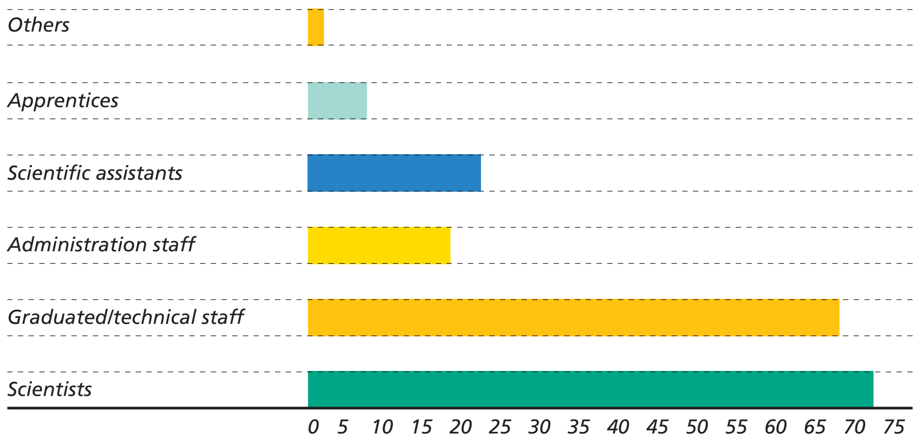
Expenditure



Income



Staff Development



THE FRAUNHOFER-GESELLSCHAFT

Research of practical utility lies at the heart of all activities pursued by the Fraunhofer-Gesellschaft. Founded in 1949, the research organization undertakes applied research that drives economic development and serves the wider benefit of society. Its services are solicited by customers and contractual partners in industry, the service sector and public administration.

At present, the Fraunhofer-Gesellschaft maintains 67 institutes and research units. The majority of the more than 23,000 staff are qualified scientists and engineers, who work with an annual research budget of 2 billion euros. Of this sum, more than 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits perceived by the customer: Through their research and development work, the Fraunhofer Institutes help to reinforce the competitive strength of the economy in their local region, and throughout Germany and Europe. They do so by promoting innovation, strengthening the technological base, improving the acceptance of new technologies, and helping to train the urgently needed future generation of scientists and engineers.

As an employer, the Fraunhofer-Gesellschaft offers its staff the opportunity to develop the professional and personal skills that will allow them to take up positions of responsibility within their institute, at universities, in industry and in society. Students who choose to work on projects at the Fraunhofer Institutes have excellent prospects of starting and developing a career in industry by virtue of the practical training and experience they have acquired.

The Fraunhofer-Gesellschaft is a recognized non-profit organization that takes its name from Joseph von Fraunhofer (1787–1826), the illustrious Munich researcher, inventor and entrepreneur.

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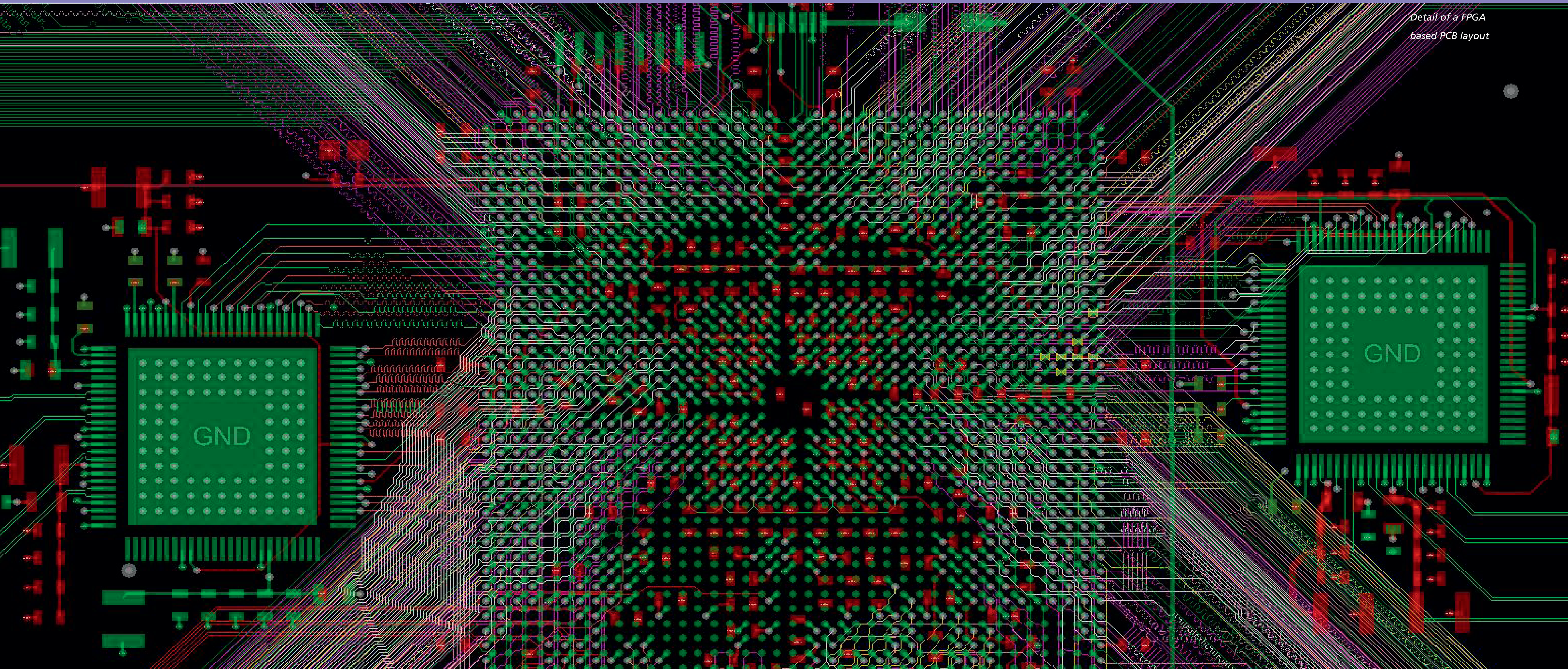
LOCATIONS OF THE RESEARCH FACILITIES

MICROSYSTEMS TECHNOLOGY, MEMS AND IC DESIGN



Detail of a FPGA based PCB layout

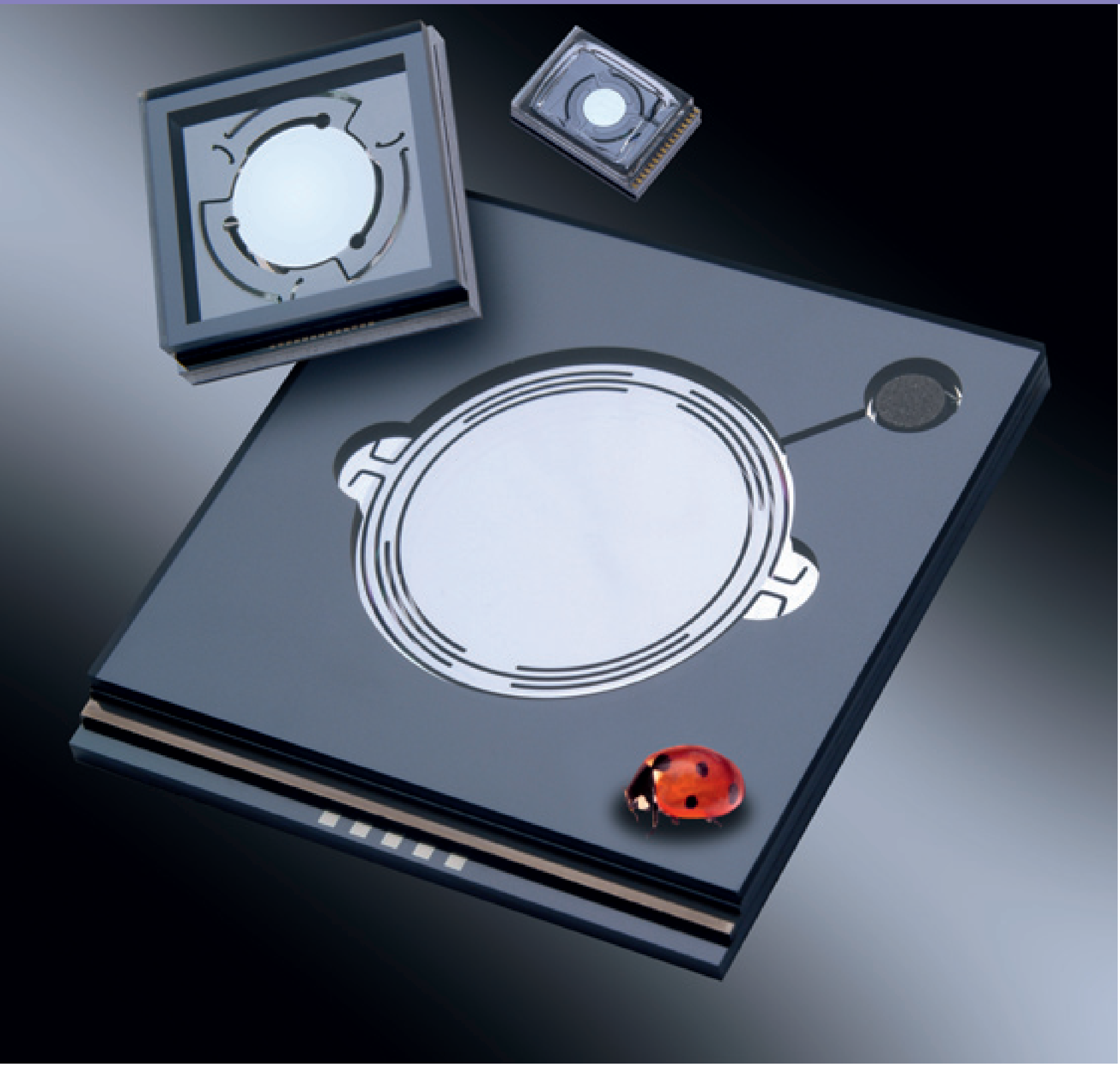


Figure 1:
Different variants of MEMS
scanning mirrors in their hermetic packages

LARGE APERTURE MEMS SCANNING MIRRORS (LAMM)

At Fraunhofer ISIT, MEMS scanning mirrors have been developed since 1995. Based on electrostatic actuation they serve many different applications, such as endoscopic imaging, confocal laser scanning microscopy and optical coherence tomography. They have been developed for biaxial beamsteering in large matrices of optical cross-connects in optical telecommunication networks, while another class of biaxial scanning mirrors has been developed for high resolution laser video projection purpose to be applied in automotive head-up displays, dashboard displays, smartphones, digital cameras, wearable displays (augmented reality displays) and gesture control.

ISIT was first to develop and successfully apply wafer level vacuum packaging of MEMS scanning mirrors in 2007. Hermetic wafer level packaging is a key factor to enable reliable low-cost mass producible optical MEMS for automotive and consumer industry. Besides protection against contamination by particles and moisture, vacuum packaging additionally allows to effectively reduce energy dissipation caused by gas damping. Resonant MEMS scanning mirrors thereby can achieve Q-factors up to 140,000. This enables to accumulate oscillation energy over a large number of resonant mirror oscillations. Conserving the energy in the vacuum packaged MEMS allowed to largely increase the parameter range in comparison to other MEMS mirror concepts: While some of the MEMS mirrors achieve scan frequencies higher than 100 kHz, others have been designed to achieve optical scan angles larger than 100 degrees.

In 2013, a new development has begun which exploits the advantage of vacuum packaging for biaxial actuation of large aperture MEMS scanning mirrors with diameters up to 20 mm. Such large aperture MEMS mirrors (LAMM) can serve many new applications such as 3D Time-of-Flight cameras and LIDAR systems, but also applications where laser power exceeds the typical milliwatt-range which conventional MEMS-mirrors so far often have been restricted to.
In contrast to the fabrication technology used for the typical 1 mm MEMS mirror in which a device layer thickness of 80 µm is used, the new class of LAMM-scanners applies a 10 times greater thickness which is necessary to minimize dynamic mirror deformation. Appropriate dielectric coatings which provide a high reflectivity of greater than 99% will enable to use such MEMS scanning mirrors in high power laser applications.

Author: Ulrich Hofmann

PROGRESS IN THE COLLABORATIVE RESEARCH CENTER SFB 855 "MAGNETOELECTRIC COMPOSITE MATERIALS – FUTURE BIOMAGNETIC INTERFACES"

The Fraunhofer ISIT is part of the Collaborative Research Center SFB 855 "Magnetoelectric Composite Materials - Future Biomagnetic Interfaces" established at Christian-Albrechts-University of Kiel. The ambitious objective of this collaborative project is the development of a biomagnetic interface for contactless measurements of brain and cardiac currents.

Typical biomagnetic signals caused by such currents range from a few 10 pT above the chest due to cardiac muscle contraction down to several 100 fT for the magnetoencephalography. In comparison, the earth's magnetic field amounts to some 10 µT and is, therefore, up to 8 orders of magnitude greater than such biomagnetic signals.

So far, only helium cooled, bulky and costly SQUID sensors are available for measuring biomagnetic signals.
The expected widespread use of MEG (Magnetoencephalography) and MCG (Magnetocardiography) in medical diagnostics has not taken place due to these drawbacks. Moreover, in everyday medical practice, the use of bioelectric signals is favored, as they are known from ECG or EEG, although for such measurements a good and stable skin contact is required. Besides the advantage of contactless measurement, magnetic signals are not scattered by skin, tissue and bones.

This is a crucial advantage of the magnetic method over the electrical one. Due to the absence of signal diffusion in the body, the reconstruction of the magnetic field and, therefore, of the signal origin and pattern is not only easier but also more accurate.

Sensing principle

In close collaboration with scientists from the institutes of material science, electrical engineering, physics and the faculty of medicine at the University of Kiel, a highly sensitive MEMS magnetic field sensor was developed at ISIT, which is based on a magnetoelectric (ME) sensor approach (figure 1). The combination of high sensitivity, high spatial resolution and operation at room temperature significantly expands the range of possible medical applications of MEG and MCG.

In this sensor, the ME signal is generated by mechanical coupling between a piezoelectric layer and a magnetostrictive layer made of an alloy of $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$. In this material, the magnetostrictive strain is always parallel to the magnetization. By annealing the magnetostrictive layer in

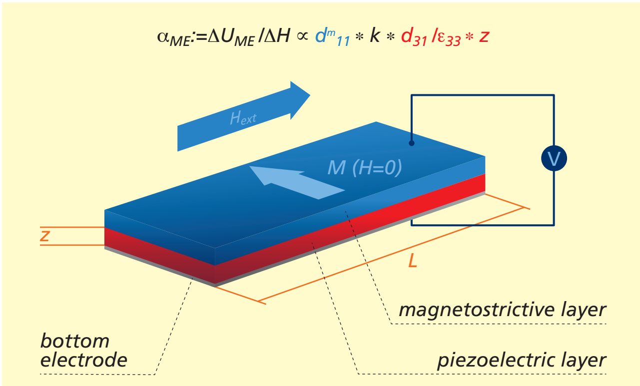


Figure 1: Working principle of the MEMS ME sensor, which is based on a magneto-electric 2-2 composite consisting of a magnetostrictive ($(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$) and a piezoelectric layer (AlN)

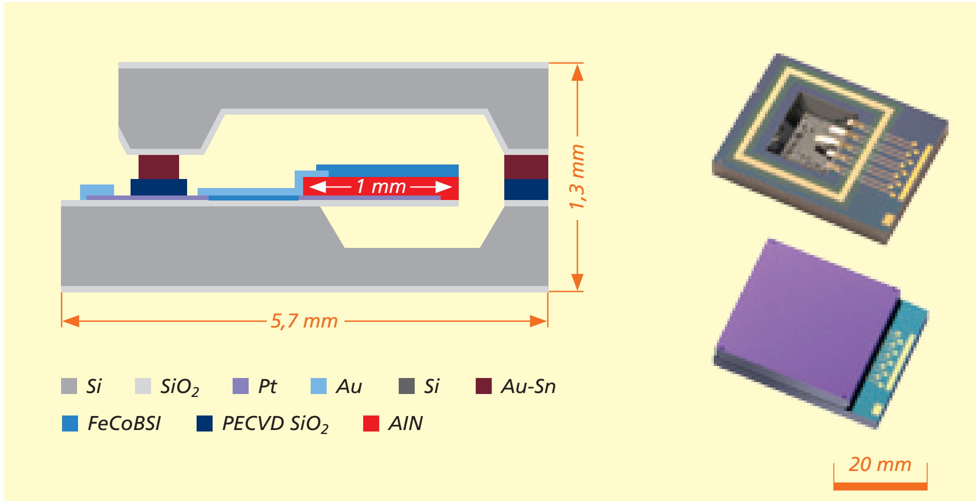


Figure 2: Sketch (left) and photograph (right) of the MEMS ME sensor

a strong external magnetic field, a small magnetocrystalline anisotropy can be generated, which ensures a certain basic orientation of the magnetization. If this magnetization points parallel to the short axis of the bi-layer cantilever sensor structure in figure 1, an external magnetic field parallel to the long axis generates a magnetostrictive stretching.
This magnetostrictive stress response is described by the magnetostrictive coefficient d^m_{11} and is proportional to the gradient of magnetostriction.

The stress is transferred to the piezoelectric layer, which is AlN in the case of the ISIT sensor. The coupling of the two layers is thereby captured by a coupling constant k. In the plate capacitor configuration shown in figure 1, the piezoelectric voltage response is proportional to the piezoelectric coefficient d_{31} and the thickness of the piezoelectric material, and inversely proportional to its relative permittivity ε_{33}.

The performance of a ME sensor can be described on the basis of the magnetoelectric coefficient α_{ME}, which assesses the ratio between voltage response and applied magnetic field. If the described two-layer system is deposited onto a cantilever operating at its resonance frequency, α_{ME} is also proportional to the quality factor. The performance of the sensor can be improved several orders of magnitude by the use of high-Q resonators.

Sensor design and performance evaluation

The ISIT MEMS ME sensor was built on a cantilever with 1 mm length and 200 µm with. A cross section of the ISIT sensor is shown in figure 2. MEMS technology is necessary first for miniaturization of the device as well as for elimination of substrate clamping by the release of the cantilever.

By vacuum encapsulation, the resonator quality and thus the sensor performance can be further improved.

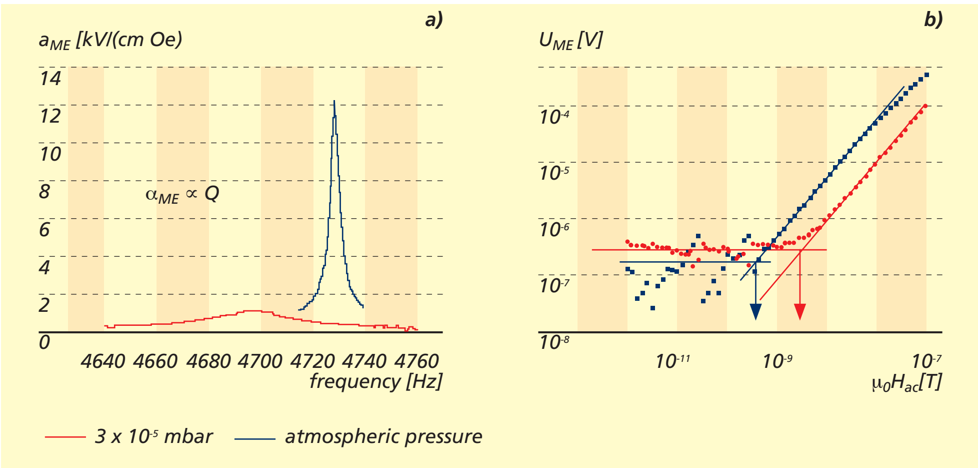


Figure 3: (a) ME coefficient and resonance frequency of the MEMS ME sensor under vacuum and at ambient conditions (red)

(b) Sensitivity of the MEMS ME-sensor at resonance frequency (5 kHz). The sensitivity and resolution of the evacuated sensor (black) is 11 times better compered to ambient conditions (red)

Measurements of the Q-factor as a function of gas pressure p for the micro cantilevers of our sensor reveal that the Q-factor increases by a factor of 11 between 10^{3} mbar and 10^{-2} mbar, as shown in figure 3 (a). At lower residual gas pressures, intrinsic damping mechanisms are dominating and the Q-factor does not change any more. Due to the improved signal-to-noise ratio, a strong sensitivity enhancement is expected in encapsulated ME sensors with moderate vacuum.

The sensitivity measurements of a sensor at atmospheric pressure and at 10^{-5} mbar are shown in figure 3 (b). ME-voltage scales linearly with the external excitation field B_{AC} down to the noise level which determines the limit of detection. It is observed that vacuum operation lowers the detection limit by one order of magnitude, from 3 nT/Hz$^{1/2}$ to 300 pT/Hz$^{1/2}$.

Assessment of wafer-level packaging

To operate the sensor by default at pressures <10^{-2} mbar without changing the compact design, wafer-level packaging technology was chosen for encapsulation. For this, a cap wafer with cavities is bonded onto the sensor wafer as illustrated in figure 4.

Since the wafer bonding process is performed at elevated temperatures, the influence of thermal treatment onto magnetic sensing properties is crucial. Corresponding investigations have shown that the magnetic layer should not be exposed to temperatures above 250°C after the deposition, otherwise the material loses its soft magnetic characteristic and, thereby, it's excellent sensing capabilities. A low temperature transient liquid phase (TLP) bonding process has been developed at ISIT. With this method, bonding

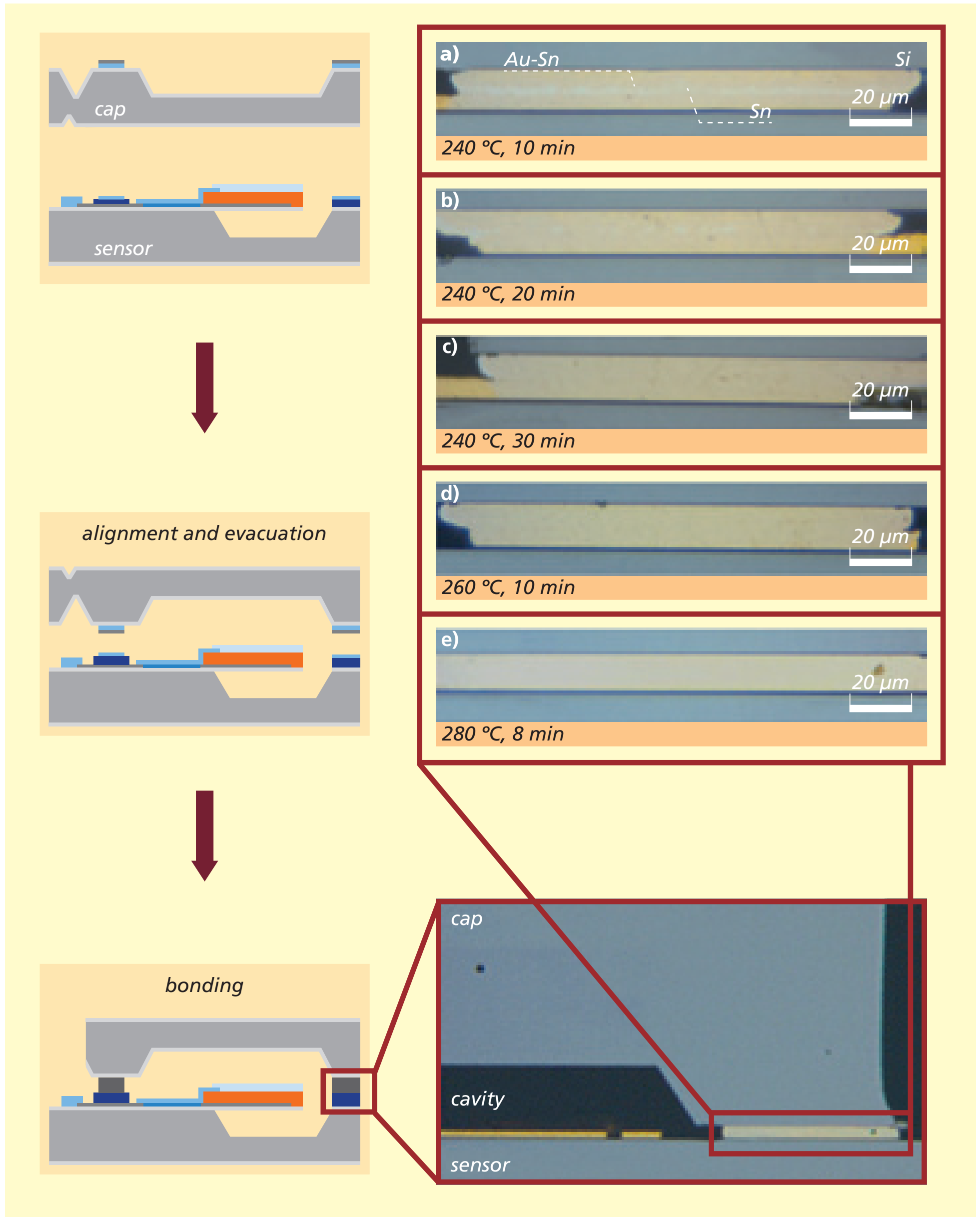


Figure 4: Schematic of the stages during TLP bonding for a binary material system (left hand side); photograph of polished sample (lower right); cross-sectional photographs of polished Au/Sn bond samples. The bond temperatures and the dwell times are indicated at the lower left corner of each picture.

