Fraunhofer
ISIT

FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE ISIT

Achievements and Results Annual Report 2014

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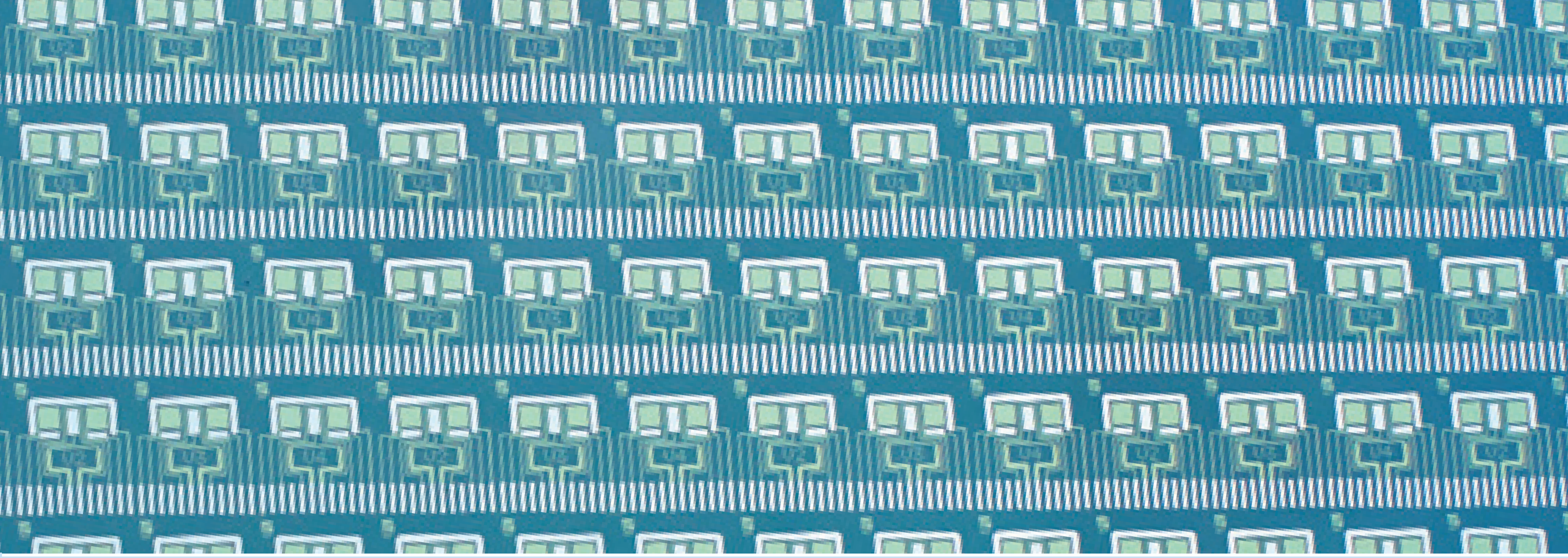
2014

ACHIEVEMENTS AND RESULTS ANNUAL REPORT 2014



REPRESENTATIVE RESULTS OF WORK

PREFACE

Together strong in research and teaching: CAU Vice President Prof. Karin Schwarz and Prof. Bernhard Wagner, Deputy Director of Fraunhofer ISIT

Promote joint research projects from Hamburg and Schleswig Holstein
Jochen Möller, MOE, Prof. Ralf Thiericke, IZET, Senator Frank Horch, Hamburg, Prof. Wolfgang Benecke, and Minister of Economic Affairs Reinhard Meyer, Schleswig-Holstein

Senator for Science Dr. Dorothee Stapelfeldt and
Prof. Holger Kapels, head of the ISIT application center at the
HAW in Hamburg

Member of Fraunhofer Board
Prof. Alfred Gossner

Dear readers,
dear business partners,

We are very pleased to present you with this copy of our annual report. In it you will learn about the outstanding developments and innovations with which we are giving impetus to the markets of the future.

The year 2014 saw Fraunhofer ISIT set out on a course for the future. Thanks to the trust that you, our customers and patrons have placed in us, together we were able to further strengthen the fields of MEMS technology and power electronics and expand these solid pillars of our institute. We officially opened our new clean room in May 2014; the state-of-the-art platform for micro /nanosystems engineering is a welcome addition to the institute. People at all levels demonstrated committed support, and for this I would like to thank them. I also wish to thank our employees, who overcame the extremely complex and wide-ranging technical challenges relating to the relocation and installation of equipment and facilities.

Fraunhofer ISIT is responding to the growing importance of systems-oriented solutions and offers by steadily expanding its relevant expertise. By forming partnerships in this area, we are bolstering and developing our performance profile to adapt it to the needs of the market. In this regard, we are particularly pleased to have set out on the road to establishing the Fraunhofer "Power Electronics for Renewable Energy Systems" Application Center in cooperation with the Hamburg University of Applied Sciences (HAW). We also managed to further

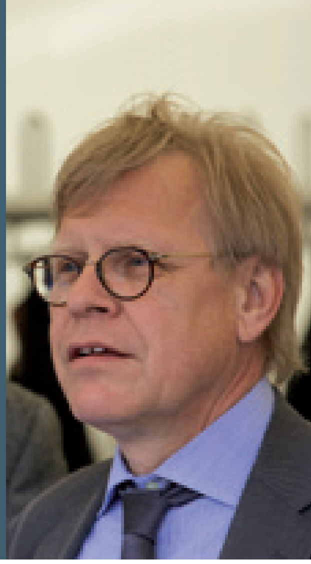
Liebe Leserinnen und Leser,
liebe Geschäftspartner,

Wir freuen uns, Ihnen mit dem vorliegenden Jahresbericht herausragende Entwicklungen, Innovationen und Impulse für die Märkte der Zukunft vorstellen zu können.

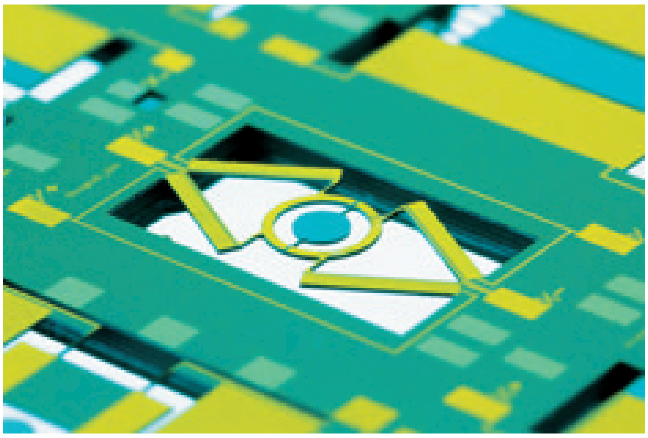
Das Jahr 2014 war für das Fraunhofer ISIT weichenstellend. Durch die vertrauensvolle Zusammenarbeit mit Ihnen, unseren Kunden und Förderern konnte die tragenden Säulen des Instituts im Bereich der MEMS-Technologien und der Leistungselektronik weiter gefestigt und ausgebaut werden. Die Erweiterung des Instituts mit einem neuen Reinraum als modernste Plattform für die Mikro- und Nanosystemtechnik ist mit der Einweihung im Mai 2014 abgeschlossen worden. Für die engagierte Unterstützung auf allen Ebenen möchte ich mich an dieser Stelle bedanken. Dies gilt ganz besonders für die Lösung der hochkomplexen und umfänglichen technischen Herausforderungen beim Umzug und der Neuinstallation der Geräte und Anlagen durch unsere Mitarbeiter.