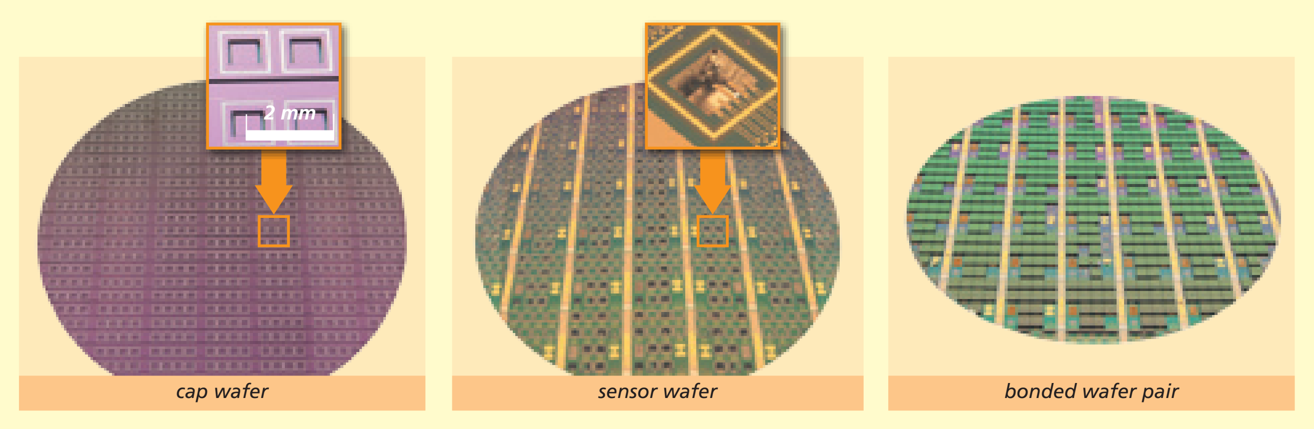


Figure 5: Photography of the cap wafer, the sensor wafer and the bonded wafer pair (from left to right)

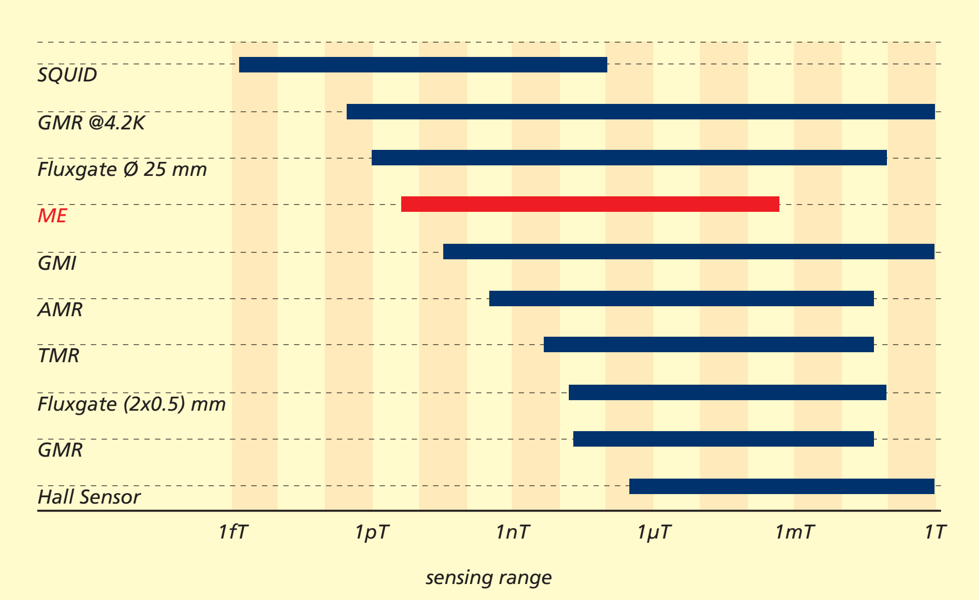


Figure 6: Comparison of the detection limit of different magnetometers with the MEMS ME sensor

temperatures below 300°C can be achieved. Cu/Sn and Au/Sn material systems have been investigated under varying bonding temperatures from 240 to 280 °C and different dwell times from 8 to 30 min. The investigated bond frame had a width of 80 µm and lateral dimensions of 1.5 mm x 1.5 mm. The sealing frame of the cap wafer consisted of Au and Cu, respectively, and Sn. The MEMS wafer only holds the parent metal of Au or Cu.

High quality bonds were confirmed by shear tests, pressure cooker test, cleavage analysis and polished cross-section analysis (see figure 4 for the Au/Sn joint). Evaluation was made using optical and electron microscopy, including energy dispersive X-ray spectroscopy. The samples showed high shear strength (>80 MPa) and nearly perfect bond regions. Figure 5 shows the photographs of the cap wafer, the s ensor wafer and the bonded wafer pair.

Comparison with other magnetic field sensors

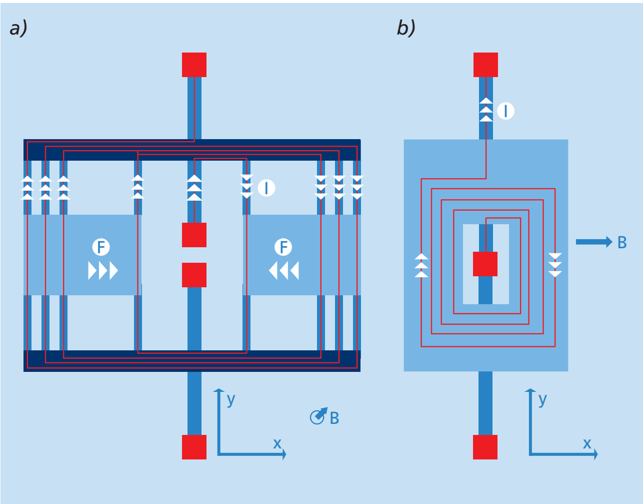
As shown in figure 6, the comparison of detection limits of different magnetometers with the MEMS ME sensor reveals that this sensor with its simple design is already better than most competing technologies. Still, the device performance can certainly be increased by new design concepts aiming for a reduction of the intrinsic damping.

Taking into account the compact design, the operation at room temperature as well as the large measurement range, the MEMS ME sensor is already today an outstanding magnetometer, even if it is presently not in a position to detect brain currents.

Author: Fabian Lofink

LORENTZ FORCE MEMS 3D-MAGNETOMETER AND THE INTEGRATION INTO A SINGLE CHIP 9D IMU

Sensors for the measurement of angular rate, acceleration and magnetic fields are seen in everyday life. Due to numerous new applications in consumer products, medical and security applications, market requirements on cost, size, power consumption and quality are ever increasing. In order to meet the requirements of these specific applications, the collaborative project '9D-Sense' which is part of the BMBF research program IKT2020, is set out to develop a small, cost efficient and autonomous multi sensor system. The sensor module within this project consists of an accelerometer, a gyroscope and a magnetometer, each for three spatial directions (9 degrees of freedom). The challenge is the integration of a Lorentz force MEMS 3D-magnetometer, a 3D-gyroscope and a 3D-accelerometer into a single chip 9D inertial measurement unit using one processing technology. The advantage of this concept is the inherent precise adjustment of all spatial axes of all sensors. This improves the measurement accuracy and reduces the final packaging costs.



The function of a Lorentz force magnetometer based on the well-known equation $F_L = I \times B$, where I is a vector whose magnitude is the length of wire, and whose direction is along the wire. It is also aligned with the direction of conventional current flow I. B is the magnetic field vector. In the 9D IMU discussed here, the magnetometer acts as a magnetic compass which should measure the earth's magnetic field of 30–60 µT with a resolution of 0,3 µT. Looking for a compact chip, the length l of the coil is limited and for technological reasons the current I within the coil is also restricted. To amplify this small resulting Lorentz force into a high measurement signal, a resonant concept for the sensor design is used. Therefore, the current I is modulated with the resonance frequency of the spring-mass-system of the designed sensor. The amplitude of the moving mass will be registered by a capacitive measurement. If the moving mass is running in an environment with a reduced gas pressure, a further sensitivity enhancement could be reached.

To measure all 3 spatial axis on one chip, two different sensor designs are needed: One for the magnetic field perpendicular to chip level (z-sensor, see figure 1a) and one for a magnetic field within chip level (xy-sensor, figure 1b). The latter design is placed twice on the chip, 90° rotated to each other.

Figure 1: Sensor designs for measuring a magnetic field perpendicular to chip level (left) and a magnetic field within chip level (right)

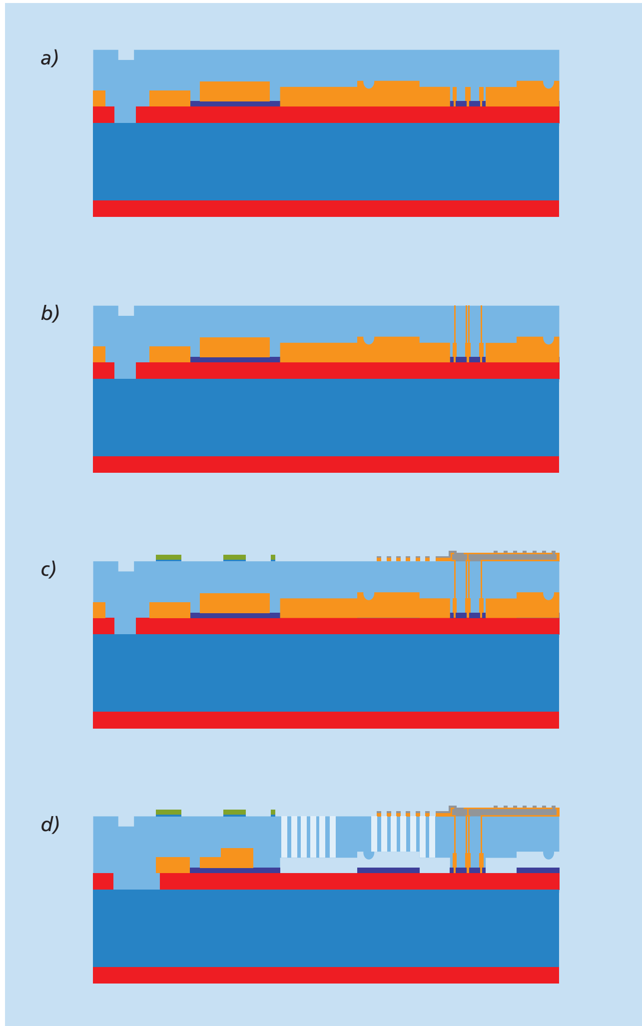


Figure 2: Schematic of fabrication process

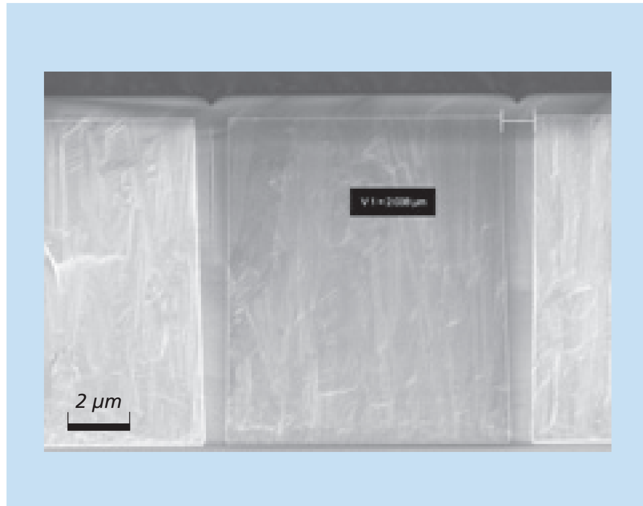


Figure 3: Poly via connecting buried poly wiring level below the moving mass with the coil on the upper surface of the moving mass

The z-sensor's spring-mass-system is moving in chip level and has in-plane reference electrodes; the xy-sensor is moving out of plane and needs an underlying reference electrode.

Taking the surface micromachining fabrication process for a gyroscope as a basis /1/, two more technology modules have to be introduced. A poly via technology is needed to route the electrical signal for activating the coil from the buried poly wiring level below the moving mass to the upper surface of the moving mass, where the coil will be structured.
The only place where this can be done is the highly conductive poly silicon post, on which the moving mass hangs via the spring structures. Within the post, two columns of poly silicon are separated by a 2 µm trench using a DRIE process.

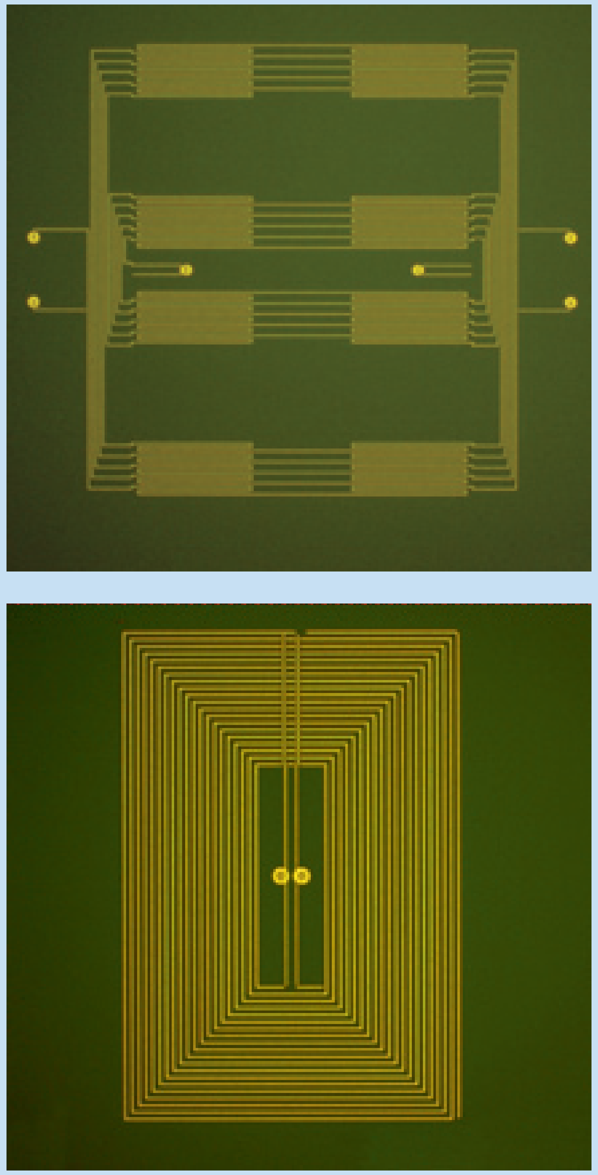


Figure 4: Aluminum coil on upper surface of moving mass (top out of plan direction, bottom in plane direction)

The trench is filled with LPCVD TEOS and the poly silicon surface is leveled using CMP and passivated with SiO_2. The SiO_2 will be opened in the column area, which is now ready for metal contact deposition (figures 2a and 2b; figure 3). The other technology module which has to be added is the fabrication of the coil on the upper surface of the moving mass. The coil consists of aluminum and has to be isolated with respect to the high conductive poly silicon of the moving mass, using a SiO_2 layer. Within the surface micromachining fabrication process for gyroscopes, SiO_2 is the sacrificial layer material, therefore ISIT developed a sophisticated process which wraps the aluminum coil with the SiO_2 layer below in a protection layer being resistant against the HF gaseous phase etch process (figures 2c and 2d; figure 4).

The technical challenge integrating accelerometers, gyroscopes and magnetometer in one chip arises from the fact that common MEMS accelerometers are operated in damped mode to reduce shock and vibration sensitivity, while vibrating gyroscopes and magnetometer require a high quality factor for low voltage operation and high signal response. Therefore, two different pressure regimes have to be controlled on one chip. ISIT developed a specific process technology for combined MEMS inertial sensors /2/.
The accelerometer and the gyroscope together with the magnetometer are side by side on the chip, but separated (gas-tight) by individual cavities. The cavities could be prepared individually with a getter layer to absorb gas molecules inside the cavity volume (figure 5).

After finalization of the wafer processing, the 9D IMU has to be characterized for each sensor element separately, but also with respect to cross talk between the different sensor elements. A vision for the future is to realize a vertical integration as shown in figure 7, where the cap wafer contains also active MEMS elements, in this case the magnetometer. This technology could give a further push to shrink 9D IMUs.

/1/ P. Merz, W. Reinert, K. Reimer, B. Wagner; PSM-X2: Polysilicon surface micromachining process platform for vacuum-packaged sensors; in: Mikrosystemtechnik Kongress 2005, Freiburg, Germany; VDE Verlag, 2005, S. 468-471
/2/ P. Merz, K. Reimer, M. Weiß, O. Schwarzelbach, A. Giambastiani, A. Rocchi, M. Heller; COMBINED MEMS INERTIAL SENSORS; in: MME 2009, 20th Micromechanics Europe Workshop, 20–22 September 2009, Toulouse, France.

Author: Dr. Klaus Reimer

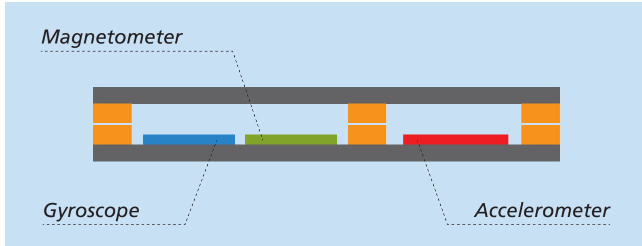


Figure 5: Horizontal 9D sensor integration in dual-cavity technology

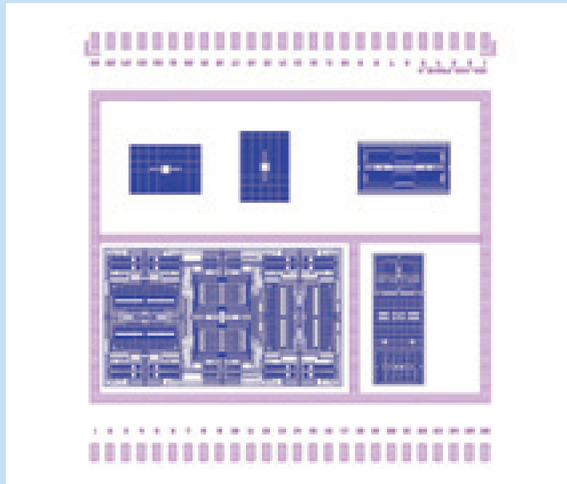


Figure 6: 9D sensor element

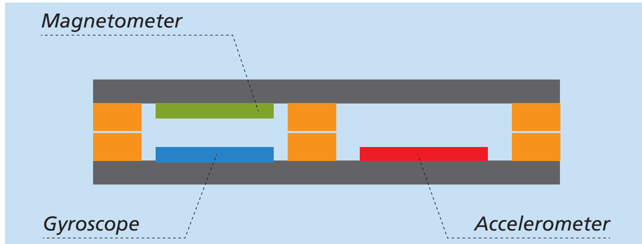


Figure 7: Vertical 9D integration concept

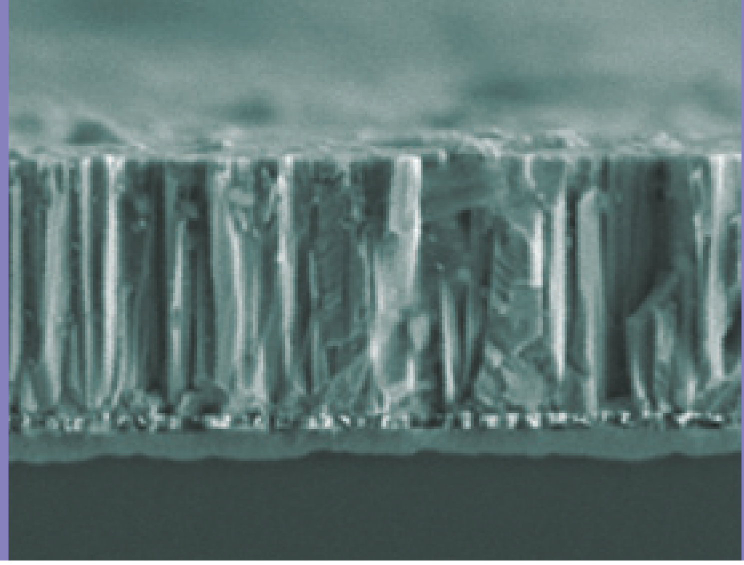


Figure 1: SEM image of a 2 µm thick PZT film with its characteristic columnar structure

PROJECT "MIKRO-AUGE": MULTIAXIAL PIEZOELECTRIC ACTUATOR FOR OPTICAL COMPONENTS

Optical and mechanical micro-components are typical innovation drivers for new generations of optical data storage systems, faster data speed in fiber optics and more precise optical measurement systems as in Fabry-Pérot interferometers. In these systems, an in-situ adjustment for lenses and mirrors is inevitable. Most of the current micro lens actuators are based on electrostatic, electromagnetic or thermal actuation principles, suffering from several drawbacks like lack of speed, unintentional tilting or difficult dynamic control. In this project, different piezoelectric micro actuators are developed, which can be used for focusing and tilting purposes of lenses or mirrors.

Piezoelectric materials produce forces caused by the deformation of its crystalline structure when a voltage is applied to the material. The piezoelectric material PZT (lead-zirconate-titanate) is frequently used, as it is capable of generating high forces at high speed and low power consumption. The integration of PZT in MEMS production is relatively new and therefore challenging. The processing technology of PZT at Fraunhofer ISIT has been well developed in the past years and now Fraunhofer ISIT can provide processes for sputtering and structuring thin film PZT layers to develop micro actuators. Figure 1 shows a SEM image of a 2 µm thick PZT film with its characteristic columnar structure as it is sputtered at Fraunhofer ISIT.

Design

The actuating element of a piezoelectric actuator with PZT often is a cantilever consisting of a passive layer, preferably silicon, and the PZT layer, which is similar to a plate capacitor with lower and upper electrode. For the design development of the PZT actuator, analytic modeling has been performed to determine the thickness of the cantilevers passive layer to enable good deflection in respect of stiffness and eigenfrequency of the actuator.

The first design (Figure 2a) consists of four piezoelectric cantilevers operating in piezoelectric transversal mode, which are connected via hinges to the lens holder. Design 1a features 1 mm long and 500 µm wide cantilevers, whereas design 1b has 2 mm long and 500 µm wide cantilevers. The lens holder in each case is 2210 × 2210 µm² in size and has an octagonal opening in order to allow light transmittance.

Figure 2b shows design 2 with a two-sided suspension without hinges, enabling a compact side-by-side arrangement. To account for the resulting s-shaped displacement profile under actuation, the 2 mm long cantilevers are subdivided into two parts of equal length operating in piezoelectric transversal and longitudinal mode and using interdigital top electrodes, respectively.

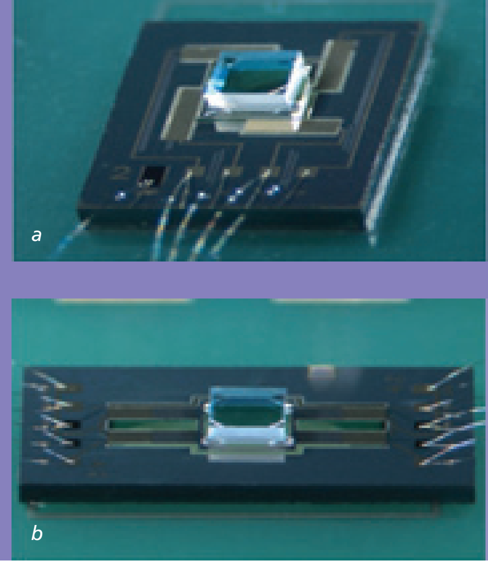
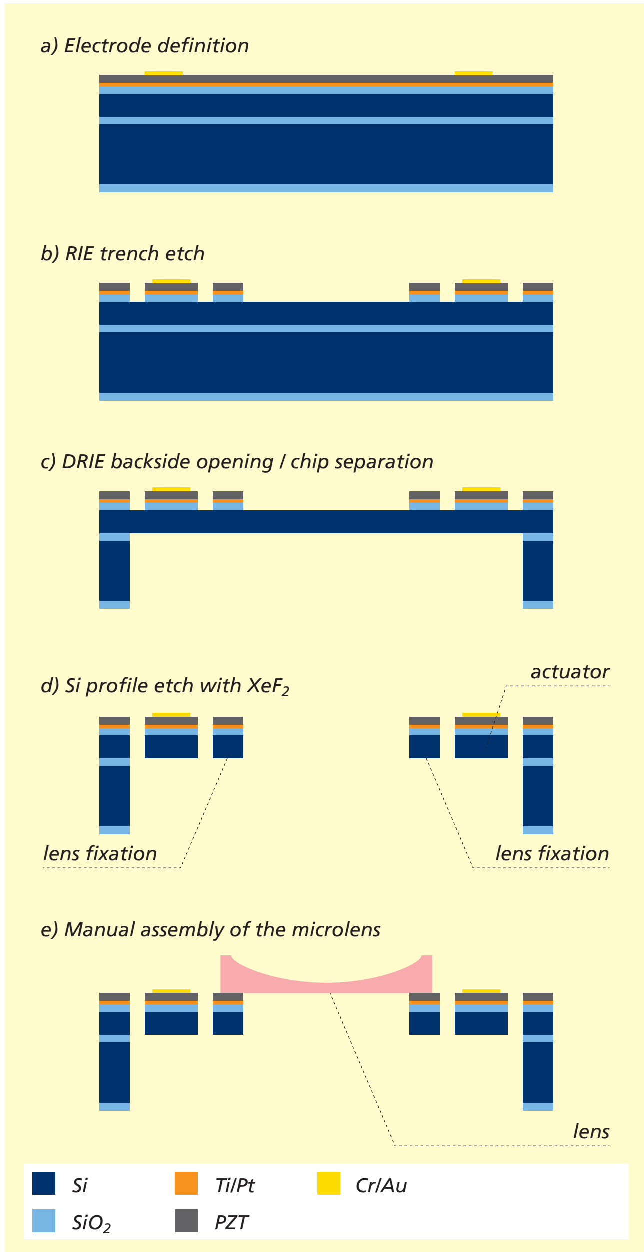


Figure 2: Mounted and wire bonded devices with glued lens:
(a) Design 1b with four 2mm long piezoelectric actuators, which are connected via hinges to the lens holder.
(b) Design 2 with a two-sided suspension without hinges.



Fabrication process

The fabrication process, which uses bulk silicon micromachining, is shown in figure 3. Silicon-on-Insulator (SOI) wafers consisting of 725 µm Si, 1 µm SiO_2 and a 19 µm polysilicon device layer have been used as starting material. After deposition of 1 µm high temperature oxide, the bottom electrode (20 nm Ti and 100 nm Pt) is realized by evaporation and lift-off patterning. Then 1 µm PZT thin-film is deposited by magnetron sputtering, followed by sputtering and wet etching of 40 nm Cr and 250 nm Au. Subsequently, the PZT, Ti/Pt and SiO_2 layers are etched by RIE. A DRIE process was used for backside opening. Due to the still intact 19 µm polysilicon device layer, the wafer could be diced into single devices without damaging loose parts. Finally, the cantilevers and the lens mount have been released by etching the device layer in XeF_2 atmosphere.

The fabricated devices were assembled on PCB. The lens is produced separately in a glass flow process and is manually assembled after actuator fabrication using two-component glue.

Characterization

The static deflection at the intersection of cantilever and lens holder was measured on a microscope with micrometer caliper. This was done by gradually increasing the driving voltage and focusing the device. All cantilevers were actuated simultaneously. The PZT film was poled prior to measurement (120°C, 15 V, 10 min).

Figure 3: Cross-sectional fabrication process flow of the micro lens actuator. Five masks in total are used. The lens is hybrid mounted.

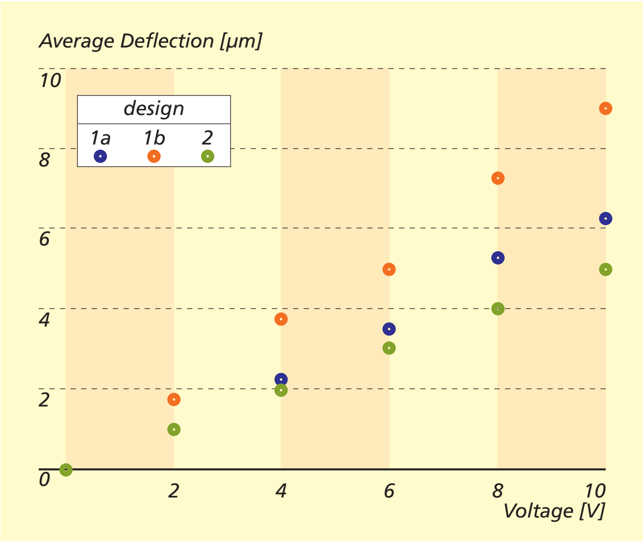


Figure 4: Measured average static deflection of the piezoelectric actuator of design 1a, 1b and 2 without lens.
The PZT film was poled prior measurement (120 °C, 15 V, 10 min).

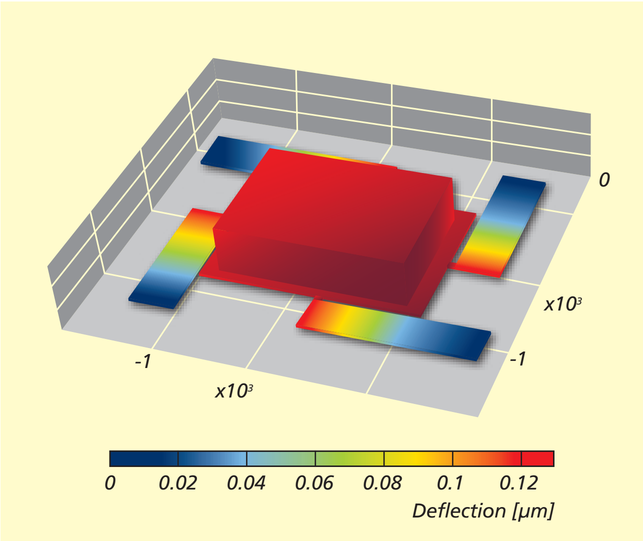


Figure 5: FEM simulation (COMSOL) of the static deflection (µm) of design 1b with mounted lens at 0.1 V.

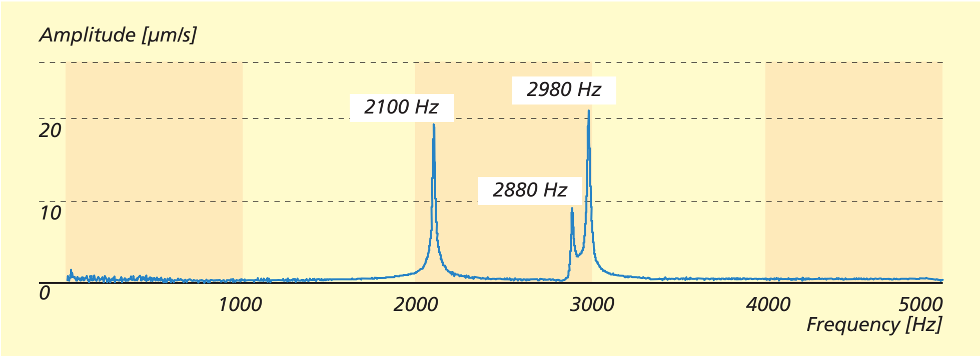


Figure 6: Representative frequency spectrum of design 1a (with lens) measured by laser Doppler vibrometer.
The 1., 2. and 3. eigenfrequencies are 2100 Hz, 2880 Hz and 2980 Hz respectively.

The measured average maximum static deflections (figure 4) were between 5 µm for design 2 and 9 µm for design 1b at 10 V applied voltage. The corresponding angle for design 2 was about 0.14° and 0.21° for design 1b. Highest deflection could be achieved with design 1b due to its 2 mm long piezoelectric cantilevers.

A FEM simulation of the actuators with mounted lens was performed with COMSOL. The material parameter "PZT-5H" from the internal library was used for the PZT material parameters. As determined by the simulation, the static deflection of design 1b is 1,2 µm/V (figure 5), which is consistent with the measured value of 0,9 µm/V (figure 4).

The frequency spectra of the micro lens actuators were measured by a laser Doppler vibrometer (figure 6). Prior to measurement, the devices were tempered on a hotplate (120 °C for 30 min). The measured eigenfrequencies of design 1a, 1b and 2 with 2098 Hz, 1040 Hz and 990 Hz respectively are in good accordance with the finite element method (FEM) simulated eigenfrequencies of 2356 Hz, 993 Hz and 1155 Hz. Design 1b and design 2 show a similar frequency behavior due to their identical cantilever length of 2 mm.

The Q-factors were calculated with decay curves, which were recorded by a laser Doppler vibrometer. For this, the actuators were excited once by a voltage pulse and the recorded curve was analyzed graphically. The Q-factors of design 1a, 1b and 2 were 240.8, 97.8 and 96.3 respectively.

The piezoelectric actuator enables vertical deflection and, to a small extend, the tilt of a hybrid mounted optical element. Higher tilting is required for better application possibilities, such as spectrometer. For this, new actuator designs are under development.

Acknowledgments

The project "Mikro-Auge" is carried out in cooperation with the research group Integrated Systems and Photonics (ISP) at the faculty of engineering of Christian-Albrechts-Universität of Kiel. The project is funded by the Deutsche Forschungsgemeinschaft (DFG).

Author: Michael Kampmann

MICROMACHINED OPTICAL MULTIPATH CELL FOR IR GAS SENSORS

A growing number of micro-optical electro-mechanical systems (MOEMS) are used in system applications like IR-detectors, projection displays or LIDAR systems. However, to complete MOEMS systems, often a number of passive optical functions are required. Therefore, miniaturised optical components have to meet specifications with respect to quality and cost that are comparable to microelectronic devices. The example presented here shows the application of wafer-level manufactured spherical micromirrors in a Herriott cell. This assembly of two micromirrors allows a multiple reflection of an incident laser beam and is therefore useful for building miniaturized gas detectors.

Description of the glass flow process

Through several years, the Fraunhofer-Institute for Silicon Technology ISIT developed an approach that allows the cost-effective production of precise optical glass components in a batch process on 8-inch wafers that can be processed in a MEMS foundry. Lenses and mirror surfaces can be shaped without any mechanical tool contact by ISIT's glass flow process, leading to excellent surface qualities with surface roughness in the nanometer range.

The method of viscous forming of optical elements uses the characteristic viscous behavior of glass at elevated temperature. For this microforming technology, a structured silicon wafer is used as a tool to generate the desired aperture of the lens tightly attached to a glass wafer by anodic bonding. Using a pressure difference between the ambient and the bonded silicon-glass cavities, convex and concave lenses or various forms of optical cap elements and mirrors can be formed. Due to the non-contact manufacturing of the optical surfaces, very smooth surfaces with typical RMS roughness values of 1-2 nm can be obtained. The process flow used for the production of micro-mirrors is shown in figure 1. The process starts with an 8″ silicon wafer that is patterned by standard lithography. Using an anisotropic deep reactive ion etch process (DRIE), cavities are etched into the silicon with step heights of several hundred microns and vertical side walls (1). After wet cleaning, the structured silicon wafer is hermetically bonded to an Alkaline-Borosilicate glass substrate (Schott Borofloat® 33) by an anodic bonding process. Since the thermal coefficient of Si and Borofloat glass is almost identical, thermal processing of the glass-silicon combination does not affect the bond. The bonding process is done in an inert gas atmosphere at a pressure slightly above atmospheric pressure (2). Due to the hermeticity of the silicon-glass joint, the initial pressure P_i is preserved in the silicon cavities. The wafer bonding process is followed by an annealing process in an atmospheric furnace system at a temperature in the range of 700° C to 900° C. Thus, the viscosity of the glass is drastically lowered. The higher pressure inside the sealed cavities pushes the hot glass upward. This forming process stops when the internal cavity pressure equals to the outer atmospheric pressure P_A. Since the glass cover is firmly bonded to the edges of the cavities, the final glass shape results by the initial dimensions of the cavities and by the initial pressure P_i. In case of a cylindrical cavity with circular top, a sphere is formed in the inner surface of the glass cover (4). With a well-suited cavity pressure at a given cavity diameter, perfectly spherical surface shapes can be produced. When the temperature is decreased below the glass temperature, this form is literally frozen in the glass wafer. During the cooling, the gas pressure inside the silicon cavities

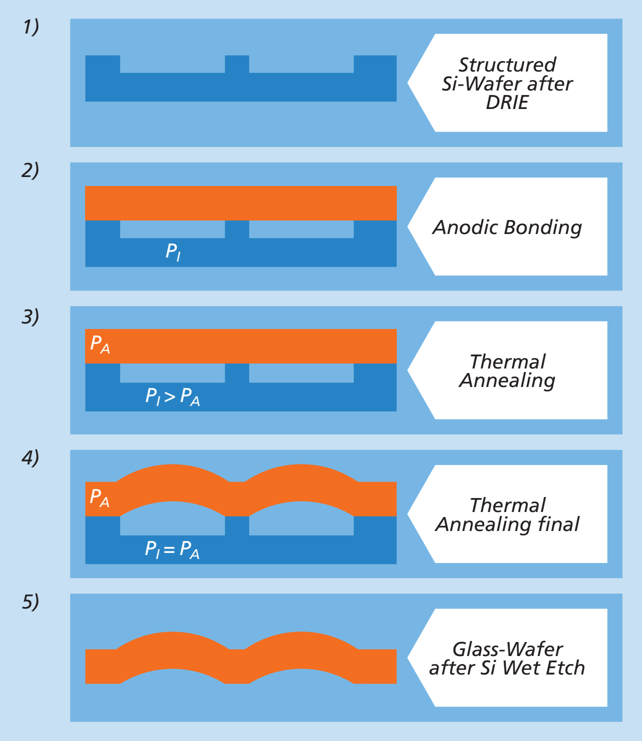


Figure 1: Process sequence for production of concave micro-mirrors by viscous glass forming

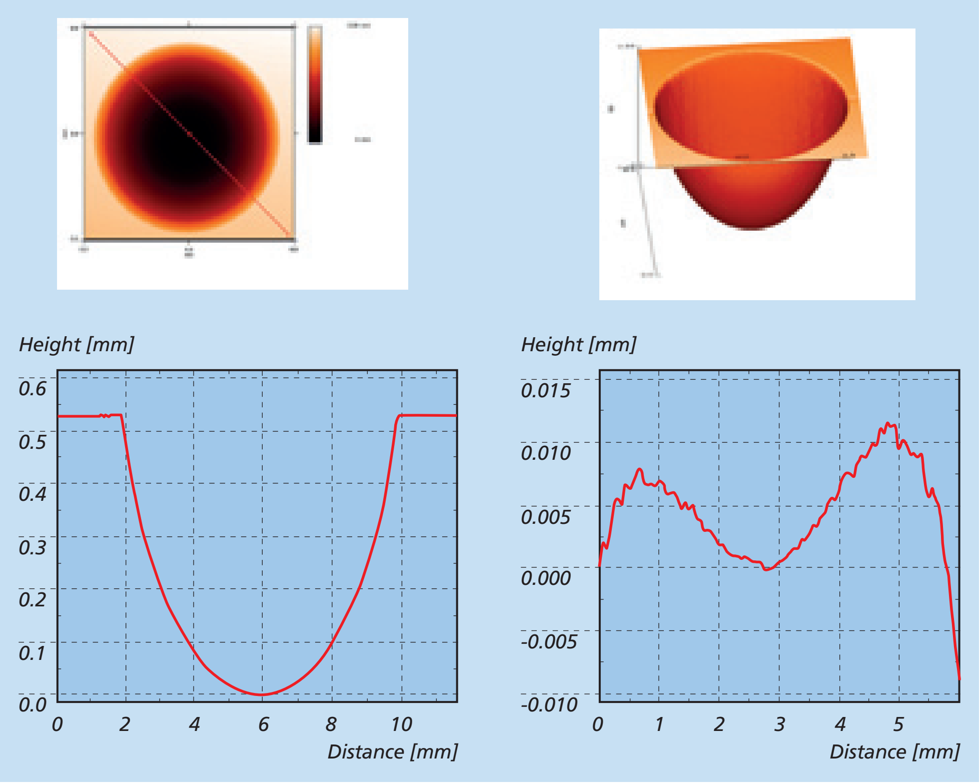


Figure 2: Measurement of the profile of an 8 mm diameter reflector surface. Left diagram shows a cross-section, right diagram below shows the difference to a spherical form. Maximum deviation of this sample from a sphere is 12 µm. Axis of abscissas is given in mm, ordinate units of right diagram are 5 µm

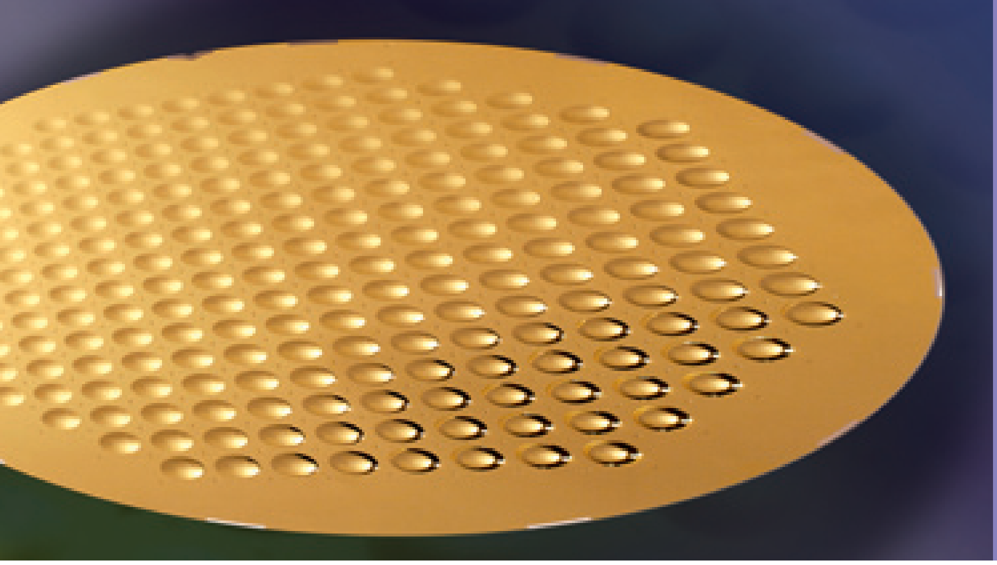


Figure 3: 8" glass wafer with 8 mm reflectors. The wafer is coated with a gold thin film for optimised reflectivity in the IR-range

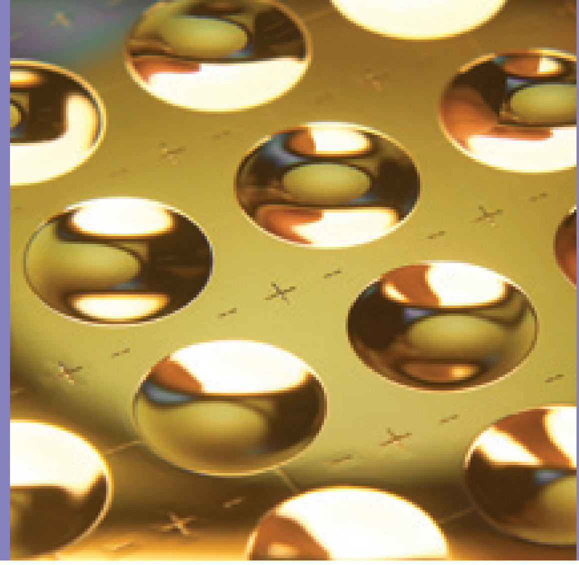


Figure 4: Detail view of gold covered reflector surfaces on 8"-glass-wafer

decreases and generates a pressure difference that acts on the hot glass form. Since the glass is still very viscous, the flow front starts moving again, which affects the spherical shape of the lens, especially for elements with relativ large apertures. Finally, the silicon wafer is removed by wet etching in tetramethylammonium hydroxide (TMAH) or KOH, and the backside of the glass wafer is mechanically planarized. Subsequently, the mirror surfaces are metallized by a metal evaporation process. For a high reflectivity in the IR range, the mirrors are coated with a gold film. After processing, the optical elements are separated by dicing.

Achieved optical quality

In several trials, the glass-flow process with 8"-wafers was optimised for manufacturing mirrors with a diameter of 8 mm and a radius of curvature (ROC) of 20 mm corresponding to a lens height of 400 µm. Test mirrors with a
diameter of 2 mm could be produced with a surface roughness below 1 nm and a maximum deviation from a spherical form of 0.3 µm PV (peak to valley).

For mirrors of larger diameter the manufacturing process is more sensitive to cooling induced deformation and process variations. For a diameter of 8 mm and a curvature of 20 mm, a curvature uniformity of 3.5 % was achieved over an 8"-wafer. The spherical mirror surface with 8 mm diameter showed a deviation from the ideal spherical shape in the range of 6 µm PV. Surface roughness is below 1 nm due to the contactless production method. For CO_2 absorption measurements at the IR wavelength λ=4.2 µm, this form deviation is below 2 λ and acceptable for most applications.

Multipath reflector assembly based on Herriott cell

The mirrors are assembled to realize a compact type multiple pass cell with a large internal optical absorption path. These cells can be used as a compact IR-absorption cell inside gas sensors.

For the set-up of a multiple-reflection cell, the design of a Herriott cell with two sherical mirrors was chosen. This is a simple cell design that is relatively tolerant in the aligment of the components. For an estimation of the fault tolerances of the chosen cell set-up, the optical path was simulated with a ray tracing method (Zemax-EE). For the design used here, the incident beam and the detection beam are coupled into the cell from the edge of a mirror at an angle of 8°. The mirrors are produced with a curvature radius of 20 mm, then fixed at a distance of 50 mm which should result in an eightfold reflection of the incident beam. Initial prototypes of the Herriott cell are manufactured from stainless steel. For the IR-emitter and IR-detector, fittings are prepared that lock into position the required incidence angles of 8°.