Der wachsenden Bedeutung von systemorientierten Lösungen und Angeboten wird im ISIT durch den stetigen Aufbau von Systemkompetenz Rechnung getragen. Durch Partnerschaften im Umfeld des ISIT wird das Leistungsprofil des ISIT weiter gestärkt und erweitert und so den Erfordernissen des Marktes angepasst. In diesem Sinne ist sehr erfreulich, dass

Interview with Andreas Timmermann, architect of the new ISIT cleanroom



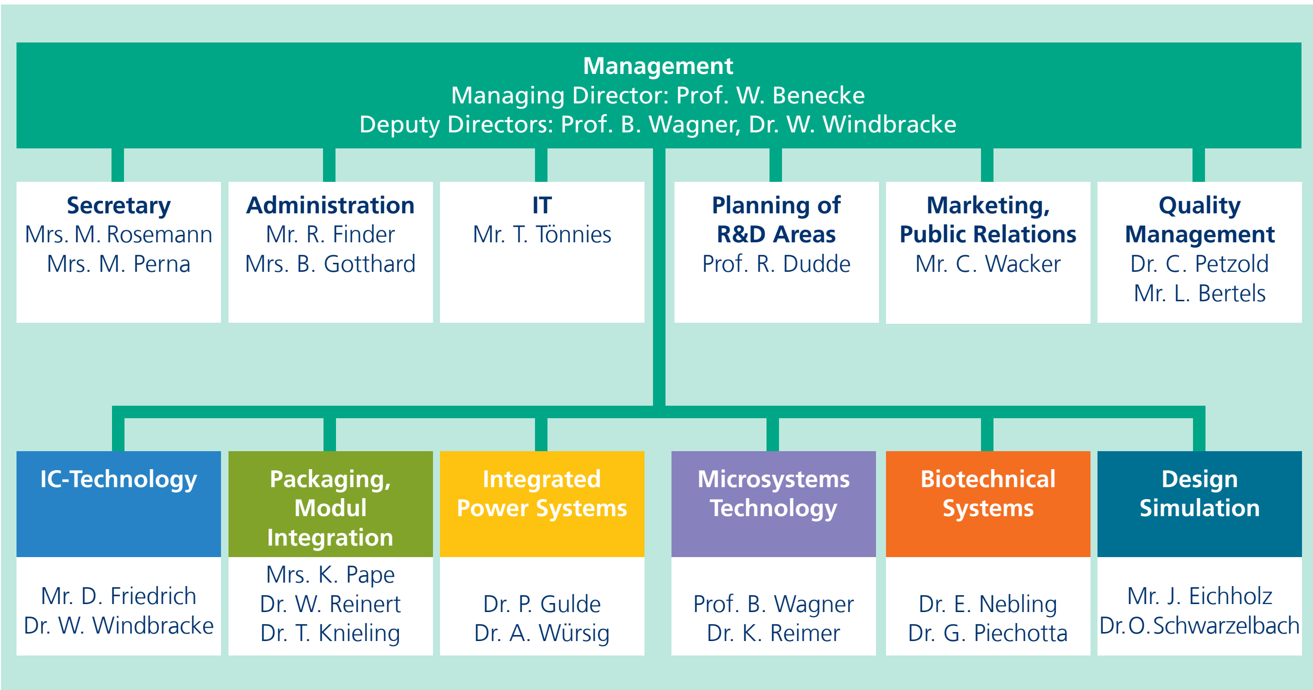
Dr. Gerfried Zwicker, ISIT coordinator for the construction of the new cleanroom



2D piezoelectric micro mirror

das Fraunhofer- Anwendungszentrum „Leistungselektronik für regenerative Energiesysteme“ in Kooperation mit der Hochschule für Angewandte Wissenschaften (HAW) im Bundesland Hamburg an den Start gebracht werden konnte.

Die Zusammenarbeit mit der Fachhochschule Westküste in Heide (FHW) unter dem Dach der Fraunhofer-Projektgruppe„Mikrosysteme für neue Mensch-Maschine-Schnittstellen“ wurde weiter ausgebaut und vertieft. Zur Intensivierung der langfristigen Vorlaufforschung und zur besseren Vernetzung mit



Organizational chart, ISIT

ISIT Curator Dietrich Austermann in conversation with Minister of Economic Affairs Reinhard Meyer

IHK award for ISIT trainees Paul-Felix Hanßen, Markus Schröder and Sören Queck together with their trainers Anja Ambrosius and Jan Lähn (in the background)

expand and deepen our cooperation with the West Coast University of Applied Sciences, Germany (FHW) under the auspices of the Fraunhofer "Microsystems for new human-machine interfaces" project group. A branch lab with laboratory space was established at Kiel University (CAU) in order to intensify long-term preliminary research and better leverage university resources and expertise.

We were able to further consolidate Fraunhofer ISIT's core competence and its unique profile in the field of semiconductor technologies for power electronics and MEMS thanks to trusting, intensive collaboration with our strategic cooperation partners VISHAY Siliconix and XFAB-MEMS Foundry Itzehoe. We expect these partnerships to continue to deliver more and more advantages and opportunities for our various customers in the future. The Itzehoe location now offers excellent potential for developing innovative new products – playing a major role in helping to strengthen German and European industry.

On behalf of Fraunhofer ISIT's employees, I would like to thank all our partners, customers and patrons for their trust and cooperation. I hope that reading this report gives you plenty of stimulating insights.

We look forward to an invigorating dialog with you!

den universitären Ressourcen und Kompetenzen ist eine Außenstelle mit Laborarbeitsplätzen an der Christian-Albrecht-Universität zu Kiel (CAU) eingerichtet worden.

Die Kernkompetenz und die Alleinstellung des ISIT auf dem Gebiet der Halbleitertechnologien für Leistungselektronik und MEMS konnte durch die vertrauensvolle und intensive Zusammenarbeit mit unseren strategischen Kooperationspartnern VISHAY Siliconix und XFAB-MEMS Foundry Itzehoe weiter konsolidiert werden. Wir erwarten durch diese Partnerschaften auch für die Zukunft stetig wachsende Vorteile und Chancen für unsere Kunden und Auftraggeber. Für die Entwicklung neuer und innovativer Produkte sind am Standort Itzehoe herausragende Möglichkeiten entstanden wodurch ein wesentlicher Beitrag zur Stärkung der Industrie in Deutschland und Europa geleistet wurde.

Im Namen der Mitarbeiterinnen und Mitarbeiter des ISIT danke ich allen Partnern, Auftraggebern und Förderern für die vertrauensvolle Zusammenarbeit und hoffe, dass Sie beim Lesen des Berichtes viele interessante Anregungen aufnehmen.

Wir freuen uns auf den Gedankenaustausch mit Ihnen!

Prof. W. Benecke

The new ISIT cleanroom building

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.

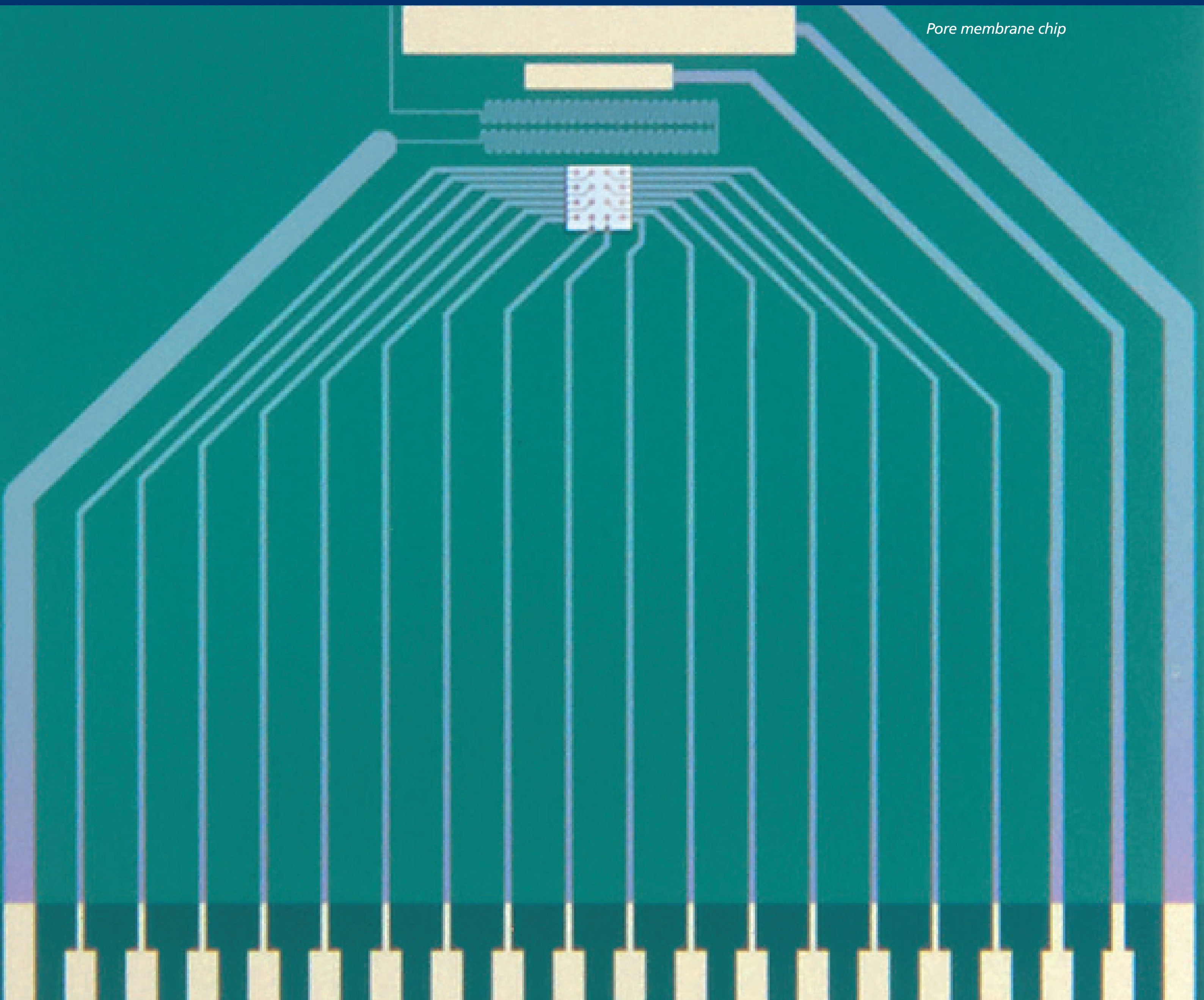
Fraunhofer ISIT supports customers right the way from design and system simulation to the production of prototypes, samples, and preparation for series production. The institute currently employs a staff of 160 persons with engineering and natural sciences backgrounds.

Fraunhofer ISIT deals with all the important aspects of system integration, assembly and interconnection technology (packaging), and the reliability and quality of components, modules, and systems. The institute also provides manufacturing support for application-specific integrated circuits (ASICs) to operate sensors and actuators. Activities are rounded off by the development of electrical energy storage devices, with a focus on Li-polymer batteries.

One point 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



Pore membrane chip

Capped micromirror mounted on PCB

Drive electrodes for large aperture MEMS mirrors

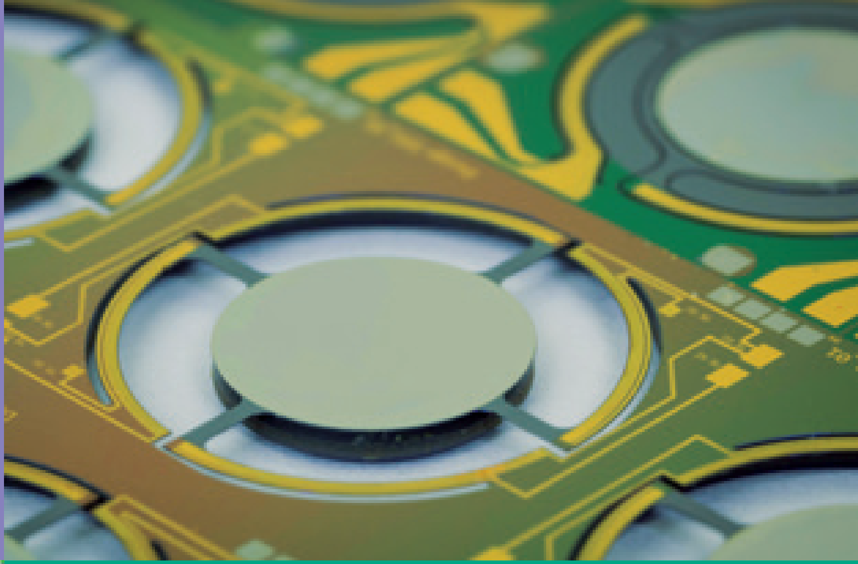
MICROSYSTEMS TECHNOLOGY, MEMS AND IC DESIGN

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.

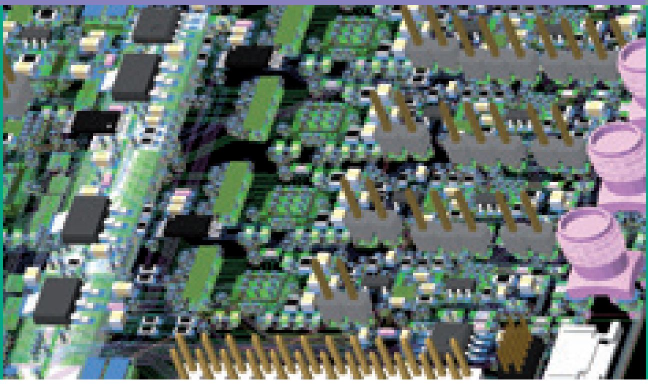
ISIT has also the possibility to offer fabrication of prototypes and low volume pilot production. If high volume MEMS production is requested the on-site operating industrial partner X-FAB MEMS Foundry Itzehoe GmbH is able to meet this demand. All services are offered on a 200 mm wafer technology-platform.

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,



Piezoelectric driven microactuator



3D-model of a PCB layout

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 XeF_2 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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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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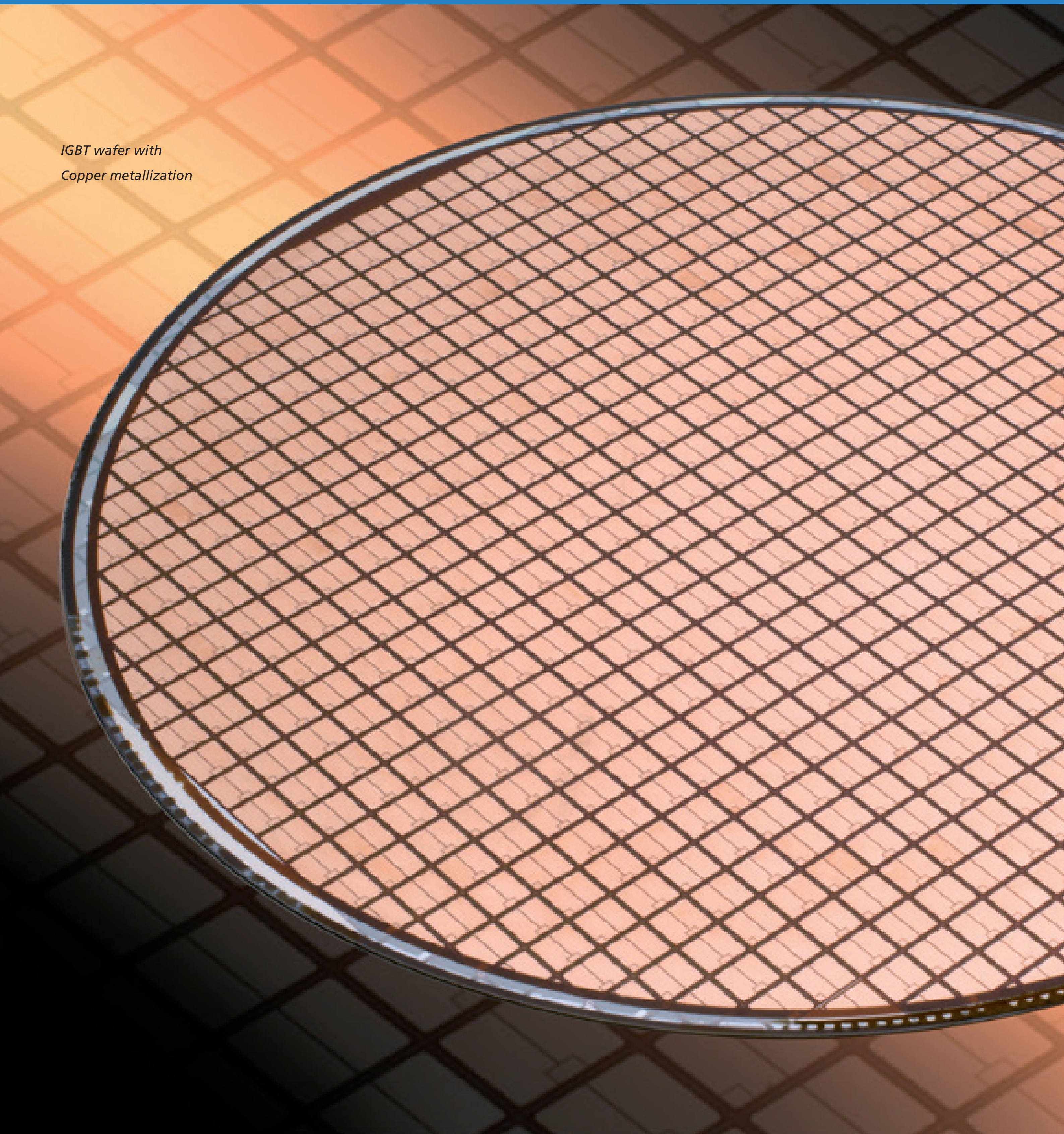
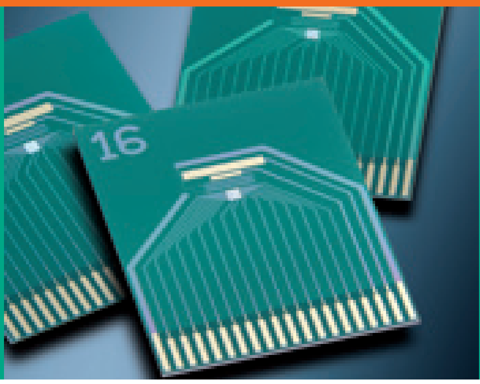