First tests of the optical elements were performed using an optical bench. The mirrors were attached to carriers that allowed positioning the components relative to each other. A visible laser beam (635 nm) was used to monitor the IR optical path. In figure 6, the path of rays is made visible by aerosol spray. Laser radiation is emitted from a small cut-out at a mirror edge at an incidence angle of approximately 8°. As figure 6 shows, the intended symmetrical light path in the Herriot cell is achieved. Further trials are ongoing to investigate stability of the mechanical set-up and to maximise the path length by optimising the number of reflections.

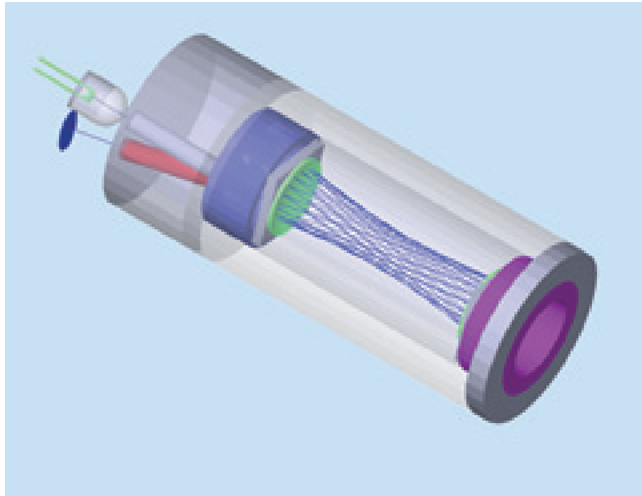


Figure 5: Simulation of the optical rays in the Herriott reflection cell

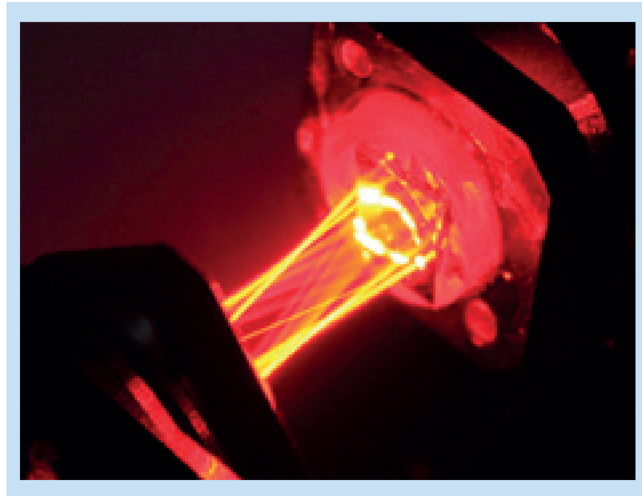


Figure 6: Test of optical path by adjusting two mirrors on an optical bench

In the first tests it was observed that the beam divergence of the chosen IR emitting diodes was too large for a strong CO_2 absorption signal. A disadvantage of Herriott type cells is that they do not operate with high numerical aperture optical beams due to interference with stray reflections. Therefore, for further evaluation of the designed absorption cell IR-emitting laser diodes will have to replace the IR-diodes. The IR-absorption cell described here is designed for continuous measurement of atmospheric CO_2 concentration. Initial measurements will soon determine the beam attenuation at the 4.25 µm CO_2 absorption line.

The work presented here was supported by the German Ministry for Education and Research under the research programme "Geotechnologien" (BMBF, grant 03G0796A), and by the Deutsche Forschungsgemeinschaft (DFG, grant WA 1114/4-1).

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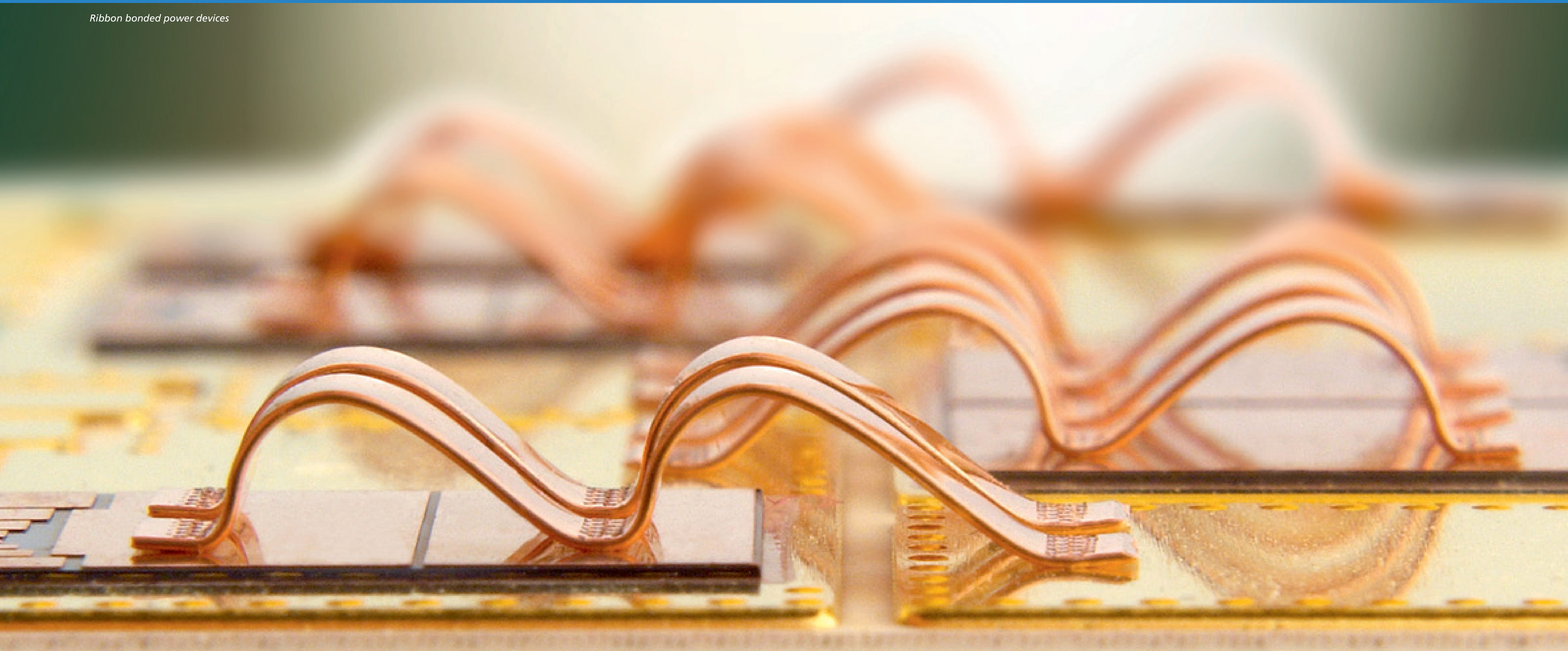
IC TECHNOLOGY AND POWER ELECTRONICS



Ribbon bonded power devices

Figure 2: Battery storage system with Li-Titanate cells

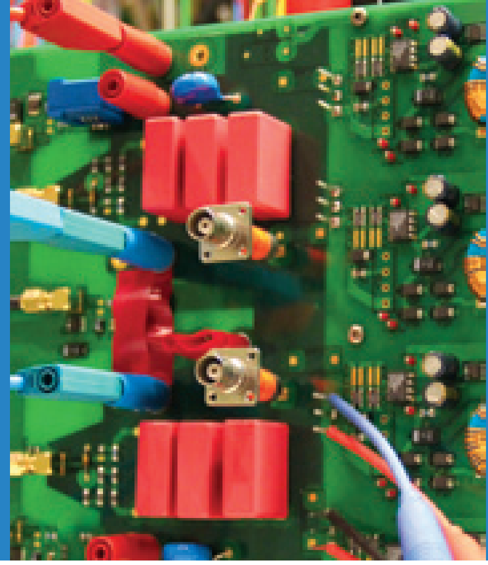


Figure 3: DC/DC-converter with > 99 % efficiency

Figure 4: Storage system

FLEXIBLE, SCALABLE AND HIGH EFFICIENT BATTERY STORAGE SYSTEM WITH BIDIRECTIONAL MULTI-PHASE DC/DC-CONVERTER

High-efficient DC/DC-converter are essential for storing generated energy without losses. Typical application fields are battery storage systems for decentralized power supplies or battery operated vehicles. The Fraunhofer ISIT has developed a novel system solution for decentralized electric power supplies like PV systems with connection of the battery storage on the DC voltage side. A previously developed DC/DC-converter reaches already 98 % efficiency. By using latest SiC MOSFET technology the efficiency of the bidirectional DC/DC-converter could be further increased up to more than 99 % over a wide output range and 98 % efficiency even at 10 % light load.

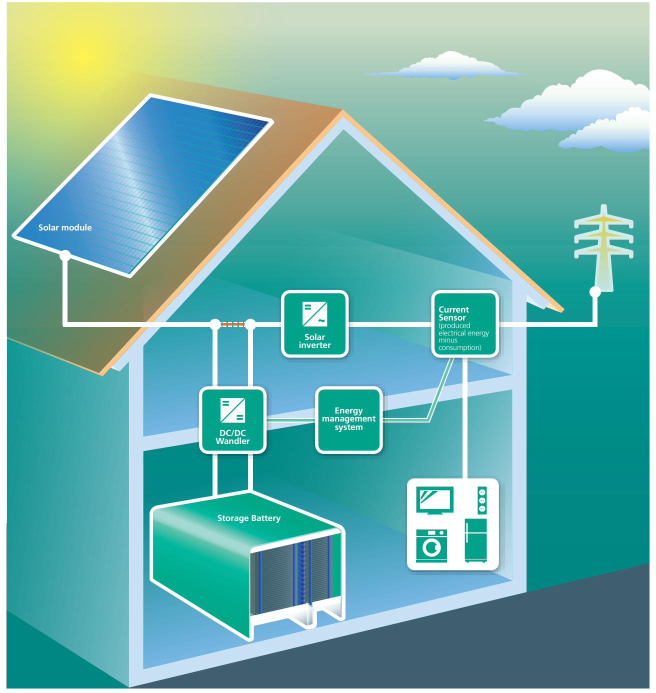


Figure 1: System concept

The battery storage system consists of a battery unit, a bidirectional DC/DC-converter for setting the charge or discharge current and an energy management system (EMS) to control the overall system with the measured values of a current sensor at electrical mains supply. The system is connected to the DC side between the solar collectors and the existing solar inverters. The battery storage system is connected via a bidirectional DC/DC-converter with the DC side of the photovoltaic system.

To achieve highest efficiency of the DC/DC-converter, a scalable storage battery system has been developed which can be built in Li-Ion technology, as well as long-lasting Li-Titanate batteries. A feature in the realized battery storage sys-tem is the way how the cells are contacted. The concept of dynamic cell balancing implies that each cell is connected with two transistors, which are used to activate or bypass the cells. If these are designed as DirectFETs, the cap can be used to realize the contact to the cells. A further advantage of this construction is the ability to dynamically adjust the battery voltage to the particular situation and to operate the bi-directional DC/DC-converter for each solar voltage in a most optimal operating point. For this purpose, the number of active cells is varied such that the voltage of the battery module is located close to this optimal operating point.

For a high long-term reliability and high efficiency of the battery system, a battery management concept was developed that dynamically adapts the battery voltage and uses a dynamic single-cell-balancing. The core idea of the system is to be able to activate or bypass each cell individually. Defective cells may be isolated from the string so that they cannot affect the performance of the overall system. This again increases the long term reliability of the battery storage significantly.

The battery storage system was built in two versions. A first series consists of a series connection of 120 18650 standard round cells with graphite anode. A higher reliability and micro-cycles stability is achieved by using batteries with Li-Titanate anode. The lower cell voltage was compensated by 240 cells in series. The active, dynamic cell-balancing prevents drifting of the cell voltages and achieves an efficiency of 99 %.

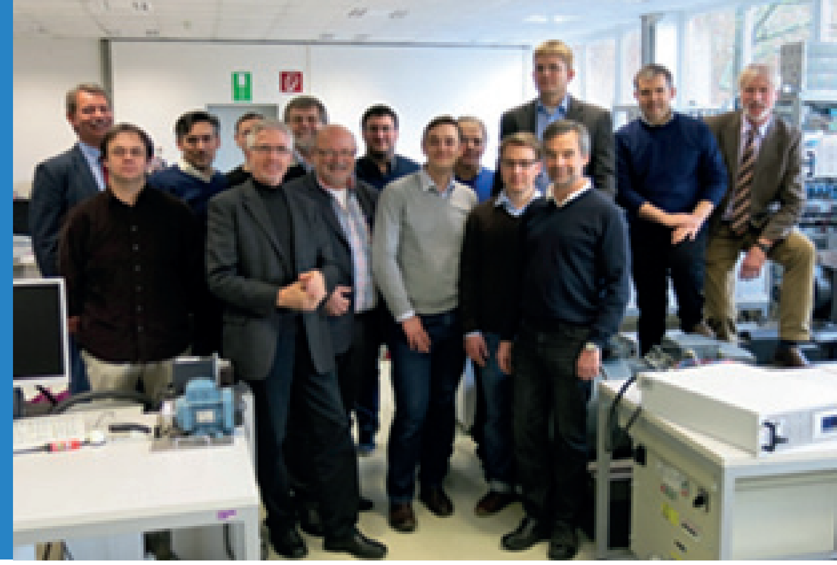
Two bidirectional DC/DC-converters were built in MOSFET technology. Both have a very wide input and output voltage range up to 550 V and 1.000 V respectively. By implementing a three-phase construction, where each phase can be activated separately and using phase-shift, a high total and partial load efficiency of 98.5 % at 20 % load can be achieved.
By implementing resonant switching and 1.200 V SiC MOSFETs, the efficiency can be dramatically increased up to 98 % at 10 % light load and more than 99% over a wide output range.

For the pure battery operation (without sunlight), the DC/DC-converter simulates on the input side the characteristic curve of a solar cell. Thus, the MPP (maximum power point) tracking of the existing solar inverter is able to reliably find an operating point for efficient operation. The DC/DC-converter includes an innovative, highly dynamic control method with a state regulator according to the state-space averaging method, which perfectly adjusts dynamic voltage jumps when the amount of battery cells is switched. A prerequisite is a mathematical model of the closed loop con-trolled system and thus the converter. The addition of the weighted state-space models leads to the overall state space model of the converter, which describes each operating point of the converter approximately.

An energy management system (EMS) monitors all incoming voltages and currents, supplemented by the SOC (State of Charge) of the battery system, and decides whether the batteries are charged or energy from the battery system must be provided. If the open circuit voltage of the solar cells is below the threshold limit of the solar inverter, the energy can be used to charge the batteries when needed. The EMS also assumes the MPP tracking for power adjustment.

The DC/DC-converter system was developed in cooperation with the HAW and the HSU Hamburg.

Author: Prof. Holger Kapels



The Innovation Cluster Team

THE NORTH IS IN FRONT: INNOVATION CLUSTER "POWER ELECTRONICS FOR RENEWABLE ENERGY"

In times of globalisation and export oriented economy, regional networking between industry and academic institutions is still a powerful element for strengthening innovation and competitiveness. An efficient way to create economic success, knowledge and employment for regional development is the three-column cooperation model consisting of applied research at Fraunhofer institutes, basic research at universities and R&D transfer for innovative products by industry. Based on this approach, the Fraunhofer society in Germany and the regional governments are currently funding 23 so-called "Innovation Clusters". These clusters have their focus on enhancing regional networking and thus strengthening activities of high societal interest in the respective areas.

One of the naturally given highlights in northern Germany is renewable energy provided by wind power. More than 11 GW of nominal power are currently installed in the German federal states Schleswig-Holstein and Niedersachsen, which is about one third of the total wind energy exploitation in Germany. For offshore wind parks, no better location will be found than the North Sea and the Baltic Sea, offering the highest potential for steadily harvesting wind energy. More than 20 offshore wind parks are projected and approved in this area. Therefore, many companies like wind power plant manufacturers, component suppliers and service providers for projecting and operating wind parks are located in Schleswig-Holstein and Niedersachsen.

This economic infrastructure gives ideal conditions to establish Fraunhofer Innovation Cluster activities focused on wind energy related topics in the north. In Schleswig-Holstein, the Innovation Cluster "Power Electronics for Renewable Energy" is already working since January 2013, while another Innovation Cluster in Niedersachsen is about to start in 2014. The activity perfectly matches with the successful "Competence Center of Power Electronics Schleswig-Holstein" (Kompetenzzentrum Leistungselektronik Schleswig-Holstein, KLSH) founded in 2008, with the same intention to mutually benefit from regional networking between Fraunhofer ISIT, universities and industry.

Situated between the Northern and the Baltic Sea, Schleswig-Holstein offers a beautiful landscape and "typically northern" weather conditions that make it an ideal place to develop and test power electronics for harvesting the abundantly available wind energy in large quantities. Already more than 80 % of the gross regional electrical power consumption are covered by renewable energy, with a wind energy share of 50 % in 2012. For comparison: The share of the renewables on the gross German electrical power consumption amounts to 23 %, with 8 % provided by wind power.

Talking about failure rates and correlated down-times of wind power plants, statistics show that 15-20% of loss rate are due to converter failures. If we assume a lifetime specification of 20 years for electronic components (especially for offshore operation under critical maintenance conditions), an urgent need for improvement of the aging behaviour becomes obvious. Hence, the Innovation Cluster "Power Electronics for Renewable Energy" aims at understanding and improving power electronic components for generators in the MW range on all levels of their integration with regard to increased efficiency, reliability and lifetime. Furthermore, new components for wind power converters will be developed and tested all along the industrial value chain: Application specific

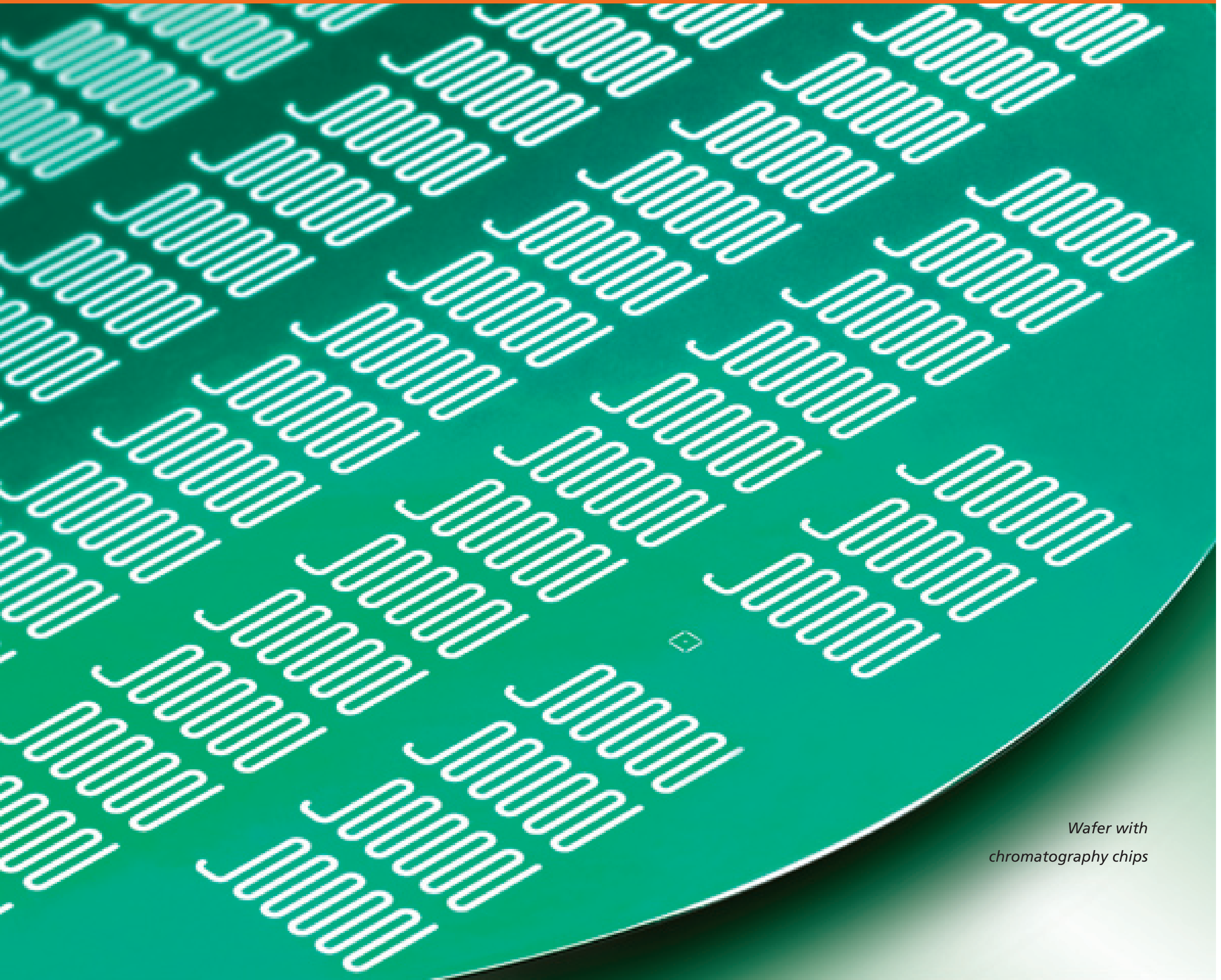
Silicon power devices (like IGBTs) suitable for innovative assembly techniques, power modules with highest reliability based on
sintering and copper wire bonding, efficient converter topologies and driver circuits as well as new mechatronic concepts are the base for an advanced powerstack generation.
As a challenging demonstration project, a modular 3-phase powerstack with a rated power of 1 MW will be developed and tested for the application in back-to-back full power converters.

The consortium consists of the companies Vishay Siliconix Itzehoe GmbH, Danfoss Silicon Power GmbH, Reese & Thies and Senvion Wind Energy Solutions as well as the academic institutions Christian-Albrechts-University of Kiel, University of Applied Sciences Kiel and the University of Applied Sciences Westküste Heide, all located in the federal state of Schleswig-Holstein. Fraunhofer ISIT is the coordinator of the Innovation Cluster in Schleswig-Holstein. The political interests of the local government are represented by the "Wirtschaftsförderung und Technologietransfer Schleswig-Holstein GmbH" (WTSH). A governmental funding is given within the framework of "Zukunftsprogramm Wirtschaft", a European regional development fund supported by the Ministry of Economy of Schleswig-Holstein. In addition to these activities, the Innovation Cluster of the German federal state Niedersachsen is addressing complementary tasks such as analysis of overall failure causes, condition monitoring and lifetime predictions, as well as failure tolerant system concepts for power electronics in wind power plants. The Innovation Cluster of Niedersachsen is coordinated by the Fraunhofer-Institute for Wind Energy and Energy System Technology, IWES. Both Innovation Cluster activities complement each other in terms of expertise, technical cooperation and coordination of joint workshops.

The German word "Energiewende" expresses a paradigm change in all aspects of energy economy including consumer awareness, political conditions and technological innovation. The Innovation Cluster "Power Electronics for Renewable Energy" is one of the building blocks for a successful implementation of this challenging project. Another one will be the "Intelligent Energies Showcase" project of the German Federal Ministry of Economy destined to fund large demonstrator projects for the "Energiewende". It is the goal to demonstrate that 100 % reliable energy supply and system stability become possible by means of intelligent grids powered with renewable energy. The northern German region could become one of these model regions: Within the next years, Schleswig-Holstein will be the first federal state in Germany that will cover its total electrical energy consumption by renewable energies mainly coming from wind power. The target for the year 2023 is to supply three times more electrical energy than the proper consumption. We expect this joint effort of the Ministry of Economy and the Ministry of "Energiewende" in Schleswig-Holstein in cooperation with industry, academic institutions and the Fraunhofer-Institute ISIT to become a meaningful and long-lasting contribution to an exciting new era of a sustainable energy economy: The north is in front!