IGBT wafer with
Copper metallization



Pore membrane chips for transmembrane protein analysis

Wafer with lactate sensor chips

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.

Biotechnical Microsystems
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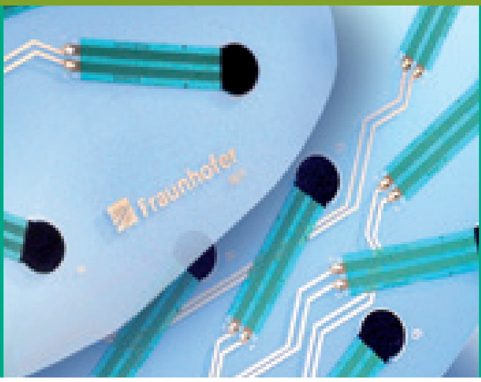
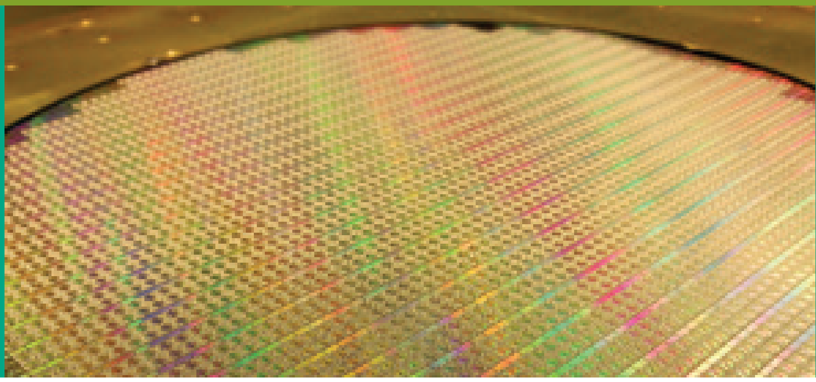


Foil sensors in functional shoe inlays for acustic gait analysis



Waferlevel packages with attended solder balls

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 2000 µm 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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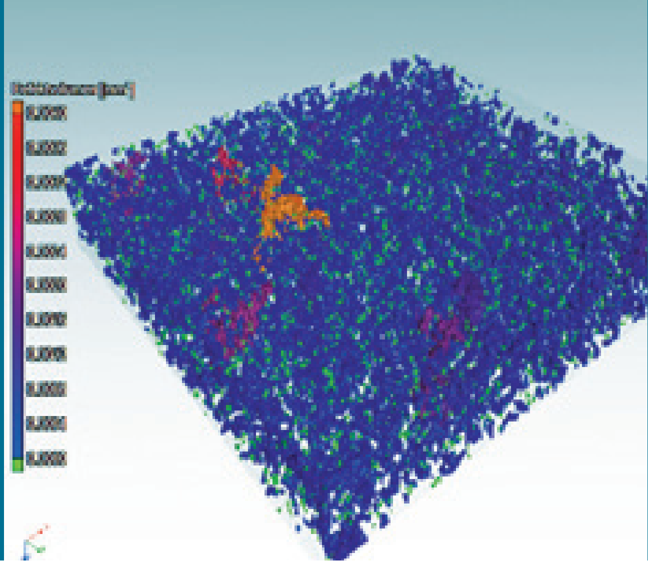
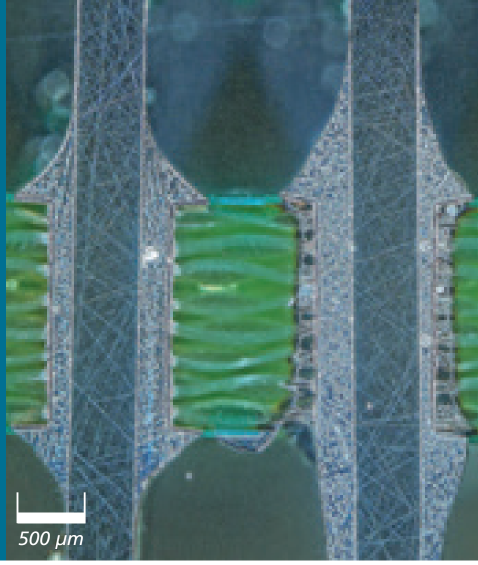


CT analysis of different components in a color



Cross section of a THT contact

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. Important fields of activity are quality assessment, reliability of electronic part, modules and systems. Moreover evaluation and standardization of test methods for quality assessment of printed and hybrid electronics are being developed.

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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Development of secondary Lithium batteries at ISIT

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

Integrated Power Systems

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OFFERS FOR RESEARCH AND SERVICE

Inside the new cleanroom laboratories

Clean sub-fab in the new cleanroom building

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 for realizing their technological innovations.

FACILITIES AND EQUIPMENT

Fraunhofer ISIT has access to a 200 mm Silicon technology line (2 500 m²) for front-end processes (MOS and PowerMOS). Specific processes for MEMS and NEMS as well as for packaging are implemented in a new cleanroom (1 000 m²), dedicated to microsystems technology. 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 1 500 m² are dedicated to electrical and mechanical characterization of devices, assembly and interconnection technology, and reliability testing. Fraunhofer ISIT also operates a pilot production line for Li-polymer batteries. The institute's facilities have been certified to ISO 9001:2008 for many years.