Author: Detlef Friedrich

BIOTECHNICAL MICROSYSTEMS



Wafer with chromatography chips

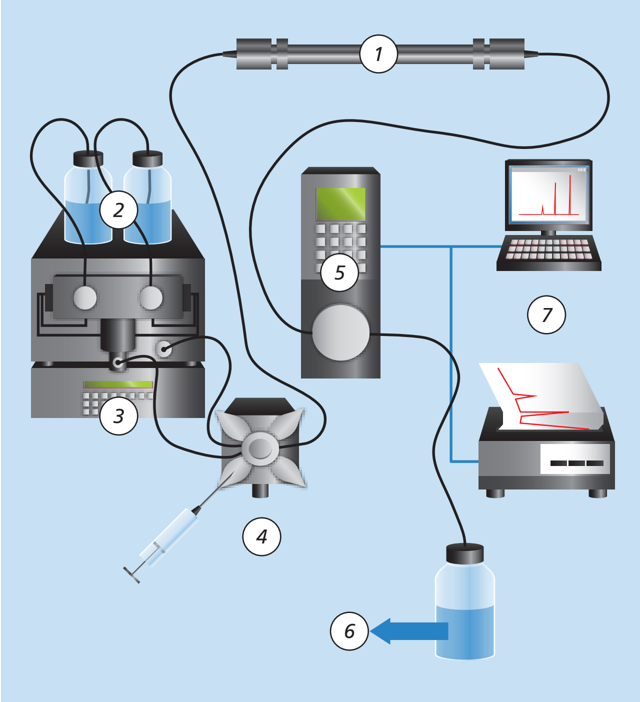
LIQUID CHROMATOGRAPHY IN A MICROSYSTEM

Liquid chromatography techniques and especially the High-Performance Liquid Chromatography (HPLC) are well established and commonly used methods in analytical chemistry. Typical fields of application are for example food chemistry, environmental chemistry, diagnostics and biochemistry. Up to now, HPLC analytics is limited to laboratories, because integrated miniaturized systems do not exist. Essential components of a common HPLC system are a high-pressure pump, a sample injector, a separation column, a detector and a computer for system control and data display (see figure 1).

In an ISIT internal project, the department Biotechnical Microsystems (BTMS) leads the development of a chromatography chip for miniaturized liquid chromatography that will allow fast and flexible on-site analyses.

The principle of a HPLC system is as follows: For sample separation and analysis, a solvent called the "mobile phase" is pumped constantly with high pressure through a separation column, which is tightly packed with a porous material like e.g. silica particles. A sample liquid with unknown amount and type of substances is injected into the mobile phase.
Due to their characteristic properties, different molecules have different transit times through the separation column.
Behind the separation column, a detector cell is located where the separated analytes are detected in the mobile phase.

The time-resolved detector signal appears like a spectrum of different species regarding their mobility in the column: Because the sample decomposition occurs according to specific molecular interaction with the column material surface and the solvent, the quantification of analytes is done by determining the height or area of each peak that can be attributed to a single type of molecules.



1 HPLC column
2 Solvents
3 Pump
4 Sample injector (injection valve)
5 Detector
6 Solvent waste (recycling)
7 Data integration system

Figure 1: Scheme of a conventional HPLC

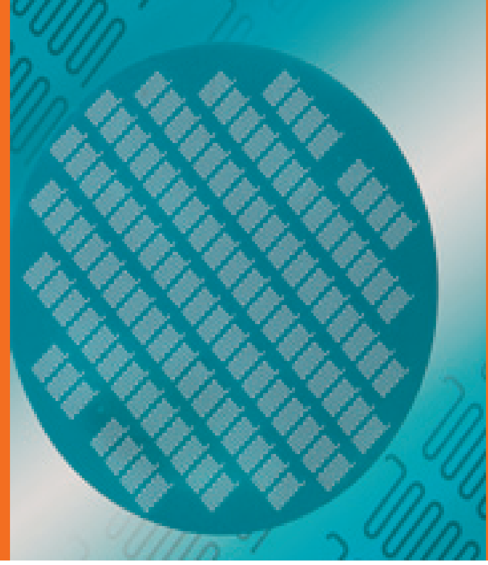


Figure 3: Silicon wafer with "on-chip" porous separation columns

Figure 4: Chromatography chip with hermetically sealed column structure

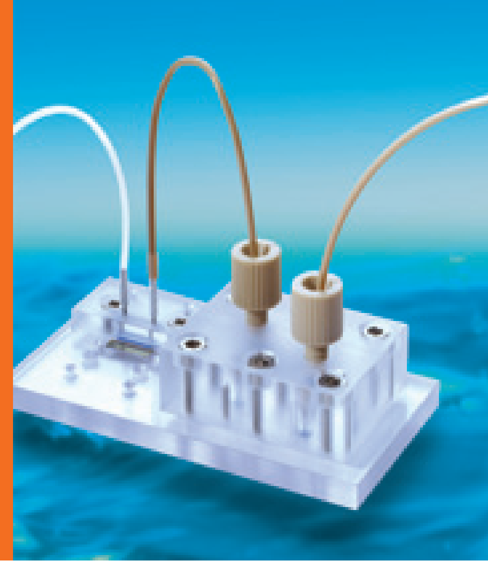


Figure 5: Cartridge for chromatography chip with fluidic connectors

Project targets

Our aim at Fraunhofer ISIT is to miniaturize liquid chromatography, and especially HPLC technology, for fast, flexible and portable applications. The development is carried out on 8"-wafers with processes based on Silicon- and micro system technology. It is envisaged to shrink the system down to handheld size, including the chip together with a cartridge containing further fluidic function elements and the electric connection.

Essential parts of the concept and the development are:

1. Integration of a three-dimensional porous separation column on wafer level,
2. Micro-electrodes for electrochemical detection of separated analyte peaks,
3. Hermetic, high-pressure resistant chip bonding,
4. Cartridge for chip packaging, fluidic and electric connection,
5. Fluidic environment providing high pressure pumps and sample uptake,
6. Electronics and software for system control and data evaluation.

The miniaturized high-pressure pump will be integrated in a later project phase.

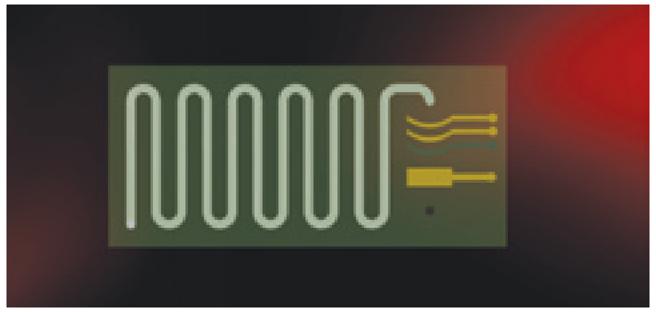


Figure 2: Construction scheme of chromatography chip

Design and Results

As a first step, the chip design was carried out. All processes will be done on wafer level, which means that the single chromatography chips are separated finally by dicing the fully processed wafers.

The final chip consists of two wafers, the bottom level containing the porous column ("column wafer") and the upper one for capping the column wafer ("cap wafer"). The cap wafer equally carries the electrodes for the on-line electrochemical detection. A construction scheme of the chromatography chip is shown in figure 2.

The column wafer process starts by dry etching the outer column structures into a 8"-Silicon wafer. Afterwards, a tight three-dimensional porous structure is filled into the etched meander-shaped cavity (see figure 3).

The cap wafer is made of Borofloat® glass. Into this wafer, holes for the later fluidic connections to the separation column are drilled. The hermetically tight sealing of the columns by the cap wafer is ensured by glass frit bonding. Figure 4 shows a fully processed chromatography chip of 10 x 20 mm^2 size after wafer dicing.

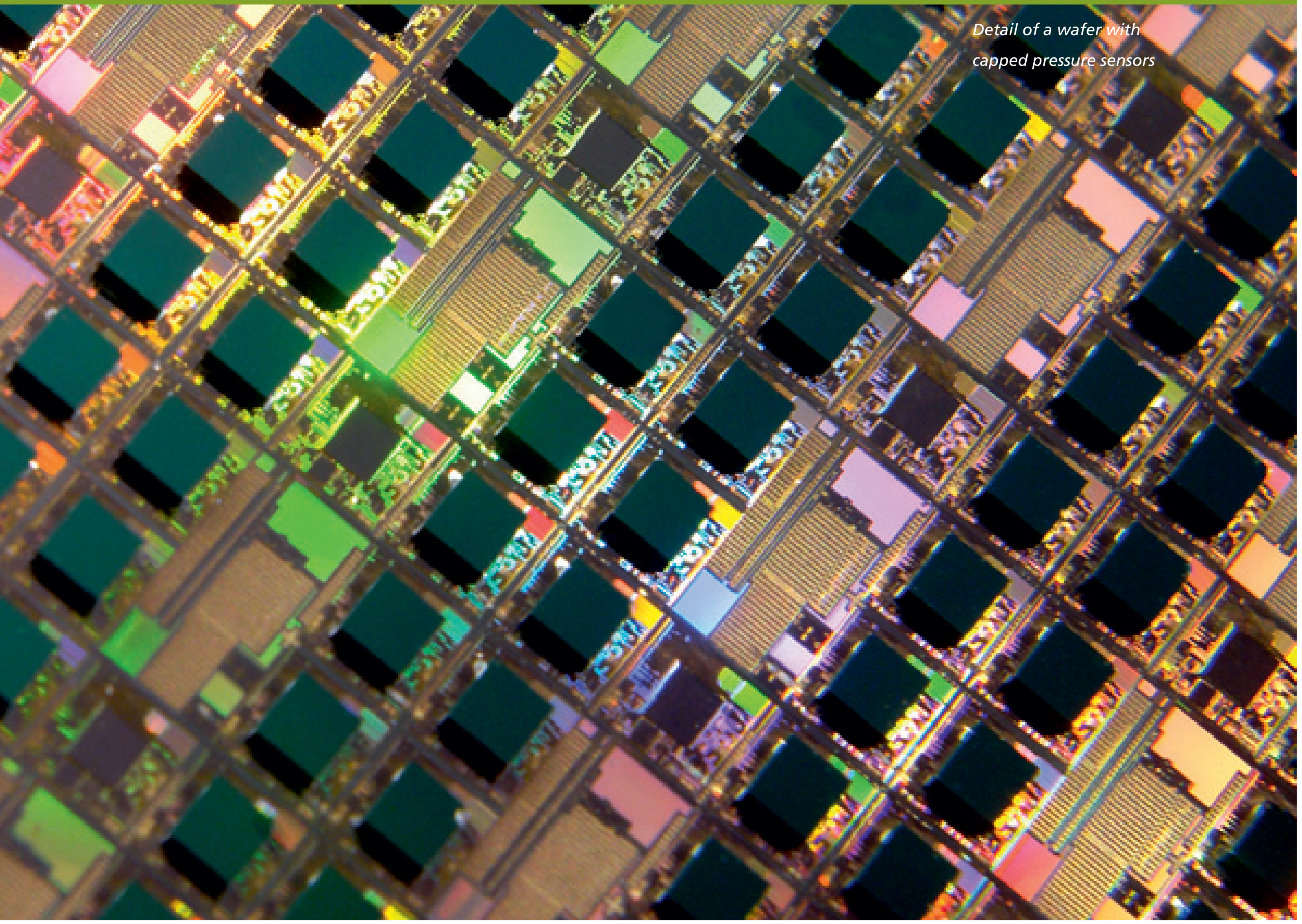
The process of noble metal vaporization for the electrodes was not yet included in this project phase. To carry out the detection, a second chip is therefore placed behind the chromatography chip and a cartridge was designed for this two chip arrangement. The fluidic connectors are classical HPLC fittings for high pressure connection. A photo of the constructed two chip cartridge and flow-through detector cell is shown in figure 5.

As a second detection chip, seen on the right side in the cartridge, we use our array biochip. This chip is provided with sixteen Gold working electrodes, a Gold counter electrode and an Iridium oxide reference electrode. Here, only a subset of the available working electrodes is needed for amperometric detection.

Next important steps in this project are the silanization of the column surface with C18-strands, functionalizing the column for reversed-phase chromatography, and to evaluate the system in comparison to established laboratory equipment.

Authors: Lars Blohm, Dr. Gundula Piechotta

MODULE INTEGRATION



Detail of a wafer with capped pressure sensors

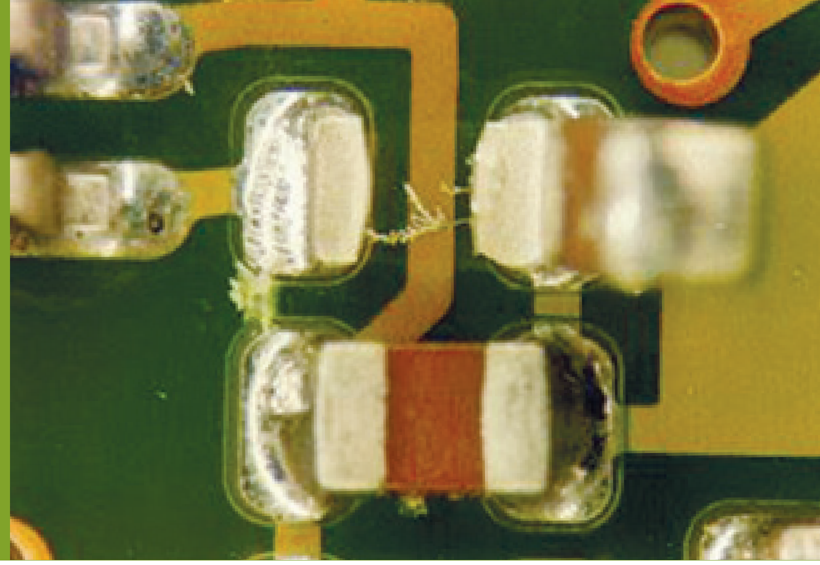


Figure 2: Short circuit beneath a ceramic capacitor

SURFACE INSULATION RESISTANCE (SIR) MEASUREMENT OF JETTED SOLDER PASTE

Introduction

Electronic assemblies grow more and more complex. The need to integrate increasingly functions into even smaller systems reduces the isolation distances in such a way that the risk of electrochemical corrosion increases critically. Climatic conditions such as high temperatures and humidity as well as temperature changes, which can lead to condensation, often have a damaging effect on the operation of electronic assemblies.

The interaction of moisture, different electrical potential and ionic contamination may lead to corrosion and electrochemical migration (figure 1). In particular, residues of fluxes, which are typically left on the circuit board surface and components after soldering, are often hygroscopic and thus promote electrochemical migration or corrosion. The result is reduced isolation resistance on the circuit board surface that might cause short circuits and ultimately leads to irreversible damage to the system, as shown in figure 2.

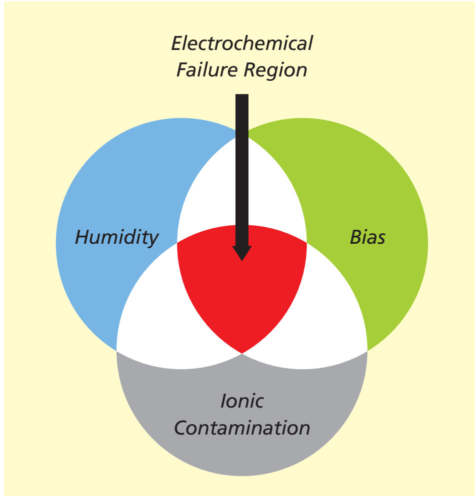


Figure 1: Electrochemical Failure Region (IPC-9201a-1-1)

The target of electronic assembly production is to produce acceptable soldering quality. To achieve this, it is important to apply to each single joint the correct amount of solder paste. In case of closely adjacent component terminations with greatly different requirement of solder paste volume, this presents a big challenge for solder paste application. Additive solder paste deposition might be necessary. This additional solder paste can be very effectively applied by use of jet printing. However, the question arises whether the mix of various fluxes (printed and jetted solder paste flux) is harmful.

Here, SIR test results of an investigation of flux mixtures are presented. Solder paste is applied first by stencil printing, then necessary additional solder paste is jetted. An interesting aspect in this case is that both solder pastes are delivered by different manufacturers and thus even have different flux mixtures. Both considered alone are so-called "No Clean" products, but what happens when the two fluxes are mixed and reflow-soldered?

Implementation

The Surface Insulation Resistance (SIR) Test is a method to characterize fluxes by determining the degradation of electrical insulation resistance of rigid printed wiring board specimens in the presence of moisture. The test is carried out according to IPC J-STD-004B referring to IPC-TM-650 2.6.3.3 (Surface Insulation Resistance, Fluxes) on standardized comb test patterns according IPC-B-24 (Surface Insulation Resistance Test Board), where an individual comb structure has defined lines and spacing. The solder paste is stencil-printed first and then additional solder paste volume is jetted onto the test board consisting of FR-4 epoxy-glass laminate material.

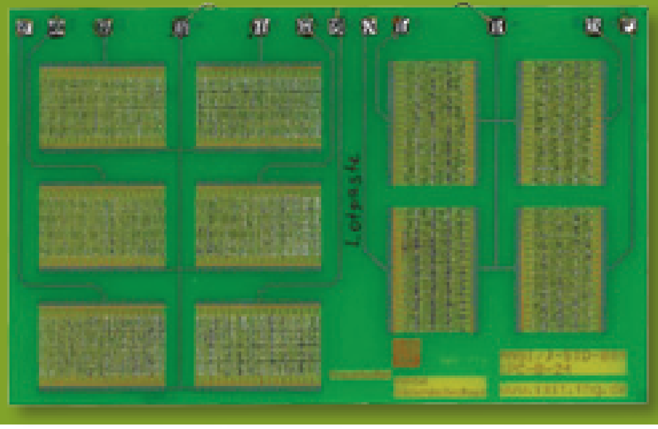


Figure 3: PCB with soldered comb structures according to IPC-B-24

The samples run through a reflow soldering process using a lead free SnAgCu temperature profile with a peak temperature of 245° C. This reflow profile can be individually adapted on customer request. The SIR Test is carried out at high humidity (85 % rh) and heat (85° C) conditions for 168 hours. A voltage of 100 V is applied to the comb structures and the resistance is measured at regular intervals.

Different types of solder pastes and mixtures thereof are examined with respect to their surface resistance. Figure 3 shows a test board with soldered test structures. As a reference, a printed circuit board with empty combs is also measured (figure 4). The graphs in figures 5 to 7 show an example of the measured surface resistance of the different solder pastes and their combinations specified by the time.

Evaluation and error condition

Each comb pattern on each test PCB has been evaluated by the insulation resistance values during the climate testing. If the readings at the end of the measurement period are less than 100 megohm (1E8 ohm), the test is evaluated as fail.

All specimens have been examined optically within 24 hours of completing the testing. Visible discoloration, corrosion or dendritic growth, which will constitute a failure, have been reported.

Conclusion

The measured curve in figure 4 shows that the empty comb has almost 2 orders of magnitude higher resistance values (1E10 Ohm) than required. In all the samples, a reduction of the surface resistance compared to the blank comb can be seen. There are slight uncritical differences in resistance between the solder pastes. The mixtures provide no negative effects and the measured surface isolation resistances are in the range of the base materials. All investigated solder pastes and mixtures thereof show sufficiently good SIR test results. Complying with all tested combinations however, the limit of 100 megohm is safe.

This study covers only a small number of possible combinations of flux materials. Additional combinations should be tested if needed. The question of the flux behavior in case of repair process remains unanswered: What will happen if flux or mixtures of fluxes are heated up to undefined temperature time profiles? Ionic contamination could remain on the PCB surface and lead to corrosion and migration. This question is part of an actual investigation project; please feel free to contact Fraunhofer ISIT for further information.

Author: Helge Schimanski

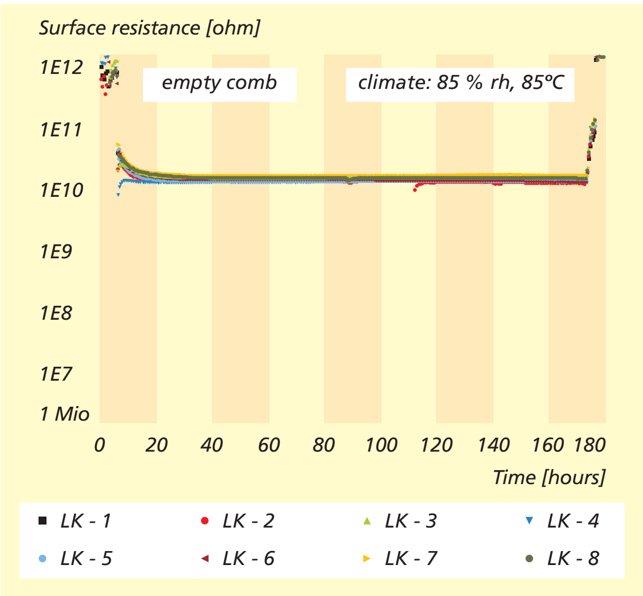


Figure 4: SIR measurement of the empty combs

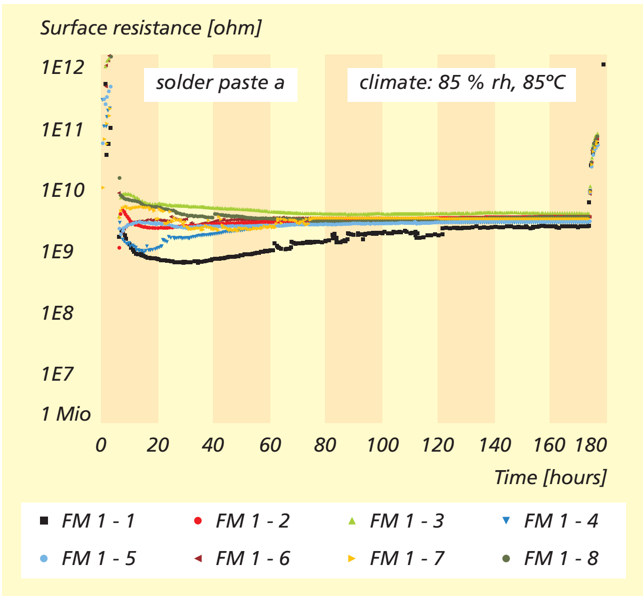


Figure 5: SIR measurement using solder paste A

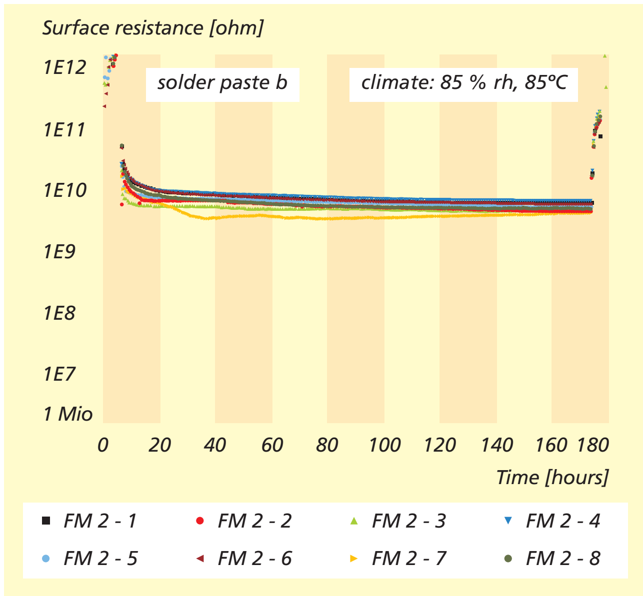


Figure 6: SIR measurement using solder paste B

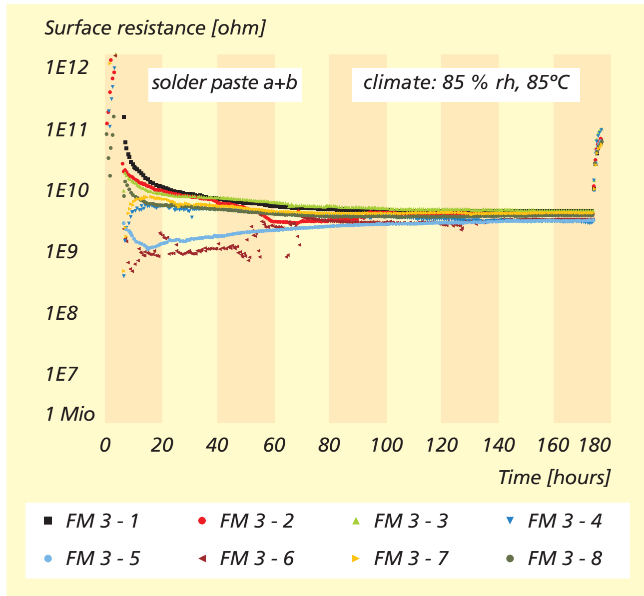


Figure 7: SIR measurement using combination of solder paste A + B

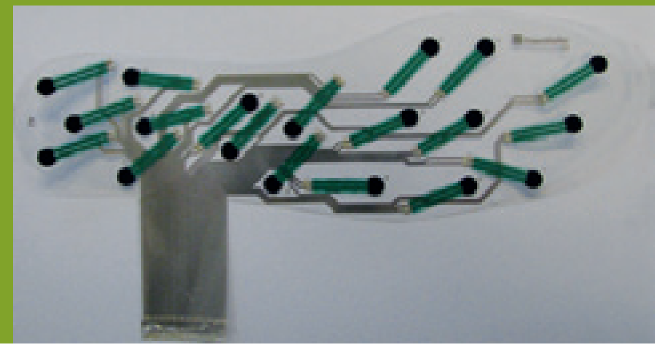


Figure 3: PET foil with inkjet-printed lines and assembled foil force sensors. For sensor protection and to obtain a smoothing effect, this sensor matrix will be embedded between two textile sheets.