CUSTOMERS

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

3-D-Micromag GmbH, *Chemnitz*

4tiitoo GmbH, *München*

ABB AG, *Ladenburg*

Adam Opel AG, *Rüsselsheim*

Advaplan, *Espoo, Finland*

Airbus-Systeme, *Buxtehude*

aixACCT Systems GmbH, *Aachen*

alpha-board GmbH, *Berlin*

Aluminium-Veredelung GmbH, *Ennepetal*

Analytik Jena AG, *Jena*

Andus electronic GmbH, *Berlin*

Asteelflash Hersfeld GmbH, *Bad Hersfeld*

Atotech Deutschland GmbH, *Berlin*

austrianmicrosystems, *Unterpremstätten, Austria*

Basler AG, *Ahrensburg*

Bosch Sensortec GmbH, *Reutlingen*

B. Braun Melsungen AG, *Melsungen*

H. Brockstedt GmbH, *Kiel*

Brückner Maschinenbau GmbH & Co. KG, *Siegsdorf*

CAPRES A/S, *Kongens Lyngby, Denmark*

CarboFibretec GmbH, *Friedrichshafen*

Cassidian Electronics, *Ulm*

CCI GmbH, *Itzehoe*

Condias GmbH, *Itzehoe*

Continental Automotive GmbH, *Karben*

Conti Temic microelectronic GmbH, *Nürnberg*

Daimler AG, *Stuttgart*

Danfoss Drives A/S, *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*

Disco Hi-Tec Europe GmbH, *München*

Dräger AG, *Lübeck*

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

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

Endress + Hauser GmbH Co. KG, *Maulburg*

Engineering Center for Power Electronics GmbH, *Nürnberg*

EPCOS AG, *München*

Eppendorf Instrumente GmbH, *Hamburg*

ESCD GmbH, *Brunsbüttel*

ESPROS Photonics AG, *Switzerland*

Evonik Degussa GmbH, *Hanau*

Evonik Litarion GmbH, *Kamenz*

Foxboro Eckardt GmbH, *Stuttgart*

Freudenberg Gruppe, *Weinheim*

FTCAP GmbH, *Husum*

FRH Anlagenbau GmbH, *Ottendorf-Okrilla*

FMP TECHNOLOGY GMBH, *Erlangen*

GÖPEL electronic GmbH, *Jena*

Hako-Werke, *Bad Oldesloe*

Hannusch Industrieelektronik, *Laichingen*

Harman Becker Automotive Systems GmbH, *Karlsbad*

Hauzer Techno Coating BV, *Venlo, Netherlands*

Hella KG, *Lippstadt*

Heraeus Materials Technology GmbH Co. KG, *Hanau*

Honeywell Deutschland AG, *Offenbach*

HSG-IMIT, *Villingen-Schwenningen*

ifm ecomatic GmbH, *Kressbronn*

ifm electronic GmbH, *Tettnang*

INGECAL, *Vaux en Velin, France*

IMS Nanofabrication AG, *Wien, Austria*

In-Core Systems SARL, *Saint Priest, France*

Innovavent GmbH, *Göttingen*

Institute of Electron Technology, *Warsaw, Poland*

ISRA Vision AG, *Darmstadt*

Isola GmbH, *Düren*

Jenoptik Automatisierungstechnik GmbH, *Jena*

Jenoptik GmbH, *Wedel*

Jonas & Redmann Group GmbH, *Berlin*

Jungheinrich AG, *Norderstedt*

Kristronics GmbH, *Harrislee-Flensburg*

Kuhnke GmbH, *Malente*

Lenze Drive Systems GmbH, *Hameln*

Liebherr Elektronik, *Lindau*

LightStat LCC, *Texas, USA*

Mair Elektronik GmbH, *Neufahrn*

Maxim Integrated GmbH, *Lebring, Austria*

Meder eletronic AG, *Engen-Welschingen*

Melexis Ieper N.V., *Belgium*

MicroMountains Applications AG, *Villingen-Schwenningen*

Miele & Cie KG, *Lippstadt*

MKS Instruments Deutschland GmbH, *München*

Novelis Deutschland GmbH, *Göttingen*

NXP Semiconductors Germany GmbH, *Hamburg*

Oerlikon AG, *Liechtenstein*

Okmetic Oyj, *Vantaa, Finland*

Opel AG, *Rüsselsheim*

OSRAM GmbH, *München*

OSRAM Opto Semiconductors GmbH, *Regensburg*

Otto Bock HealthCare GmbH, *Duderstadt*

PAC Tech, Packaging Technologies, *Nauen*

Panasonic Automotive Systems Europe GmbH, *Neumünster*

PAV Card GmbH, *Lütjensee*

Peter Wolters GmbH, *Rendsburg*

Picosun Oy, *Espoo, Finland*

Plan Optik AG, *Elsoff*

Plath EFT GmbH, *Norderstedt*

POCDIA GmbH, *Itzehoe*

PRETTL Elektronik Lübeck GmbH, *Lübeck*

Raytheon Anschütz GmbH, *Kiel*

Reese + Thies Industrieelektronik GmbH, *Itzehoe*

RefuSol GmbH, *Metzingen*

Rehm Anlagenbau GmbH, *Blaubeuren-Seissen*

Renault SA, *Boulogne, Billancourt, France*

Robert Bosch GmbH, *Reutlingen*

Robert Bosch GmbH, *Salzgitter*

ROHDE & SCHWARZ GmbH & Co. KG, *München*

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

SAFT SA, *Bagnolet, France*

Saint-Gobain Centre de Recherches et d'Etudes Européen, *Courbevoice, France*

Schlötter GmbH & Co KG, *Geislingen*

Science&Motion Sports GmbH, *Rüsselsheim*

Senvion SE, *Osterröhnfeld*

Senvion Wind Energy Solutions, *Hamburg*

SGL Carbon GmbH, *Meitingen*

Silex Microsystems AG, *Järfälla, Sweden*

SINTEF ICT, *Oslo, Norway*

SMA Regelsysteme GmbH, *Niestetal*

Smyczek GmbH, *Verl*

Solvionic Site SNPE, *Toulouse, France*

STABILO International GmbH, *Heroldsberg*

Sterling Industry Consult GmbH, *Itzehoe*

Still GmbH, *Hamburg*

Stolle Sanitätshaus GmbH, *Hamburg*

tagitron GmbH, *Salzkotten*

Technolas Perfect Vision, *München*

TESAT SPACECOM GmbH, *Backnang*

Theon, *Athens, Greece*

Trainalytics GmbH, *Lippstadt*

Treichel Elektronik GmbH, *Springe*

Trinamic Motion Control GmbH & Co. KG, *Hamburg*

Umicore AG & Co., *Hanau*

Umicore NV, *Olen, Belgium*

USound GmbH, *Graz, Austria*

Vakuum- und präzisions-fertigung Dresden GmbH, *Ottendorf- Okrilla*

Vectron International GmbH & Co. KG, *Neckarbischofsheim*

Vishay BCcomponents BEYSCHLAG GmbH, *Heide*

Vishay Siliconix Itzehoe GmbH, *Itzehoe*

Vishay Siliconix, *Santa Clara, USA*

VocalZoom, *Yokneam Ilit, Israel*

Volkswagen AG, *Wolfsburg*

Von Ardenne Anlagentechnik GmbH, *Dresden*

WABCO GmbH, *Hannover*

Witt IndustrieElektronik GmbH, *Berlin*

Würth Elektronik GmbH, *Schopfheim*

Xenon Automatisierungstechnik GmbH, *Dresden*

X-FAB MEMS Foundry Itzehoe GmbH, *Itzehoe*

X-FAB Semiconductor Foundries AG, *Erfurt*

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 utilization of patents and licences is included in the service.

Product / Service	Market	Contact Person
Testing of semiconductor manufacturing equipment	*Semiconductor equipment manufacturers*	*Dr. Gerfried Zwicker + 49 (0) 4821/17-4309 gerfried.zwicker@isit.fraunhofer.de*
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 klaus.reimer@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. Thomas Lisec +49 (0) 4821/17-4512 thomas.lisec@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.reimer@isit.fraunhofer.de*

Product / Service	Market	Contact Person
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*
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) 4821/17-1437 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*
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	*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*
Wearable, flexible and hybrid electronics	*Electronic industry, medical and sports applications*	*Dr. Thomas Knieling + 49 (0) 4821/17-4605 thomas.knieling@isit.fraunhofer.de*
Thermal measurement and simulation	*Microelectronic and power electronic industry*	*Dr. Max 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	*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

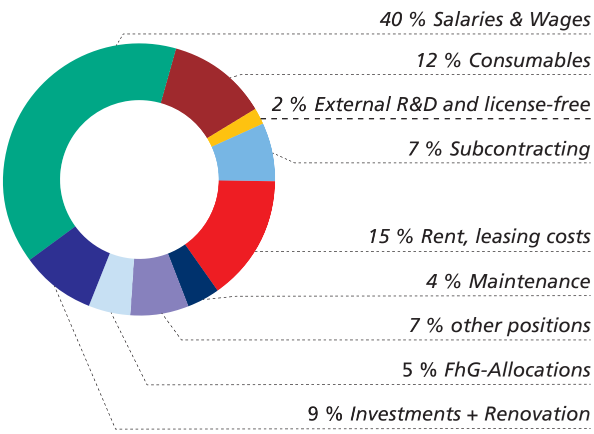
EXPENDITURE

In 2014 the operating expenditure of Fraunhofer ISIT amounted to 27.819,7 T€.
Salaries and wages were 11.193,8 T€, material costs and different other running costs were 14.050,2 T€.
The institutional budget of capital investment and renovation was 2.575,7 T€.