"AKUSTISCHE GANGANALYSE": ACOUSTIC GAIT ANALYSIS WITH FLEXIBLE SENSOR INLAYS

Obtaining biofeedback during body motion by sensing, measuring and visualization of health parameters like heart rate, temperature or blood composition has been a valuable tool for health monitoring for many years. However, an "acoustic" feedback by the sonification of motion parameters is quite new and has only recently been tested with success for motion sequence improvement in competitive rowing sports, namely with the German Olympic rowing team.

Sonification means the use of non-speech audio to convey information obtained from measured data. Acoustic feedback is particularly effective due to the specific properties of the human auditory system, which is extremely sensitive to time-dynamic aspects and to subtle temporal characteristics of events. At the same time, multiple information streams are perceivable simultaneously while executing the movement. With their ability to recognize and categorize events, human beings generally get used to repetitive similar acoustic signals; even very complex patterns are received unconsciously after a while, which avoids distraction of the actual activity. In contrast, changes in the sound pattern (e.g. if the sound suddenly increases, decreases or fades away) immediately and reliably guide the listener's focus of attention.

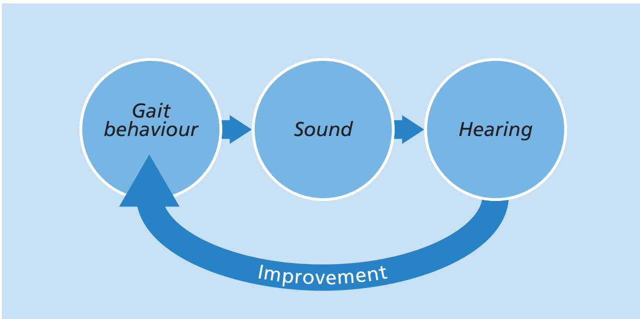
As schematically shown in figure 1, a feedback loop can provide specific acoustic information about the gait behaviour to the walking person, who, by hearing the motion-related sound pattern, relates individual "sections" of the electronically encoded signal to his or her muscular activities – just by perceiving the sound as a whole.

Sonification in Acoustic Gait Analysis

The project Acoustic Gait Analysis ("Akustische Ganganalyse") targets the development of a functional shoe inlay for the sonification of the gait and running behavior. By measuring the plantar pressure distribution, the optimization of motion processes can prevent injuries, provides assistance in rehabilitation after disease, and helps improving performance in leisure and competitive sports. Moreover, it is suited to monitor changes in standing or walking behavior, e.g. of elderly persons or patients suffering from nervous diseases.

The consortium of the project "Akustische Ganganalyse" consists of 8 partners, as shown in figure 2. Fraunhofer ISIT's work packages comprise the development and demonstration of a stretchable sole inlay with an integrated force sensor matrix and printed lines, moreover the evaluation of different sensor principles (e.g. resistive measurement by foil force sensors or by strain gauges) and also the manufacturing and implantation of flat, bendable Lithium-polymer accumulator cells in the inlay. Finally, ISIT will stress the inlays, perform reliability analysis and provide the data management.

Figure 1: Principle of acoustic feedback of gait behaviour



In the project course, two inlay prototypes will be developed and produced: A first cable-based, bendable pressure sensor inlay with discrete periphery (electronics, energy supply), simple data management and analysis after WLAN data transfer has already been created (figures 3 and 4).
This basic system will allow a comparison with already available devices for measuring plantar pressure distributions, e.g. a treadmill. It will also serve the project partners as a first tool for the acquisition of data, for sonification and for first feedback tests with human probands.

The first functional inlay consists of 19 foil-based pressure sensors, arranged individually or in groups that represent previously defined foot zones. The knowledge of the plantar pressure distribution in these zones is crucial for medical gait analysis and evaluation. However, the sensors have limited circular sensing areas with diameters of 7 mm and some millimetres distance in between.

Figure 2: Project consortium

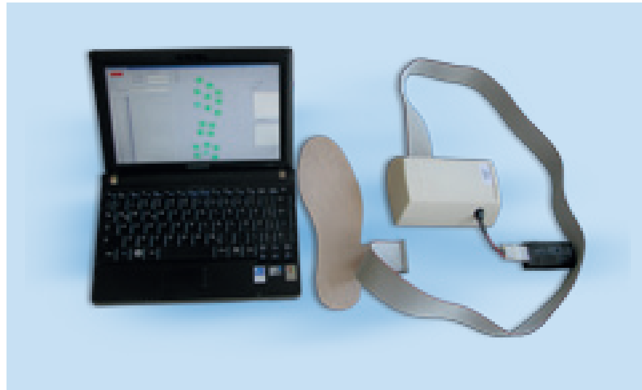


Figure 4: System of a shoe inlay (light brown), electronics (grey box), and a PC with WLAN connection

Patient feet topographies vary to a wide extend, thus force measurements with this prototype can only approximate the real pressure distribution. Consequently the second inlay version will cover the whole plantar area with sensors only spaced by small, non-conductive gaps.

Design of a foil-based pressure sensor matrix

First, pressure or force sensing is realized by flexible, commercially available sensors based on a resistive measurement principle. In detail, the sensor consists of two air-spaced membranes – one is area-conductive and consisting of carbon containing polymer, the other one is made of a plastic foil with metallic interdigital structures on its lower surface. Depending on the external perpendicular force amplitude, the carbonized surface is more or less covered by the interdigital

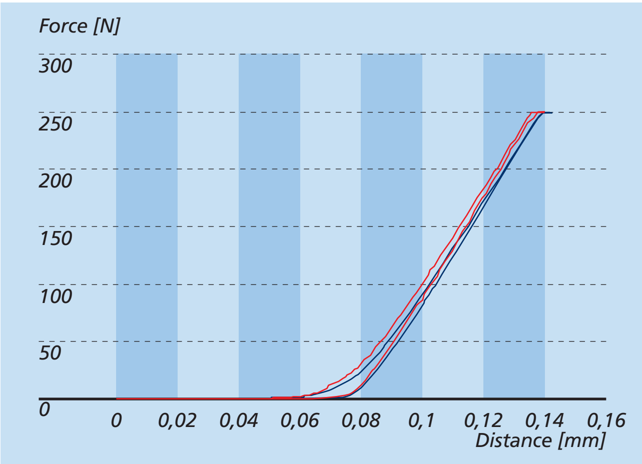


Figure 5: Force-distance measurements with foil sensor. There is a significant difference between the two time-spaced curves; hysteresis and nonlinear effects occur especially at low forces

structures, resulting in a lower or higher electrical resistance between them. This resistance can be calibrated to obtain a force-voltage relationship, which is however not linear and shows a slight hysteresis (figure 5). Measurements are time- and temperature dependent, and the sensor itself suffers from mechanical shear forces. Therefore, this approach is limited to the first inlay prototype. Although some acceptable measurements of relative pressure distributions have been achieved (figure 6), the evaluation of well-suited sensor types for the second and final prototypes requires further investigation. Beyond others, e.g. strain measurement gauges on foil, small MEMS capacitive sensors or electroactive polymers are potential candidates.

The second prototype, planned after 24 months, will be consisting of a stretchable force sensor inlay and an additional sole where functional components like electronics, NFC antenna, Lithium-polymer cells and the power- and data interface will be implemented. The stretchability of the sensor inlay enables its homogeneous covering of the topographic functional inlay surface. A schematic setup is shown in figure 7. It will provide extensive high-rate (100 Hz) data acquisition and

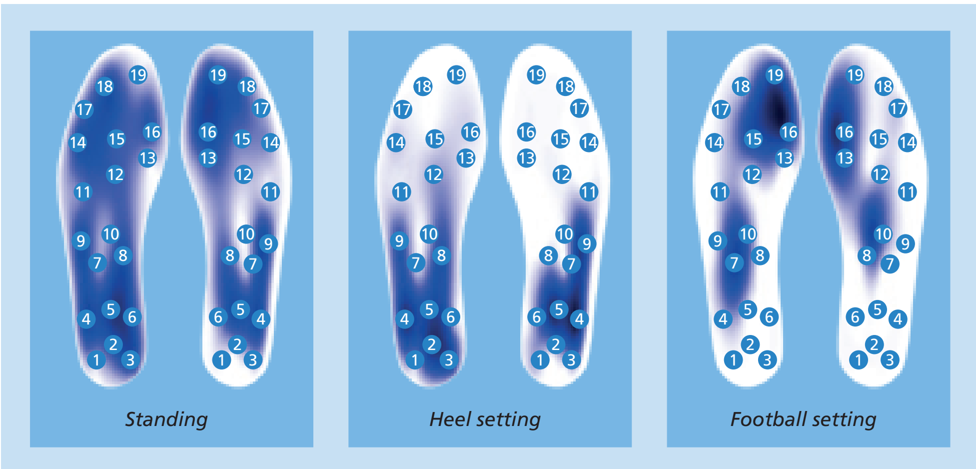


Figure 6: Graphical visualization of the relative foot pressure distribution. Standing person (left); Walking, heel setting (center) and Walking, foot ball setting (right). Dark blue means high pressure. The numbered circles represent sensor positions and areas.

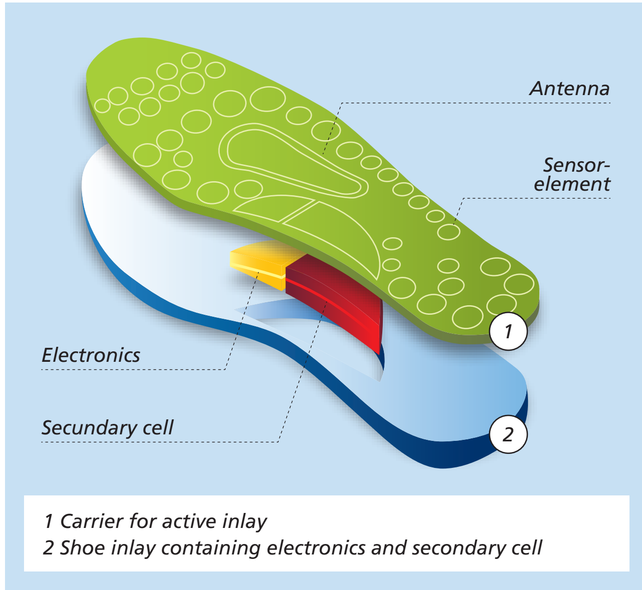


Figure 7: Schematic inlay construction of second prototype with stretchable sensor matrix and functional sole inlay

-analysis for clinical field tests. Data transfer will be supported by cable for real-time processing on a medical computer and by a wireless interface for visualization on a smartphone.

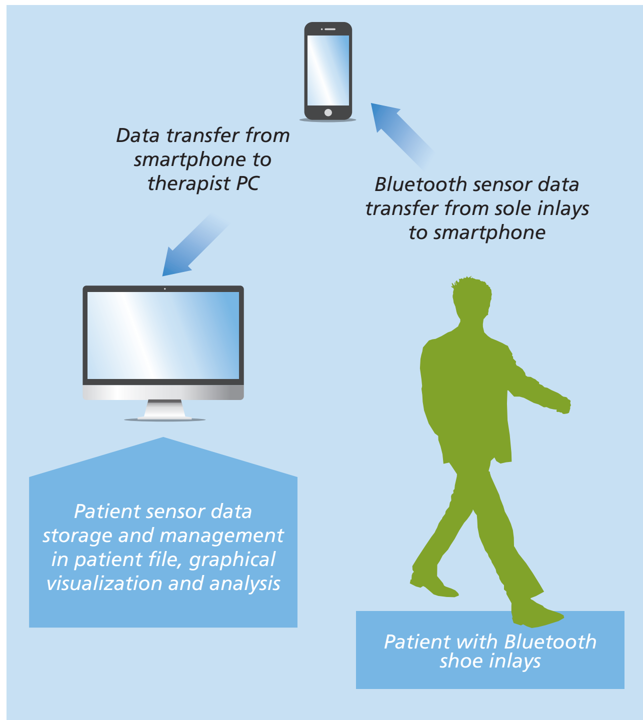
The final product including the second, stretchable prototype inlay will be available in two versions, mainly distinguished by measurable and analysed parameters, i.e. by different embedded software versions: One will be developed for private use, e.g. for leisure sports or personal health monitoring. With about 100 €, this version will be affordable to private persons. The second version will be developed for professional use under medical observation, e.g. for disease treatment after injuries or serious illness, with a price target up to 400 €.

Project data

- Project coordinator: Fraunhofer ISIT
- Consortium: 8 partners (see figure 3)
- Project duration: 3 years (11/2013 – 10/2016)
- Grant: 1.6 million €
- Funded by the German Federal Ministry for Economic Affairs and Energy (BMWi) in the ZIM innovation programme for small and medium enterprises.

Author: Dr. Thomas Knieling

Figure 8: Data transfer of the foot pressure distribution between patient inlay, smartphone and therapist PC



HERMETIC ENCAPSULATION OF MEMS AT LOW TEMPERATURE

For many cost-sensitive MEMS sensors and actuators, metallic vacuum sealing on wafer level is an enabler for the industrialization. Within the last years, ISIT provided continuous efforts in developing suitable technologies for various applications. This know how has found large interest on the customers' side. Especially the hermetic housing of micro sensors with defined vacuum is a critical key technology, but even when performed on the wafer level it remains quite costly. Depending on the material system, bonding temperatures range up to 435 °C, which limits the joining to substrate materials with exactly the same coefficient of thermal expansion (CTE). The process time is typically in the range of 2 hours, partially caused by slow cooling. This generates a drastically lower machine throughput compared to other MEMS processing steps. In addition, high process temperatures may degrade metallic microstructures within switches, mirrors etc.

The German AiF project ("Arbeitsgemeinschaft industrieller Forschungseinrichtungen") REMTEC investigates an alternative approach to produce metallic seals in a much faster process, applicable also for joining substrates with dissimilar CTE.

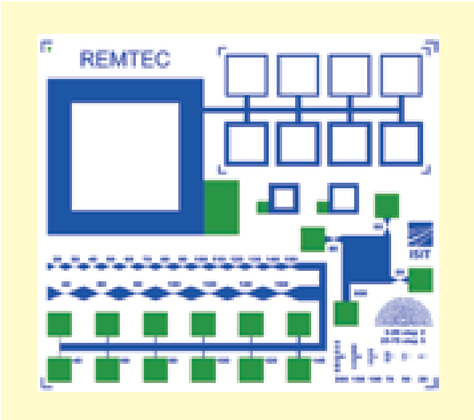


Figure 2: Layout of the test coupon

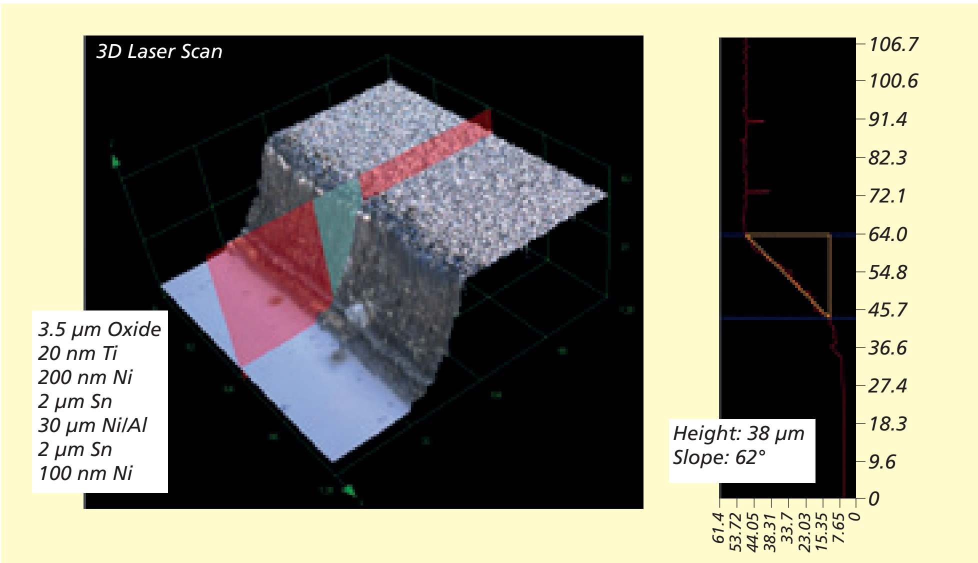


Figure 1: 3D detail of an etched Ni-Al RMS stack with 62° slope

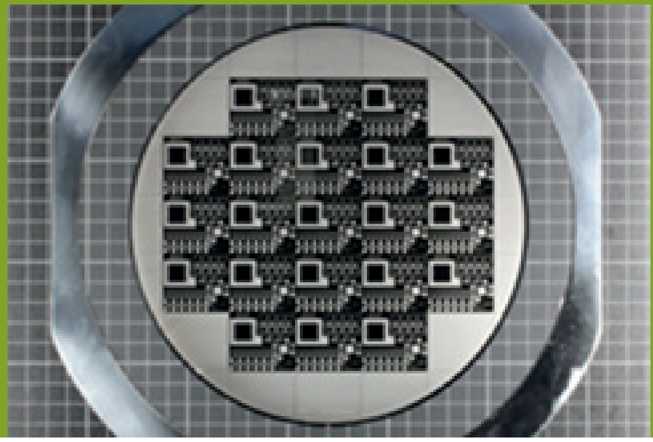


Figure 3: Structured test-coupon wafer for ignition experiments

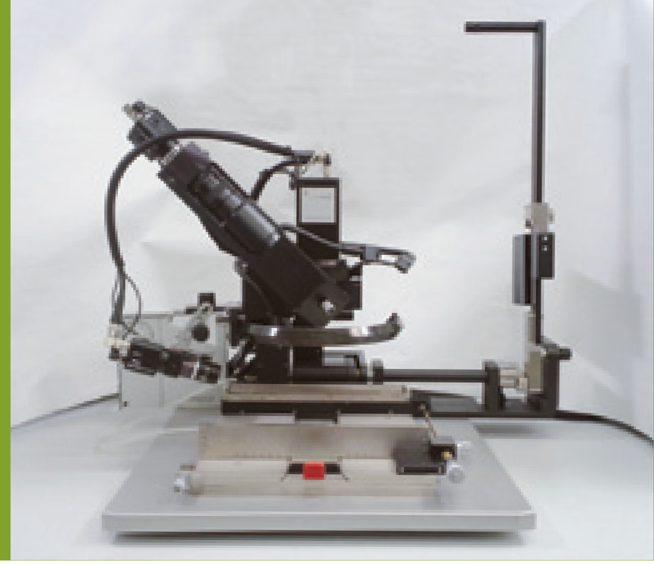


Figure 4: Fineplacer® pico with high bond force upgrade

Bonding with Reactive Metal Nanolayers

The technology is based on stacks of metal nanolayers that can react exothermally to form intermetallic phase compounds. The reactive nanolayer metal stack (RMS) is built from a sequence of ca. 2000 sputtered Nickel-Vanadium / Aluminum layers, each about 20 nm thin. The stack ends with a 200 nm thick Nickel-Vanadium layer and a 3 µm thick Tin layer as joining material. A buried Tin layer forms the lower end of the stack. ISIT develops two structuring technologies, a wet-chemical etching and a lift-off, for this complex layer system. A chemical etching recipe needs to tune the etch rates of Nickel and Aluminum to be about equal. The etchant also structures the Tin layers, see figure 1.

The structuring process has been developed on test coupons, see figure 2. The transfer to full wafer scale, a requirement to demonstrate an industrial feasibility, was achieved in the following step. Transferring the etch process to an automatic spin etcher will be the next challenge. This structuring method limits the feature resolution to about 100 µm. A lift-off process is the alternative process to increase the feature resolution to around 40 µm. The test coupon is now being used as a platform to investigate the RMS material system Titanium / Silicon, a higher energetic system.

Reactive multilayer stacks (RMS) heat up during the exothermic intermetallic phase formation. The reaction is controlled by diffusion and accelerates with the temperature of the RMS; lateral reaction propagation with 5 to 75 m/s was measured, depending on the material system.

To keep the reaction heat within the RMS stack, a thermal insulation layer is deposited on the substrate below the stack. ISIT showed that a 3,5 µm thick thermal SiO_2 layer efficiently fulfils this purpose. Processing the RMS in a cleanroom is difficult, as the reaction can be started by mechanical impact and wafer fracture. Even wafer dicing through the unreacted RMS generates a risk of ignition. Fraunhofer IWS has found a way to reduce this risk by diffusion barriers built into the RMS stack, allowing to keep control of unintended activation.

The stability of the reaction is investigated with test coupons to develop design rules and to evaluate different RMS stacks. A 20 µm narrow RMS line is able to couple the reaction front from one seal frame to the next. For longer distances, a line width of 120 to 160 µm is recommended.

Ignition of the active layers

ISIT has investigated the reaction start based on the ignition structures available on the test coupon design shown in figure 2 (green areas). The processed wafer is shown in figure 3. The electrical ignition itself is found to be unproblematic and integration into existing wafer bonders is feasible. A small short-circuit spark is sufficient to generate enough heat in a local spot to ignite the RMS. Alternatively, a laser pulse may be applied.

Bonding Tests: Conditions and Results

First studies of the joining characteristics have shown that vertical pressure on the joining partners is required to achieve a good solder connection based on RMS. Standard die attach bonders are usually not capable to apply these forces. ISIT has invested into a high-force upgrade of the available Fineplacer®, see figure 4. In tests, solder joints were obtained, but x-ray and cross section analysis indicate fractures in the RMS, see figure 5. The fractures are caused by volume shrink of the RMS during formation of intermetallic phases. The consumed RMS is wetted with Tin, but it is not yet clear whether all of the fractures are wetted and sealed by Tin. The Tin layer thickness may need to be increased and a slight substrate heating may improve the joint quality.

The next test vehicles will be glass caps with integrated corrosion-sensitive structures to assess the joint hermeticity.