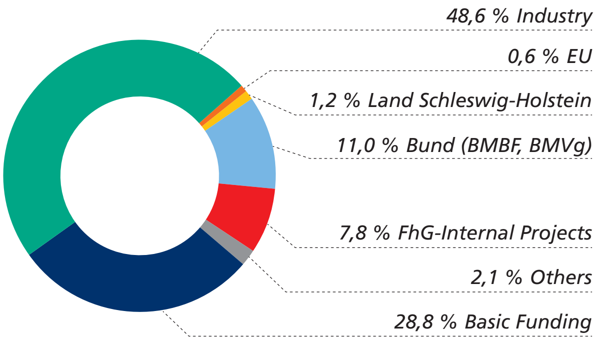
INCOME

The budget was financed by proceeds of projects of industry/industrial federations/small and medium sized companies amounting to 13.534,2 T€, of government/project sponsors/federal states amounting to 3.392,5 T€ and of European Union/others amounting to 162,7 T€.
Furthermore there were FhG-projects about 2.156,4 T€ and basic funding with 8.001,0 T€.

Expenditure



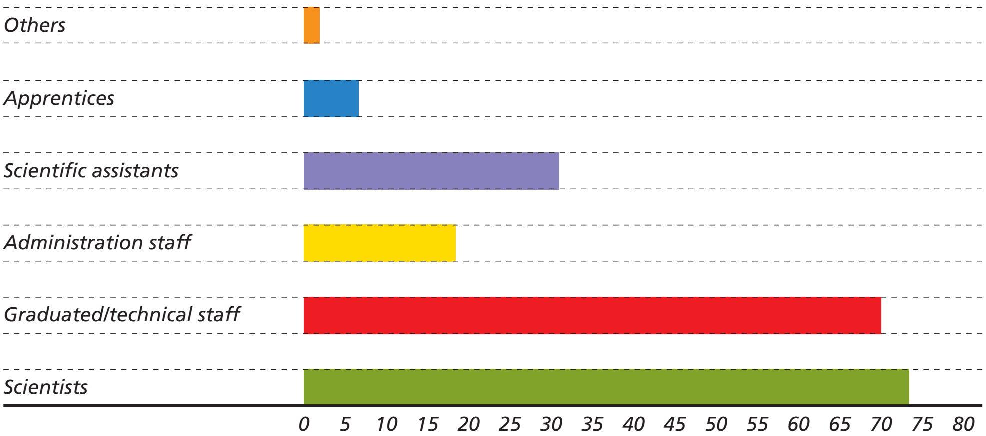
Income



STAFF DEVELOPMENT

At the end of 2014 the staff consisted of 157 employees. 73 were employed as scientific personnel, 70 as graduated/technical personnel and 18 worked within organisation and administration. The employees were assisted through 31 scientific assistants, 7 apprentices and 2 others.

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 66 institutes and research units. The majority of the nearly 24.000 staff are qualified scientists and engineers, who work with an annual research budget of more than 2 billion euros. Of this sum, around 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.

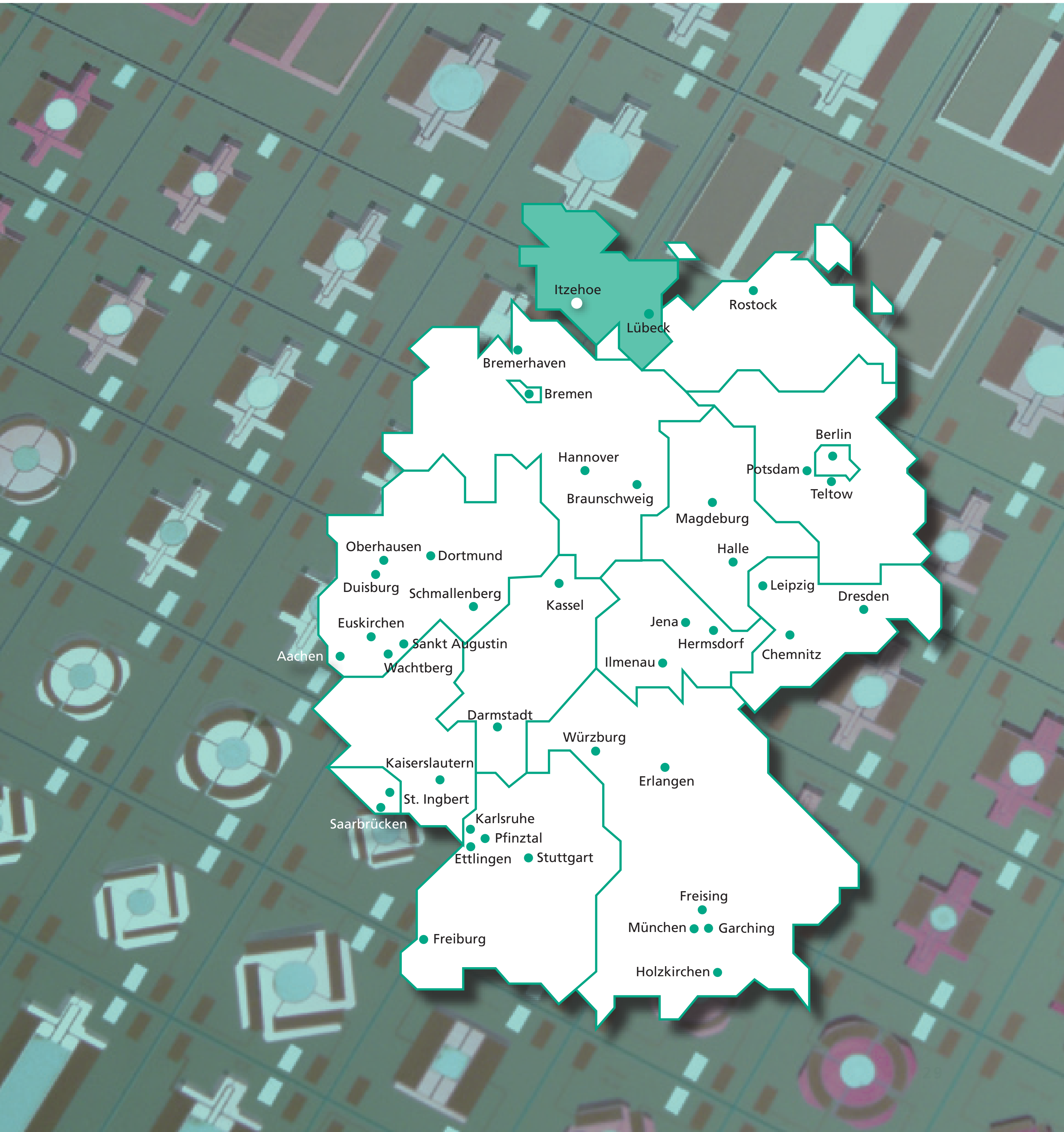
With its clearly defined mission of application-oriented research and its focus on key technologies of relevance to the future, the Fraunhofer-Gesellschaft plays a prominent role in the German and European innovation process. Applied research has a knock-on effect that extends beyond the direct benefits 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.