Author: Dr. Wolfgang Reinert

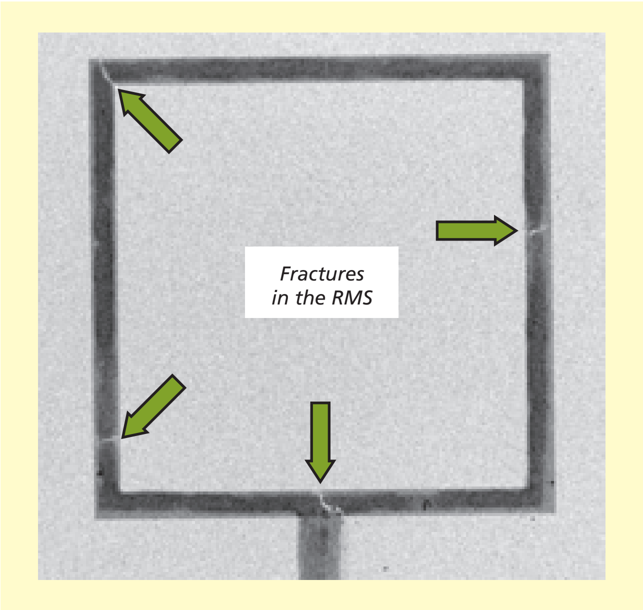
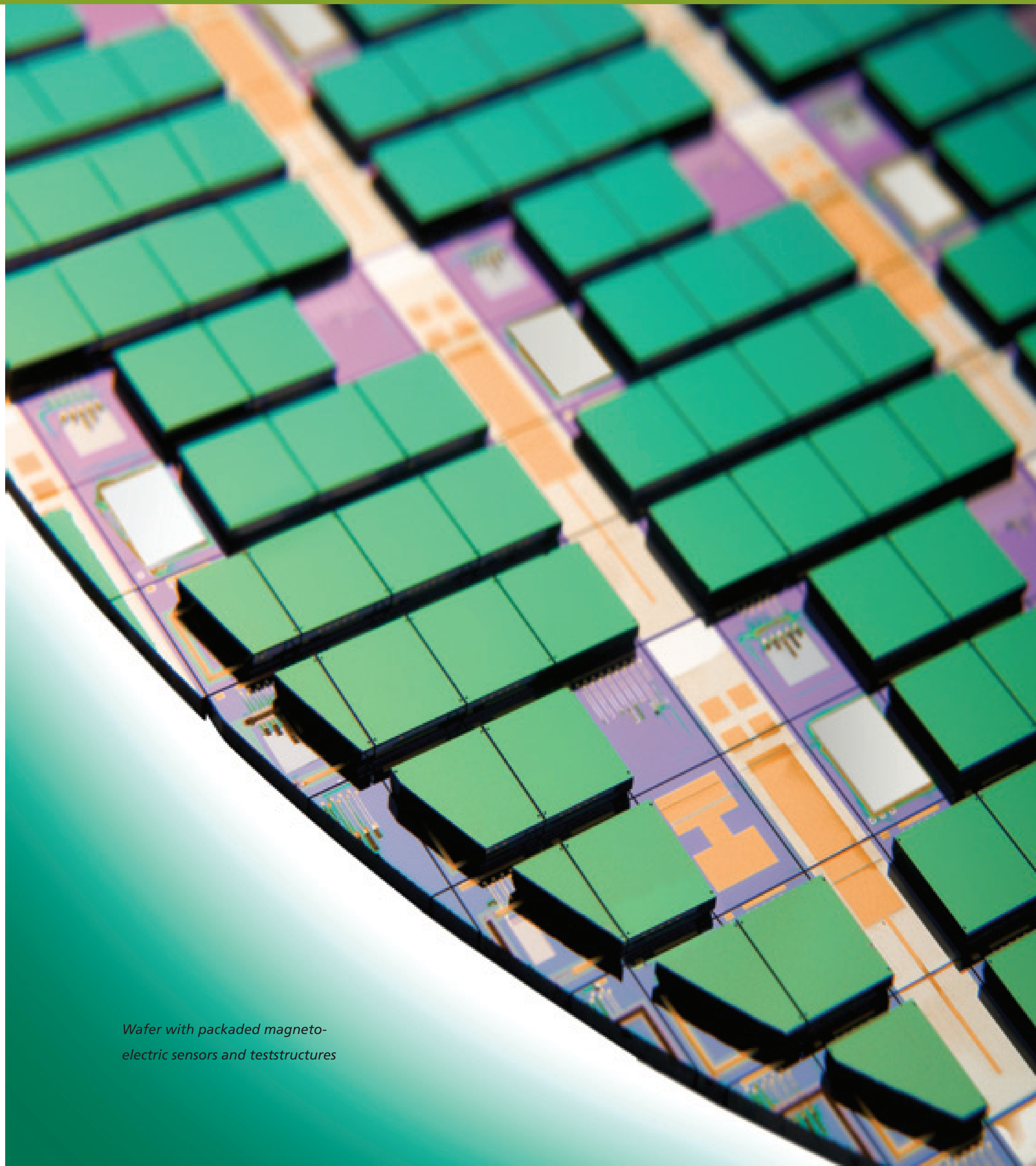


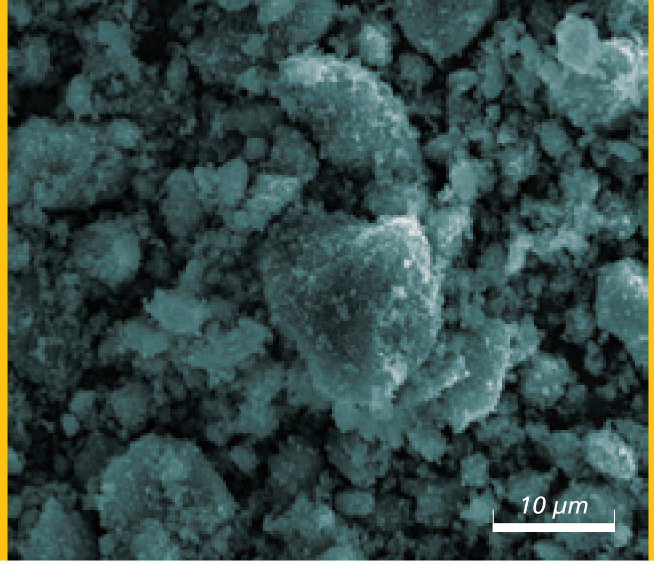
Figure 5: X-ray picture of a frame sealed by RMS soldering



Wafer with packaded magneto-electric sensors and teststructures

INTEGRATED POWER SYSTEMS

Manufacturing of electrode foils at the ISIT coater



Scanning electron microscopy of Lithium Titanate active materials

TAILWIND BY INNOVATIVE LITHIUM-ION TECHNOLOGY MADE BY ISIT

A couple of years ago, electrified bicycles were mostly used by senior citizens. Nowadays, the market as well as the utilization of electrify bicycles has changed and includes also commuters, couriers and ambitious athletes: So-called "pedelecs" support the cyclist with an electric motor and hence increase the individual cruising radius. The high economic growth observed for these vehicles is not surprising: They enable individual transportation at low cost while decreasing traffic density and thus contributing to the reduction of emission and noise pollution, especially in regional conurbations. And… it's fun to ride a pedelec!

Most of the commercially available pedelecs are more or less classical bicycles equipped with an additional electric engine. In particular the commonly used Lithium-ion accumulators give cause of concern. In spite of their high price, these accumulators had a short lifetime and, even worse, sometimes they had a serious safety gap, up to cells catching fire.

On this background, a cooperation of ISIT and other Fraunhofer-Institutes with several medium-sized companies and universities targeted the development of a novel pedelec prototype called "Velocite". The project was funded within the framework of the German governmental funding programme „Schlüsseltechnologien für die Elektromobilität (STROM)". The Velocite prototype features technical innovations like a lightweight carbon fiber construction, a novel electric engine concept and an intelligent control system. The most important component is an intrinsic safe and durable Lithium-ion battery, combined with an outstanding design specifically aiming for sportive, ecology-conscious and technophile customers.

Within the "Velocite" project, ISIT developed a Lithium-ion battery based on Lithium Iron Phosphate (LFP) and Lithium Titanate (LTO). This chemistry shows a significantly higher safety level for the whole bicycle lifetime of more than 10 years. The battery is able to power a 500 W electric motor, sufficient to attain a maximum velocity of 45 km/h.

It's a challenge to accommodate all features in the limited space of a bicycle frame, like storing enough energy for a sufficient cruising range while providing the aspired high power of the battery. Combining high energy density with high power capability is always a trade-off in the battery design that has to be adjusted for the individual requirements of the anticipated vehicle operation profile.

The fundamental components of a cell are the electrodes. These are defined on one hand by the active material and on the other hand by the production and process parameters.

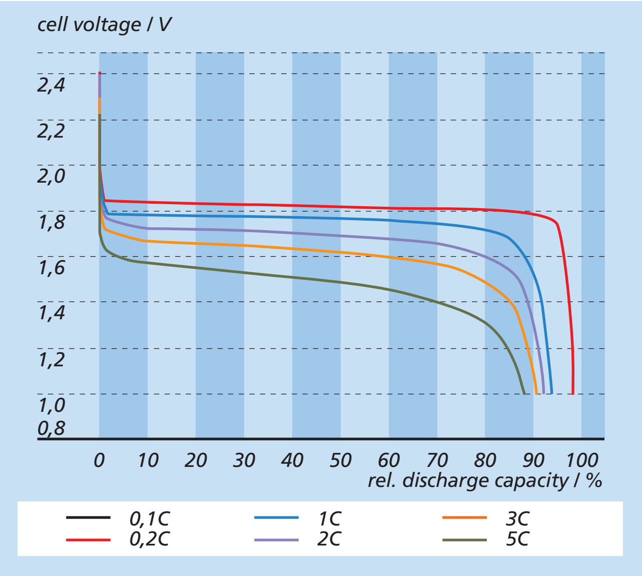


Figure 2: Discharge behavior of a LFP/LTO cell (1.05 Ah) at 20 °C

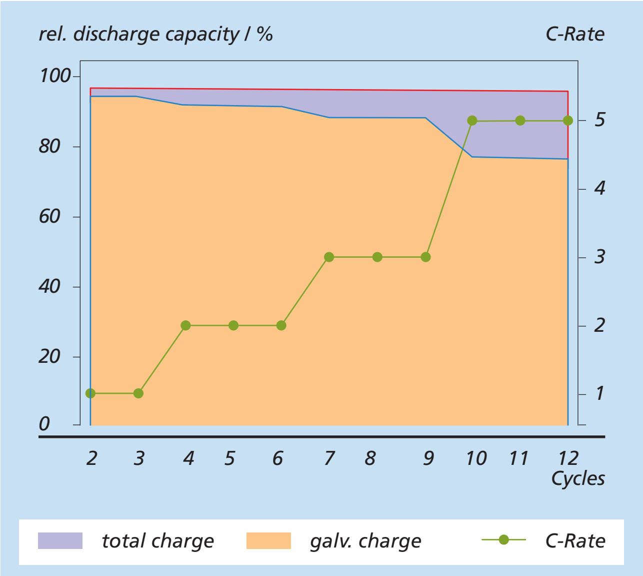


Figure 3: Charge behavior of a LFP/LTO cell (1.05 Ah) at 20 °C

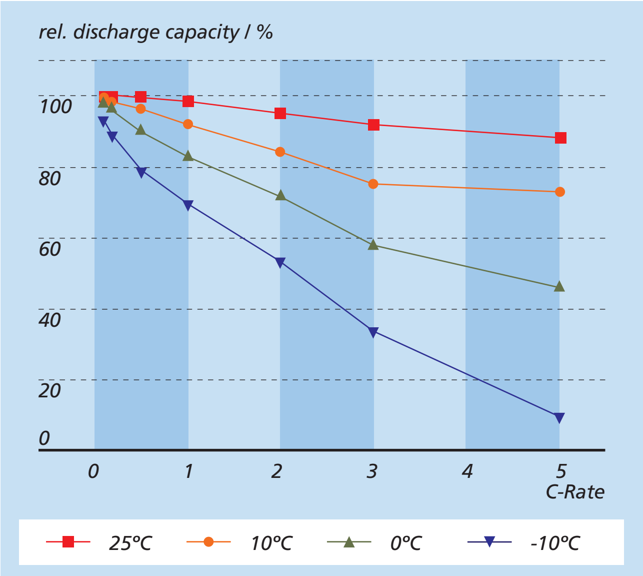


Figure 4: Temperature dependent rate capability of a LFP/LTO cell (1.05 Ah)

Both factors had to be optimized to enable a fast electrode kinetic for the multitude of different charge/discharge situations occurring in real operation. For the "Velocite" application, Lithium Titanate was chosen as anode material, which applies the required high mass loading in combination with a very well-performing charge and discharge behavior (figure 1). The discharge behavior of a cell with a mass load of 2.0 mAh/cm² is shown in figure 2. The very flat shape of the discharge curve is typical for a two phase system. At low to medium currents, the mean cell voltage is around 1.8 V and delivers at a 5C current round about 90 % of the nominal capacity, which signifies that even at high power requests the battery had enough capacity for a decent cruising range. Since the charging time considerably depends on the so-called constant current (CC) phase, in which the cell is charged by a (high) constant current, this measure indicates quite well the charging behavior of an accumulator. Figure 3 exhibits the charge behavior of the "Velocite" cell: Within 12 minutes (=5C), the cell is charged to 80 % of its nominal capacity. A high charging capability is also important for energy recuperation during braking.

Certainly, the electrical drive should also support the cyclist in winter time: Most of the common Lithium-ion cells are limited in performance at temperatures below 10°C. By optimizing the electrolyte, the usable temperature range of the cell was successfully extended down to -10 °C. Figure 4 shows that, at this temperature, 70% of the usable capacity is available up to a 1C discharge rate. To conclude, ISIT successfully developed an intrinsically safe, long-lasting Lithium-ion cell for the very demanding application in a modern and powerful pedelec.

Author: Dr. Hans-Gerhard Bremes

IMPORTANT NAMES, DATA, EVENTS

IMPORTANT NAMES, DATA, EVENTS

LECTURING ASSIGNMENTS AT UNIVERSITIES

W. Benecke
Lehrstuhl Technologie Silizium-basierter Mikro- und Nanosysteme, Technische Fakultät, Christian-Albrechts-Universität, Kiel

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H. Kapels
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O. Schwarzelbach
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MEMBERSHIPS IN COORDINATION BOARDS AND COMMITTEES

W. Benecke
Member of programming committees of:
- *IEDM (International Electron Devices Meeting)*
- *EUROSENSORS*
- *ESSDERC (European Solid-State Device Conference)*
- *ESSCIRC (European Solid-State Circuits Conference*
- *MST Kongress*

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Member of Editorial Boards
- *'Sensors & Actuators'*
- *Microsystem Technologies (MST)*

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D. Friedrich
Coordinator of Innovationscluster für regenerative Energieversorgung Schleswig-Holstein

P. Gulde
Member of Allianz Energie of the Fraunhofer-Gesellschaft

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Nanotechnik S-H

D. Kähler
OE A (VDMA)

T. Knieling
Member of Organic Electronics Association (OE-A)

T. Knieling
Member of Gesellschaft für Korrosionsschutz (GfKorr)

T. Knieling
Member of ZVEI – AK Zuverlässigkeit von Leiterplatten

T. Knieling
Member of Netzwerk organische Elektronik Nord

T. Knieling
Member of IEC: TC 119 „Printed Electronics"/DKE/ GUK 682.1 "Gedruckte Elektronik"

T. Knieling
Member of Arbeitskreis Röntgenprüfverfahren

M. Kontek
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M. Kontek
Member of AG2. 7 Kleben in der Elektronik und Feinwerktechnik

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R. Mörtel
Innovations-Allianz Elektromobilität: National Technology Roadmap Lithium-Ion-Batteries 2030

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K. Pape
Member of FED

K. Pape
Member of VDI

H.-C. Petzold
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M. H. Poech
Member of Arbeitskreis „Systemzuverlässigkeit von Aufbau- und Verbindungs-technologie" des Fraunhofer IZM

W. Reinert
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W. Reinert
Member of „DVS-Fachausschuss Mikroverbindungstechnik"

W. Reinert
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W. Reinert
Member of Technical Committee of Conference Design, Test, Integration and Packaging of MEMS/MOEMS (DTIP)

W. Reinert
Member of FA 10 AVT + Löten

W. Reinert
Member of GMM Workshop Packaging von Mikrosystemen

W. Reinert
Member of ZVEI Arbeitskreis Packaging

W. Reinert
Member of IMAPS Deutschland

K. Reiter
Member of DGM, Arbeitskreis Probenpräparation

K. Reiter
Member of Arbeitskreis Präparation

K. Reiter
Member of Metallographie Nord

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ZVEI Fachverband Arbeitsgruppe „Zuverlässigkeit von Leiterplatten"

H. Schimanski
Member of ZVEI Ad-hoc Arbeitskreis "Repair und Rework von elektronischen Baugruppen"

H. Schimanski
Member of DVS Fachausschuss Löten (FA 10)

H. Schimanski
Member of Hamburger Lötzirkel

H. Schimanski
FED Arbeitskreis „Innovative Baugruppenfertigung"

H. Schimanski
Member of FED Regionalgruppe Hamburg

R. Siegmund
Member of Arbeitskreis Akustikmikroskopie

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Member of AGEF (Arbeitsgemeinschaft Elektrochemischer Forschungsinstitutionen e. V.)

A. Würsig
Member of Bundesverband Energiespeicher (BVES)

A. Würsig
Member of Netzwerk „Elektrochemie" of the Fraunhofer-Gesellschaft

A. Würsig
Member of Kompetenznetzwerk Lithium-Ionen-Batterien (KLiB)

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G. Zwicker
Member of International Executive Committee of International Conference on Planarization / CMP Technology (ICPT)

COOPERATION WITH INSTITUTES AND UNIVERSITIES

RWTH Aachen Universitätsklinik, *Aachen*

Fachhochschule Brandenburg

Technische Universität Braunschweig

Technische Universität Darmstadt

Technische Universität Dresden, Institut für Aufbau- und Verbindungstechnik, *Dresden*

Technische Universität Dresden, Institut für Leichtbau und Kunststofftechnik, *Dresden*

Technische Universität Dresden, Institut für Halbleiter- und Mikrosystemtechnik *Dresden*

Heinrich-Heine-Universität, *Düsseldorf*

Fachhochschule Flensburg

Hochschule für Angewandte Wissenschaften, *Hamburg*

Universität Hamburg

Helmut-Schmidt-Universität *Hamburg*

TU Hamburg Harburg

Gottfried Wilhelm Leibniz Universität, *Hannover*

Fachhochschule Westküste, *Heide*

University of Helsinki

Christian-Albrechts-Universität, *Technische Fakultät, Kiel*

Fachhochschule Kiel

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Universität Ljubljana, *Slowenien*

Fachhochschule Lübeck

University of Naples Frederico II, *Naples, Italy*

Sintef ICT, *Oslo, Norway*

Süddänische Universität, Sonderburg, *Denmark*

VTT, Technical Research Center of Finland, *Tampere, Finland*

Politecnico di Torino, *Italy*

University of Twente, *Netherlands*

HSG-IMIT, *Villingen-Schwenningen*

Fachhochschule Wedel

DISTINCTIONS

M. Gäding
Distinction of being best apprentice as „Mikrotechnologe - Mikrosystemtechnik" at IHK Kiel for which he was awarded by the Fraunhofer-Gesellschaft, München, November 05, 2013

K. Reiter
Buehler Best Paper Award, September 19, 2013, Friedrichshafen, for „How exactly does this work?" – Zielpräparation an mikroelektronischen Bauteilen, Pract. Metallogr. 49, 2012 pp 633–645

TRADE FAIRS AND EXHIBITIONS

11th Bio Partnering North America, *February 24–26, 2013, Vancouver, Canada*

Battery Japan 2013
International Rechargeable Battery Expo, in Cooperation with Fraunhofer Netzwerk Batterien, February 27–March 1, 2013, Tokyo, Japan

nanomicro biz ROBOTECH 2013
International Trade Fair, July 03–05, 2013, Tokyo, Japan

New Energy 2013
International Renewable Energy Trade Fair & Congress, March 21–24, 2013, Husum

Hannover Messe Energy 2013
International Leading Trade Fair for Renewable and Conventional Power Generation, Power Supply, Transmission, Distribution and Storage, April 8–12, 2013, Hannover

SMT/Hybrid/Packaging
Hybrid Packaging System Integration in Micro Electronics,
April 16–18, 2013, Nürnberg

Control 2013
28th Control – International trade fair for quality assurance
May 14 – 17, 2013, Stuttgart

PCIM Europe
International Exhibition & Conference, Power Conversion Intelligent Motion, May 14–16, 2013, Nürnberg

European Lab Automation
June 6–7, 2013, Hamburg

LOPE-C 2013
5th International Conference and Exhibition for the Organic and Printed Electronics Industry
June 11–13, 2013, München

Transducers 2013
International Conference on Solid-State Sensors, Actuators and Microsystems, June 16–20, 2013, Barcelona, Spain

6. Entwicklerforum Akkutechnologien
June 25–27, 2013, Aschaffenburg

AzubIZ 2013
Regional Training Fair, September 13, 2013, Itzehoe

The Battery Show
The Expo for Advanced Batteries
September 16–18, 2013, Novi, Michigan, USA

microtec nord
September 19, 2013, Husum

Battery & Storage 2013
International Trade Fair for Battery and Energy Storage Technologies,
September 30 – October 02, 2013, Stuttgart

Biotechnica 2013
Europe's No. 1 Event for Biotechnology, Life Science and Lab Technology
September 30 – October 02, 2013, Hannover

MST Kongress
October 14 – 16, 2013, Aachen

Nacht des Wissens
November 2, 2013, Hamburg

Productronica 2013
20th International Trade Fair for Innovative Electronics Production
November 12–15, 2013, München

MEDICA 2013
November 20–23, 2013, Düsseldorf

MISCELLANEOUS EVENTS

Aspekte moderner Siliziumtechnologie
Public lectures, monthly presentations, Fraunhofer ISIT, Itzehoe

Die beherrschbare Baugruppenfertigung
Herstellungsqualität, Fehleranalyse und Prozessoptimierung
Seminar: February 19–21 and September 24–26, 2013, Fraunhofer ISIT, Itzehoe

ISIT Presentation in framework of „Macht mit bei Mint – Zukunftsberufe für Frauen"
Information day for schoolgirls, initiated by Volkshochschulen Kreis Steinburg, February 26, 2013, Fraunhofer ISIT, Itzehoe

Lotpastenapplikation
Technologien, Prozessoptimierung, Fehlervermeidung
Seminar: March 4–5 and November 4–5, 2013, Fraunhofer ISIT, Itzehoe

Temperaturmesstechnik
Temperaturmessung richtig durchgeführt
Seminar: March 6 and November 6, 2013, Fraunhofer ISIT, Itzehoe

Reflowprofiloptimierung
Vom Wärmefluss in der Lötanlage zum optimierten Lötprofil
Seminar: March 7 and November 7, 2013, Fraunhofer ISIT, Itzehoe

TECHNET NANO "CUTTING EDGE TECHNOLOGIES"
Microfluidics, Lab-on-Chip-Technologies and Robotic High-Throughput Screening, March 20, 2013, Fraunhofer ISIT, Itzehoe

29. CMP Users Meeting
April 12, 2013, Levitronix GmbH, Zurich, Switzerland

Wellenlöten und Selektivlöten
Technologien, Fehlervermeidung durch Prozessoptimierung, Qualitätsbewertung
Seminar: April 23–24 and December 10–11, 2013, Fraunhofer ISIT, Itzehoe

Kick of meeting Innovationscluster Leistungselektronik für Regenerative Energieversorgung
Speaker: T. Albig, Ministerpräsident of Schleswig-Holstein
May 02, 2013, Fraunhofer ISIT, Itzehoe

Inspektionsverfahren für Elektronikkomponenten und –systeme am Fraunhofer ISIT
Workshop Industrielle Lösungen, June13, 2013, Fraunhofer ISIT, Itzehoe

Information Visit of Dr. Nestlé
Staatssekretärin im Ministerium für Energiewende, Landwirtschaft, Umwelt und ländliche Räume des Landes Schleswig-Holstein
Press conference: September 9, 2013, Fraunhofer ISIT, Itzehoe