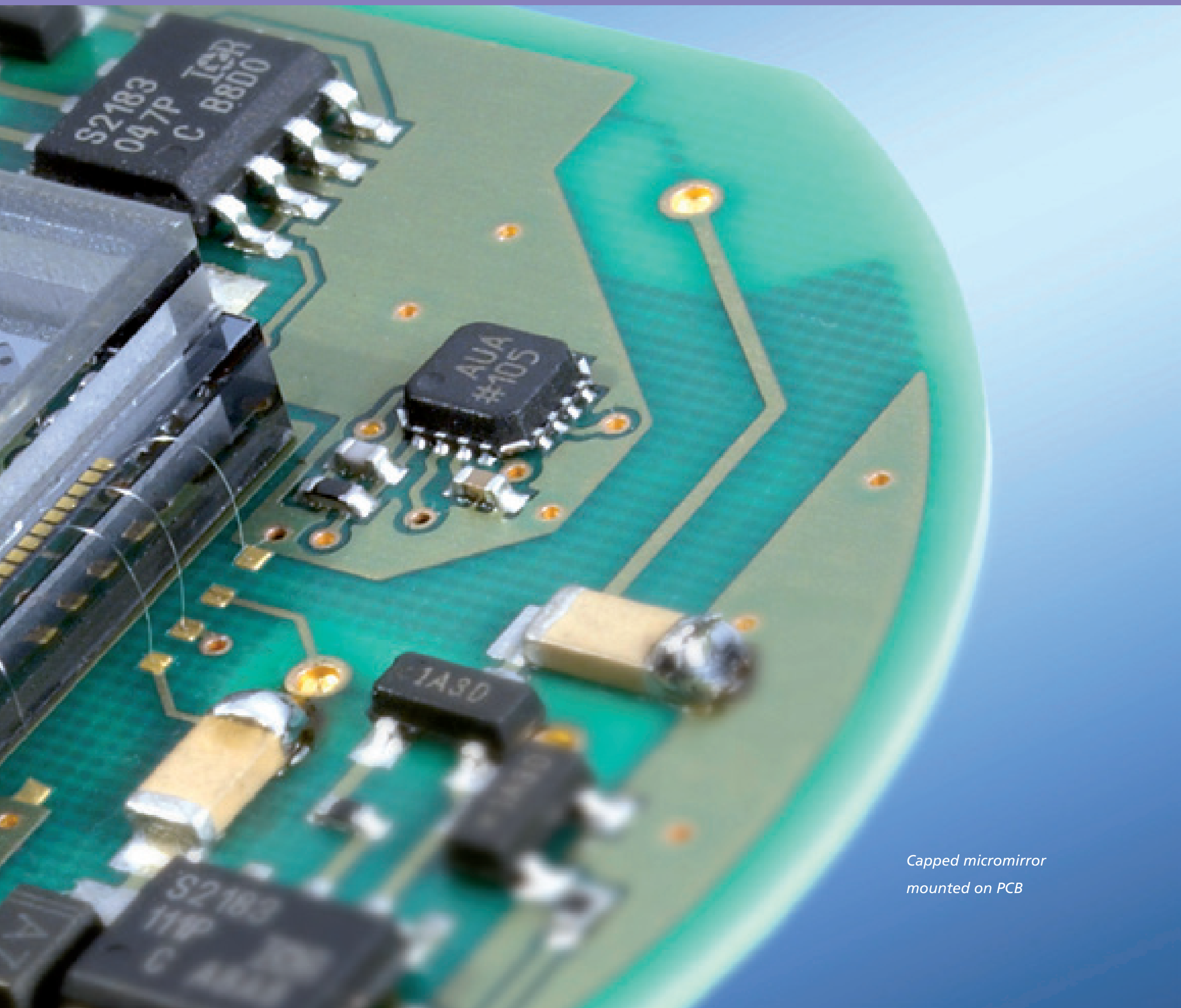
www.fraunhofer.de

LOCATIONS OF THE RESEARCH FACILITIES



REPRESENTATIVE RESULTS OF WORK

MICROSYSTEMS TECHNOLOGY, MEMS AND IC DESIGN



Capped micromirror mounted on PCB

DEPOSITION AND INTEGRATION OF PIEZOELECTRIC FILMS OF UNIQUE THICKNESSES FOR NEW FIELDS OF APPLICATION

Introduction

The ultrasound (US) imaging is one of the most important fields of technical acoustics. Ultrasound transducers of various frequencies are elementary parts in medical diagnostics, non-destructive testing (NDT) and inspection (NDI) or ultrasonic microscopy. For medical ultrasound, center frequencies in a typical range of 2,5 MHz to 15 MHz are used to date. The generation of ultrasound in this frequency range is commonly realized by piezoelectric bulk ceramics in form of massive plates or mechanical machined, separated elements of these ceramics. However, for particular medical fields of application (vascular diagnostics, dermatology, dental medicine, ophthalmology) there is a growing demand for higher resolution which can be realized by transducers that work at higher center frequencies. Also NDT and NDI require a wider range of center frequencies from 10 MHz up to 100 MHz.

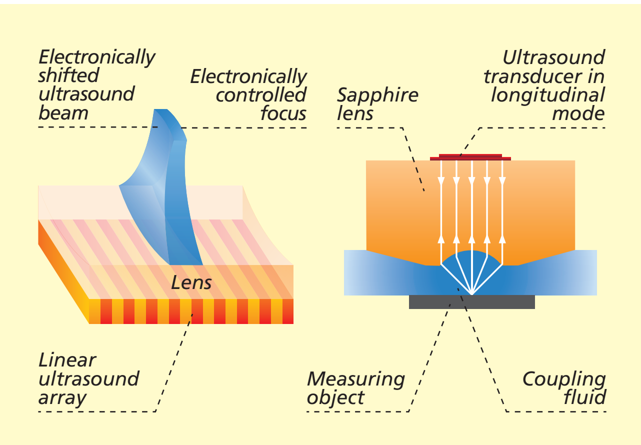


Figure 1: Principle of a linear phased-array ultrasound transducer and the high-frequency ultrasound microscopy

The main reasons for a weak diffusion of MEMS compatible piezoelectric thin films in these applications so far, are a generally limited piezoelectric performance and the achievable film thickness of currently available films.

The aim of the BMBF funded project "KOLUMBUS" was to overcome these challenges. Based on the results of a previous collaboration work between the Fraunhofer ISIT and the Fraunhofer Institute for Surface Engineering and Thin Films (Fraunhofer IST, Braunschweig), "KOLUMBUS" was initiated in the frame of a VIP project to validate the innovation potential of a promising deposition technology: the so-called gas flow sputtering. As the main objective of the project, a new and innovative system consisting of a MEMS fabricated high-resolution ultrasonic transducer and a complex high-frequency multichannel control unit was targeted. A consortium of 3 Fraunhofer institutes was involved in the project:

- Fraunhofer Institute for Biomedical Engineering (Fraunhofer IBMT, St. Ingbert)
- Fraunhofer Institute for Silicon Technology (Fraunhofer ISIT, Itzehoe)
- Fraunhofer Institute for Surface Engineering and Thin Films (Fraunhofer IST, Braunschweig)

To fulfil the ambitious aims, the project has been separated in 3 major working fields. In the first one, a deposition process for lead zirconate titanate (PZT) has been developed and optimized to synthesize piezoelectric thin films of certain properties and thicknesses (ISIT, IST), suitable as a basis for high-frequency ultrasound transducers. In the second working field, designs for various multi- and single-element US transducers have been projected and a MEMS compatible process flow for their fabrication has been conceived (ISIT). Moreover, the complete implementation of this process flow to fabricate the different ultrasound transducers on 200 mm silicon substrates has been realized at Fraunhofer ISIT. In parallel, the Fraunhofer IBMT worked on the design and the assembly of a multichannel control electronic, able to control high-frequency ultrasound transducers with up to 128 single elements and a frequency range of 50 MHz to 100 MHz.

Deposition process development

To achieve an appropriate ultrasound output, the functional thin films for the transducers have to exhibit a piezoelectric activity, quantified by piezoelectric constants $d_{33,f}$ and $e_{31,f}$, as high as possible. Lead zirconate titanate (PZT) is a ferroelectric material characterized by piezoelectric properties that exceed those of aluminum nitride (AlN) or zinc oxide (ZnO) by about one order of magnitude. The Fraunhofer ISIT is working on different deposition technologies for PZT thin films and their integration in MEMS compatible process flows for the fabrication of piezoelectric MEMS (piezoMEMS) for several years already. In collaboration with the Fraunhofer Institute for Surface Engineering and Thin Films (Fraunhofer IST, Braunschweig) a deposition process for thick PZT films, based on the so-called gas flow sputtering (GFS), was developed. Compared to competing deposition techniques, this process has certain characteristics which match the requirements for the realization of high-frequency ultrasound transducers:

- appropriate process temperature of 550° C to 600° C enabling an in-situ deposition
- high deposition rate of about 100 nm/min

Beside others, the nucleation and growth of the ferroelectric phase of PZT strongly depends on the thermal conditions