30. CMP Users Meeting
October 11, 2013, Technical University Dresden

Gründung gemeinsamer Arbeitsgruppe von Fraunhofer ISIT und Fachhochschule Westküste zur Entwicklung neuer Mensch-Maschine-Schnittstelle
November 15, 2013, Fraunhofer ISIT, Itzehoe

Workshop Innovationscluster Leistungselektronik für Regenerative Energieversorgung
November 26, 2013, Fraunhofer ISIT, Itzehoe

Der optimierte Rework-Prozess
Lernen Sie Ihren Reparaturprozess sicher zu beherrschen
Seminar: November 27–29, 2013, Fraunhofer ISIT, Itzehoe

Battery technologies for electro mobility and smart grid purposes - regional research activities and business development options
Workshop arranged in cooperation between WTSH, Fraunhofer ISIT, the eMOTION project, TINV and Lean Energy Cluster
November 28, 2013, Fraunhofer ISIT, Itzehoe

JOURNAL PAPERS, PUBLICATIONS AND CONTRIBUTIONS TO CONFERENCES

M. Behmüller, M. Weiss, M. Claus, S. Bohse, O. Schwarzelbach, C. Schröder, K. Reimer
Lorentzkraft-basierter MEMS 3D-Magnetfeldsensor für die Integration zu einer 1-Chip 9D IMU.
MST-Kongress, Aachen, October 14.–16. 2013

L. Blohm, G. Piechotta, J. Albers, L.-M. Buchmann, S. Holz, D. Rühmann, E. Nebling
Mikroelektroden und Membranen in Siliziumtechnologie für Bioreaktoren. Poster: 2. Statusseminar Fraunhofer-System-forschung „Zellfreie Bioproduktion“, March 14, 2013

L. Blohm, E. Nebling, G. Melmer
Mobiles Analysesystem für die Point-of-Care-Diagnostik.IVAM-Magazin, Schwerpunkt: Medizintechnik, 18. Jahrgang, Nr. 56, p. 4, November 2013

R.Eisele, M. Becker, A. Hindel, M. Kontek, W. Reinert
Oberseitige Chipverbindungen von Leistungshalbleitern VDI Wissensforum Leistungselektronik, Köln, November 6–7, 2013

M.-D. Gerngross, S. Chemnitz, B. Wagner, J. Carstensen, H. Föll
Ultra-High Aspect Ratio Ni Nanowires in Single-Crystalline InP Membranes as Multiferroic Composite.
Physica Status Solidi (RRL) - Rapid Research Letters, 7, pp. 352–354, 2013

U. Hofmann, J. Janes, V. Stenchly, F. Senger, C. Mallas, T. v. Wantoch, W. Benecke
Scanning Laser Display Based on Biaxial Polysilicon MEMS Mirrors.The 2nd Laser Display Conference (LDC’13), Yokohama, Japan, April 23–25, 2013

U. Hofmann, M. Aikio, J. Janes, F. Senger, V. Stenchly, M. Weiss, H.-J. Quenzer, B. Wagner, W. Benecke
Resonant Bi-axial 7-mm Mirror for Omnidirectional Scanning.Proc. of SPIE Vol. 8616, 86160C: 1-14, SPIE-Photonics West Conference, San Francisco, 2013

D. Kaden, S. Gu-Stoppel, H.-J. Quenzer, D. Kaltenbacher, B. Wagner, R. Dudde
Optimised Piezoelectric PZT Thin Film Production on 8“ Silicon Wafers for Micromechanical Applications.
Proc. Nanotechnology 2012, Santa Clara, Electronics, Devices, Fabrication, MEMS, Fluidics and Computational (Vol. 2) pp. 176–179, 2013

M. Kampmann, F. Stoppel, H.-J. Quenzer, D. Kaden, J. Janes, B. Wagner
Mehrachsiger piezoelektrischer Aktuator für optische Komponenten.
MST-Kongress 2013, Aachen, pp. 47-50, October, 2013

C. Kirchhof, M. Krantz, I. Teliban, R. Jahns, S. Marauska, B. Wagner, R. Knöchel, M. Gerken, D. Meyners, E. Quandt
Giant Magnetoelectric Effect in Vacuum.
Applied Physics Letters 102, pp. 232905, 2013

M. Kontek, T. Knieling
Die Attach and Wire Bonding on Inkjet Printed Structures on Oxidized Silicon Wafers. ICFPE 2013, Jeju Island, Korea, September 10–13, 2013

F. Lofink, S. Marauska, R. Jahns, Ch. Kirchhof, M. Claus, R. Knöchel, E. Quandt, B. Wagner
MEMS Based Magnetoelectric Field Sensor Characteristics under Vacuum and After Heat Treatment.
MST-Kongress, Aachen, October 14–16, 2013

S. Marauska, R. Jahns, C. Kirchhof, M. Claus, E. Quandt, R. Knöchel, B. Wagner
Highly Sensitive Wafer-Level Packaged MEMS Magnetic Field Sensor Based on Magnetoelectric Composites.
Sensors and Actuators A 189, pp. 321–327, 2013

S. Marauska, M. Claus, T. Lisec, B. Wagner
Low Temperature Transient Liquid Phase Bonding of Au/Sn and Cu/Sn Electroplated Material Systems for MEMS Wafer-Level Packaging. Microsystem Technologies 19, pp. 1119–1130, 2013

N. Marenco, M. Kontek, W. Reinert, J. Lingner, M.-H. Poech
Copper Ribbon Bonding for Power Electronics Applications EMPC 2013, Grenoble, Frankreich, September 9–12, 2013

R. Mörtel, M. Roth, S. Geiger
A New Type of Nonwoven Separator.
Batterietagung 2013,
Aachen, February 25–27, 2013

W. Reinert, M. Kontek, N. Lausen, A. Hindel, R. Eisele, F. Rudolf
Prozessentwicklung der Kupferband Hochstrom-Kontaktierung von Ag-gesinterten Leistungshalbleitern.
Jahrbuch Mikroverbindungstechnik, DVS 2013

K. Reiter, M. Kontek, W. Reinert
Mikroskopische Untersuchungen bei der Prozessentwicklung einer Kupferband Hochstrom Kontaktierung von Silber-gesinterten Leistungshalbleitern. Metallographietagung, Friedrichshafen, September 18, 2013

H. Schimanski
Reflowprofiloptimierung
unter Beachtung vorhandener Standards – durch Einsatz qualifizierter Messtechnik zu belastbaren Messergebnissen.
Konferenzband, 21.
FED-Konferenz, pp. 291–306, Bremen, September 19–21, 2013

O. Schwarzelbach, A. Sisto, L. Fanucci
Fully Electrical Test Procedure for Inertial MEMS Characterization at Wafer-Level.
Prime 2013, Villach, Austria, June 24–27, 2013

R.Eisele, A. Hindel, M. Kontek, W. Reinert
Leistungselektronik im Elektro- und Hybridfahrzeug.
VDI-Fachkonferenz, Frankfurt-Mörfelden, March 20–21, 2013

B. Steible, M. Stoldt, M. Tack, G. Zwicker
Application of an Abrasive-Free Cu Slurry for MEMS Devices
Proceedings of International Conference on Planarization/CMP Technology ICPT 2012, Grenoble, p. 203–208, October, 2012

TALKS AND POSTER PRESENTATIONS

L. Blohm, G. Piechotta
Elektronischer Laktatnachweis in Schweiß für die Sportmedizin (ELAN). Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, December 4, 2013

L. Blohm, G. Piechotta, J. Albers, L.-M. Buchmann, S. Holz, D. Rühmann, E. Nebling
Mikroelektroden und Membranen in Siliziumtechnologie für Bioreaktoren. 2. Statusseminar "Zellfreie Bioproduktion", Berlin, March 14–15, 2013

R. Eisele, A. Hindel, M. Kontek, N. Lausen, W. Reinert, F. Rudolf
MAXIKON Copper Ribbon Bonding for Power Electronics. Poster, PCIM 2013, Nürnberg, May 14–16, 2013

D. Friedrich
Forschung und Entwicklung für die Leistungselektronik. Elektromobilität in Schleswig-Holstein, IHK Kiel, March 12, 2013

D. Friedrich
R&D for Power Electronics. MCI-Technet Power Electronics, Sonderburg, DK, June 26, 2013

D. Friedrich
Entwicklung und Herstellung anwendungsspezifischer IGBTs in Itzehoe. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, November 6, 2013

D. Friedrich
Innovationscluster Leistungselektronik Regenerative Energieversorgung und Entwicklung und Fertigung von Hochvolt Leistungsbauelementen. Workshop Innocluster ISIT, Itzehoe, November 26, 2013

S. Gu-Stoppel
Piezoelektrische Antriebe mit geringer Treiberspannung für schnelle Mikrospiegel. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, March 6, 2013

U. Hofmann, F. Senger, V. Stenchly, J. Hagge, C. Mallas, T. v. Wantoch, J. Janes, W. Benecke
7mm-MEMS-Spiegel für einen omnidirektionalen Laserscanner. MST-Kongress, Aachen, October 14–16, 2013

M. Kalkhorst
Forschung und Produktion am Fraunhofer-Institut für Siliziumtechnologie (ISIT) mit Schwerpunkt Analytik und Schadensbewertung. 38. Arbeitskreis Bildverarbeitung der Initiative Bildverarbeitung e.V., ISIT, December 12, 2013

M. Kampmann, F. Stoppel, H.-J. Quenzer, D. Kaden, J. Janes, B. Wagner
Mehrachsiger piezoelektrischer Aktuator für optische Komponenten. MST-Kongress, Aachen, October 14–16, 2013

T. Knieling
Inspektionsverfahren für Elektronikkomponenten und –systeme am Fraunhofer ISIT. Workshop Industrielle Lösungen, Olympus, Hamburg, June 13, 2013

M. Kontek
Kundenspezifische Assemblierung komplexer Inertial-Sensorsysteme. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, February 6, 2013

R. Mörtel, M. Roth, S. Geiger
PB07: Full Cell Tests of a New Type of Nonwoven Separator. Batterietagung 2013 – Kraftwerk Batterie, Eurokongress Aachen, February 25–27, 2013

E. Nebling
Chip Technology in Point-of-Care Diagnostics. 11th Bio Partnering North America, Vancouver, February 24–26, 2013

E. Nebling
Technische Membranen. 2. Statusseminar "Zellfreie Bioproduktion", Berlin, March 14–15, 2013

E. Nebling
Silizium-Chiptechnologie als Plattform für Protein- oder DNA-basierte Point-of-Care Diagnostik. LSN-Innovation: Expertendialog „Diagnostik", Fraunhofer ISIT, Itzehoe, March 27, 2013

J. Ophey
Basics of battery technology and materials / Methods for lithium ion battery cell production – current research status & prospects for the future. Workshop „Battery technologies for electro mobility and smart grid purposes - regional research activities and business development options", ISIT, November 28, 2013

M. H. Poech
Das Reflow-Lötprofil bei eingeschränktem Prozessfenster. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21 and September 24–26, 2013

M. H. Poech
Selektivlöten in der Leistungselektronik. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21 and September 24–26, 2013

M. H. Poech
Zuverlässigkeiten von Baugruppen. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21, and September 24–26,2013

M. H. Poech
Temperaturmessung im Reflow. ISIT-Seminar: Temperaturmesstechnik, ISIT, Itzehoe, March 6 and November 6, 2013

M. H. Poech
Auswahl, Anwendung, Qualität und Kosten innovativer Kühlkonzepte in der Elektronik. 7. Tagung Elektronikkühlung, Stuttgart, April 23–24, 2013

M. H. Poech
Qualität und Zuverlässigkeit leistungselektronischer Komponenten. 1. Workshop „Innovationscluster Leistungselektronik für Regenerative Energieversorgung", ISIT, Itzehoe, November 26, 2013

M. H. Poech
Computergestützte Lebensdauervorhersage. Meeting ZVEI-ECPE AK Leistungselektronik, Nürnberg, December 9, 2013

M. Reiter
Das Reflow-Lötprofil bei eingeschränktem Prozessfenster. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21, 2013

M. Reiter
Baugruppen- und Fehlerbewertung. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, September 24–26, 2013

H. Schimanski
Baugruppen- und Fehlerbewertung. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21, and November 27–29, 2013

H. Schimanski
Prozessfenster und Zuverlässigkeit manuell reparierter Lötstellen. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21 and September 24–26, 2013

H. Schimanski
Einflussfaktoren im Lotpastendruck. ISIT-Seminar: Lotpastenapplikation, ISIT, Itzehoe, March 04–05 and November 4–5, 2013

H. Schimanski
Jetprinten und Lotpasteninspektion. ISIT-Seminar: Lotpastenapplikation, ISIT, Itzehoe, March 4–5 and November 4–05, 2013

H. Schimanski
Temperaturmessung richtig durchgeführt. ISIT-Seminar: Temperaturmesstechnik, ISIT, Itzehoe, March 6 and November 6, 2013

H. Schimanski
Der Reflow-Lötprozess ISIT-Seminar: Reflowprofiloptimierung, ISIT, Itzehoe, March 7 and November 7, 2013

H. Schimanski
Prozessfehler und ihre Auswirkungen. 16. EE-Kolleg, Col. de St. Jordi, Barcelona, Spain, March 20–24, 2013

H. Schimanski
Lötprofiloptimierung und Qualitätsbewertung. ISIT-Seminar: Wellenlöten und Selektivlöten, ISIT, Itzehoe, April 23–24 and December 10–11, 2013

H. Schimanski
Nacharbeit, Modifikation und Reparatur von komplexen Elektronikbaugruppen. Eltroplan Technologietag, Endingen, April 25–26, 2013

H. Schimanski
Reflowprofiloptimierung durch qualifizierte Messtechnik – Wir gehen in die Tiefe. Seminar für aktuelle Trends in der Aufbau- und Verbindungstechnologie, Dresden, June 26–27, 2013

H. Schimanski
Einführung und Qualifizierung von Fertigungsprozessen im ISIT-Applikationslabor für Prozesstechniken in der Baugruppenfertigung. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, September 4, 2013

H. Schimanski
Reflowprofiloptimierung unter Beachtung vorhandener Standards. 21. FED-Konferenz, Bremen, September 19–21, 2013

H. Schimanski
Lötqualität und Reflow-Lötverfahren. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, February 19–21 and Sept. 24–26, 2013

H. Schimanski
Einfluss der Nutzentrennung auf die Baugruppenqualität. Tagung der FG ZEP, Stäfa, Schweiz, November 22, 2013

H. Schimanski
(Bleifrei) Reparaturlöten. ISIT-Seminar: Der optimierte Rework-Prozess, Itzehoe, November 27–29, 2013

H. Schimanski
Baugruppen schonende Reparatur komplexer SMT-Baugruppen. ISIT-Seminar: Der optimierte Rework-Prozess, ISIT, Itzehoe, November 27–29, 2013

M. Witt
MEMS-Baustein für 20 nm Lithographie mit 260.000 ablenkbaren Elektronenstrahlen. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, May 8, 2013

A. Würsig
Advanced Manufacturing: Increasing Quality Reducing Cost. International Summit for the Storage of Renewable Energies, Energy Storage 2013, Düsseldorf, March 18–19, 2013

G. Zwicker
CMP Applications for the Fabrication of PowerMOS and MEMS Devices. Fudan University, Shanghai, PR of China, November 5, 2013

DOCTORAL THESES

S. Marauska
Hochempfindliche mikromechanische magnetoelektrische Magnetfeldsensoren
Christian-Albrechts-Universität zu Kiel,
July 2013

DIPLOMA, MASTER'S AND BACHELOR'S THESES

Torben Dankwort
Deposition of $LaNiO_3$ seed layers for the nucleated growth of hot sputtered $PbZr_{1-x}T_xO_3$
Master thesis, CAU Kiel,
January 2013

Stefan de la Cruz
Entwicklung eines integrierten Temperaturmanagements zur Optimierung von Bioassays auf Multipositions-Biochips
Bachelor's thesis,
HAW Hamburg,
March 2013

Kushal Rajabhai Soni
Development of Micromachined Silicon Sensor for Lactate Monitoring in Sweat
Master's thesis,
HAW Hamburg,
October 2013

Saskia Schröder
Optimierung des Lotpastenauftrags durch 3D-Lotpasteninspektion
Master's thesis,
FH Westküste, HAW,
October 2013

Andreas Beeck
Entwicklung eines Demonstratorsystems zur Erfassung der Schreibbewegung eines Stiftes mit Hilfe von mikromechanischen Inertialsensoren
Master's thesis,
FH Westküste,
November 2013

PATENTS

Supplement 2012
W. Reinert
Verfahren zur Herstellung eines (Vielfach-) Bauelements auf Basis ultraplanarer Metallstrukturen
DE 10 2007 060 785 B4

2013

K. Kohlmann-von Platen, D. Friedrich, H. Bernt
Halbleiterbauelement mit vertikalem Leistungsbauelement aufweisend einen Trenngraben und Verfahren zu dessen Herstellung
DE 103 00 577 B4

P. Merz, M. Weiß
Micromechanical inertial sensor for measuring rotation rates
US 8,215,168 B2

D. Kähler, S. Puls, M.-H. Poech
Unmittelbare Kontaktierung eines Energiespeichers oder einer Last mittels eines elektronischen Lastschalters
DE 10 2011 055 223 B3

W. Reinert
Gehäuste aktive Mikrostrukturen mit Direktkontaktierung zu einem Substrat
DE 10 2008 025 599 B4

H.J. Quenzer, M. Oldsen, U. Hofmann
Cover for microsystems and method for producing a cover
US 8,517,545 B2

U. Hofmann, H.J. Quenzer, M. Oldsen
Microsystem and method for the production of a microsystem
US 8,526,098 B2
JP 5353885

O. Schwarzelbach, M. Weiß, V. Kempe
Sensor for detecting acceleration
US 8,549,921 B2

P. Merz, W. Reinert, M. Oldsen, O. Schwarzelbach
Micromechanical housing comprising at least two cavities having different internal pressure and/or different gas compositions and method for the production thereof
US 8,546,928 B2

U. Hofmann, M. Oldsen
Micromirror actuator with encapsulation possibility and method for production thereof
EP 2 100 179 B1

M. Oldsen, W. Reinert, P. Merz
Solder material lining a cover wafer attached to wafer substrate
JP 5243962

R. Hintsche
Sensor for detecting fluids, and detection device comprising this sensor
EP 1 591 780 B1

N. Marenco
Semiconductor arrangement with trench capacitor and method for its manufacture
JP 5405322

W. Reinert, D. Kähler, P. Merz
Method for testing the leakage rate of vacuum capsulated devices
JP 5368705

OVERVIEW OF PROJECTS

- Ultrakompakte Leistungsmodule höchster Zuverlässigkeit ULTIMO
- Entwicklung von Fast Recovery Dioden
- Innovationscluster Leistungselektronik für regenerative Energieversorgung
- Entwicklung neuer Punch-Through-IGBTs und Field-Stop-IGBTs
- Evaluierung eines Laser-Dicing-Verfahrens für Ultradünne Leistungsbauelemente
- Entwicklung von Super-Junction Hochvolt PowerMOS Bauelementen
- Entwicklung und Herstellung von Si- und Ni-Lochmembranen im sub-0,5 µm Bereich
- Entwicklung von poly-Si CMP Prozessen für die MEMS Herstellung
- Energy-Efficient Piezo-MEMS Tunable RF Front-End Antenna Systems for Mobile Devices (EPAMO)
- 9 D Sense; Development of Magnetic Field Sensors
- High Volume Piezoelectric Thin Film Production Process for Microsystems, Piezo Volume
- Magnetoelektronische Sensoren (Sonderforschungsbereich 855 der Uni Kiel)
- Entwicklung von LIDAR Systemen, MiniFaros
- Development and Fabrication of 256k CMOS Blanking Chips for Maskless Lithography
- Development of an ASIC for the control of BLDC-motors
- Herstellung eines Multi Deflection Arrays für die hochauflösende Elektronenstrahl-Lithographie
- Entwicklung einer Montageplattform für Lasermodule und passive Optiken (PICOLO)
- Entwicklung und Herstellung eines MEMS basierten hochgenauen CO_2-Sensors
- Silizium basierte Hochtemperatur-Thermogeneratoren auf 8" Wafer-Level (SIEGEN)
- Prozessentwicklung MEMS basierter Energie-Harvester
- 3D-Signage
- Hochleistungsmikrospiegel für die Materialbearbeitung
- Kompetenzzentrum Nanosystemtechnik
- Luftmassensensor
- Waferbasierte 3D-Integration von IR Sensor Technologien (WIN-IT)
- Tiefziehen von Glaswafern (TIGLA)
- AOI Kalibriernormal
- Adaptive Lichtlenkung mit Mikrospiegel-Arrays
- 2D MEMS-Scanning Mirror
- Mikro-Auge
- PZT Transducer für Ultraschall-Anwendungen
- Piezo Stromversorgung on chip
- Zellfreie Bioproduktion
- Elektronischer Laktat Nachweis ELaN
- F&E-Projekt mit POCDIA GmbH
- MiChroChip (MEMS-Chromatographiechip) intern
- F&E-Projekt mit LightStat LLC (Bioproject Phase 1)
- Zuverlässige Kontaktierung von Höchstleistungsbauelementen in der Leistungselektronik durch innovative Bändchen- und Litzenverbindungen (MAXIKON)
- Produktionsgerechtes reaktives Nanofügen zum hermetischen Versiegeln von Mikrosensoren auf Waferebene (REMTEC)
- Glassfritt Vacuum Wafer Bonding
- Glaslotbonden mit strukturierten Capwafern und Musterwafern
- Wafer Level Packaging
- Process Development for Hermetic AuSn Vacuum Sealing of IR Sensors on Wafer Level
- Wafer Level Balling for 100 µm up to 500 µm Spheres
- Neon Ultra Fine Leak Test for Resonant Micro Sensors
- Hochzuverlässige Stromrichter für Windenergieanlagen (HiReS)
- Tiefsee-Inspektions- und Explorations Technologie (TIETeK)
- Qualitätsbewertung an bleifreien Baugruppen
- Printed Electronics (Binäruhr, neuer Drucker LP50)
- Einfluss des Lotpastendrucks auf die Zuverlässigkeit der Lötstellen kritischer keramischer SMD-Komponenten auf FR4-Leiterplatten
- Erhöhung der Lötsicherheit beim Einsatz mikro- und niedrig Ag-legierter Lote in der Fertigung elektronischer Baugruppen (IGF-Vorhaben 17941 N/1)
- Untersuchung des Einflusses der elektrochemischen Korrosion auf die Zuverlässigkeit von reparierten elektronischen Baugruppen unter Verwendung bleifreier Lote und No-Clean-Flussmittelmischungen (IGF-Vorhaben 17960 N/1)
- Akustische Gang- und Laufanalyse
- Hochenergie-Lithiumbatterien für die Zukunft HE-LION
- Hochleistungslithiumbatterien mit Nanopartikeln in Core-Shell-Technologie LINACOR
- Entwicklung einer Zelltechnologie für Solarstrom-Zwischenspeicherung
- European Li-Ion Battery Manufacturing for Electric Vehicles (ELIBAMA)
- Hybride Stadtspeicher – Stationäre Energiespeicher für die dezentrale Energieversorgung
- Innovatives Elektrofahrrad-KonzeptVelocity
- Innovatives Funktionsmaterial für Speichertechnologien „Ormocere"
- Entwicklung von Produktionstechnologien für Lithiumakkumulatoren (Protrak)
- Entwicklung und Fertigung von Elektroden für Lithium-Schwefel Batterien (Eurolis)
- Entwicklung von Hochleistungsakkumulatoren für die Elektromobilität (FSEMII)
- Temperaturoptimierte Batterietechnologien TopBat
- Neue Konzepte für die Elektroden und Separatorfertigung bei Lithiumakkumulatoren (S-Protrak)
- Durch Kohlenstoffnetzstrukturen optimierte Elektroden für Li-Akkumulatoren (LiMedion)
- Battery simulation Opel-Battery Models

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