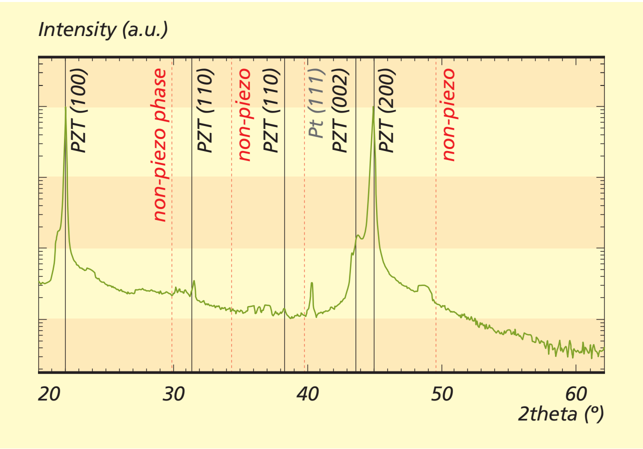


Figure 2: Crystallographic analysis of gas flow sputtered PZT thin films by XRD showing a pure perovskite phase with a distinct (100)-orientation and without any traces of competing non-piezoelectric phases

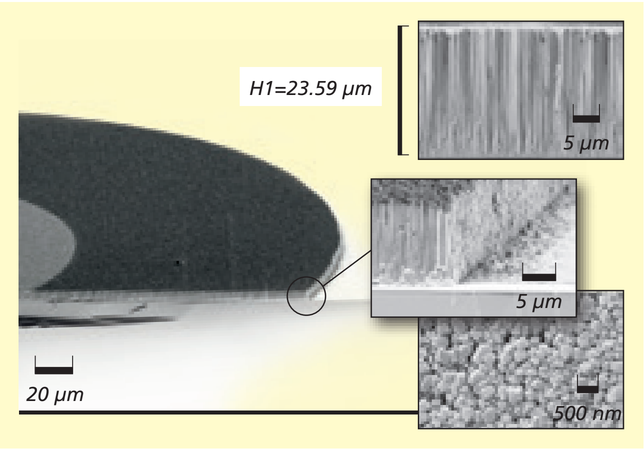


Figure 3: Scanning electron microscopy images of a single element ultrasound transducer. The pictures on the right show the characteristic columnar microstructure of the PZT in cross section and surface view

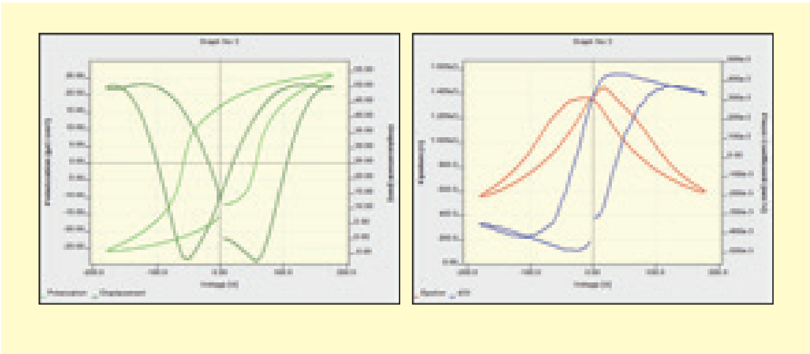


Figure 4: Large signal film displacement measurement and hysteresis loop (left) and small signal measurement for the determination of the longitudinal piezoelectric constant $d_{33,f}$ (right)

the material is exposed to. Applying process or annealing temperatures that are both, either too high or too low, result in PZT films with competing, non-piezoelectric phases which have to be minimized. Classical deposition technologies for PZT thin films are often characterized by multi-step processing, consisting of the deposition process itself and additional post-annealing steps. The GFS process is called an in-situ deposition process as the achieved process temperatures are high enough to nucleate and grow the piezoelectric perovskite phase of PZT. Additional annealing treatments become obsolete.

Although the gas flow sputtering process can be assigned to the reactive sputtering processes, the characteristic high plasma density of this technique results in high deposition rates even for oxidic materials. As a consequence, PZT film thicknesses of >20 µm, which are necessary for the targeted US frequencies, can be established within an acceptable time period.
Another GFS specific film property is the distinct columnar microstructure of the PZT thin films. Depending on applied process parameters, a film morphology from very compact to exceedingly columnar, accompanied by a reduced lateral coupling of the single columns can be realized. As the US transducers are acting in the longitudinal mode (i.e. the exciting electrical field is parallel to the direction of polarization and the utilized film displacement), a lateral decoupling is of particular importance, as the single columns shall move flexibly in this direction. An indication for this behavior is a large piezoelectric performance in the out of plane direction of the film which is quantified by a large longitudinal piezoelectric constant $d_{33,f}$ of up to 500 pm/V for these films. Values of these dimensions are comparable to bulk PZT ceramics.

Integration of thick PZT films for the fabrication of high-frequency ultrasound transducers

In the project "KOLUMBUS" ultrasound frequencies from 50 MHz to 100 MHz have been targeted. These are determined by the PZT film thickness which has to be in a range of 22 µm to 28 µm for the gas flow sputtered films.
PZT layers of these thicknesses cannot be patterned by conventional dry etching techniques anymore. As it is a particular objective within the project to fabricate US transducer arrays able to manipulate the ultrasound wave front, a new way to structure the thick PZT films had to be found. Therefore, an indirect method has been conceived and utilized which includes a pre-patterned Si substrate on which the PZT film grows in a self-structuring way afterwards.

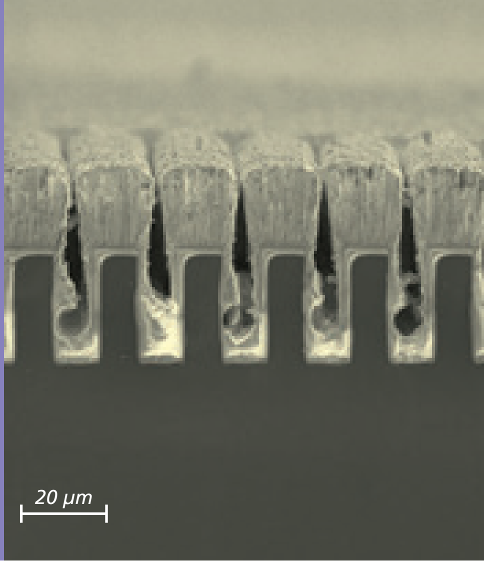


Figure 6: Structuring of thick PZT films for a separation of individual ultrasound elements by patterning the underlying silicon substrate

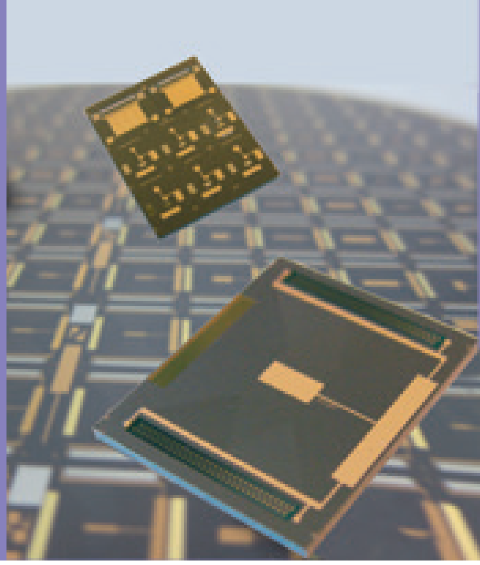


Figure 8: 200 mm device wafer with various single- (top left) and multi-element (bottom right) ultrasound transducers

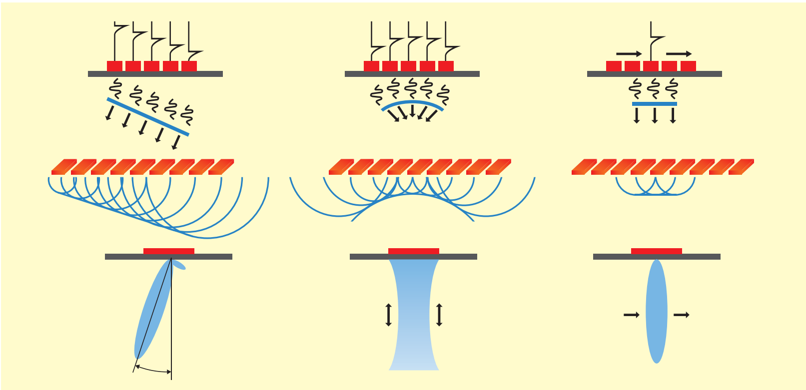


Figure 5: Manipulation of an ultrasound wavefront for an array consisting of individually controlled single elements. The ultrasound beam is formed and shifted by phase-shifting of the excitation signals

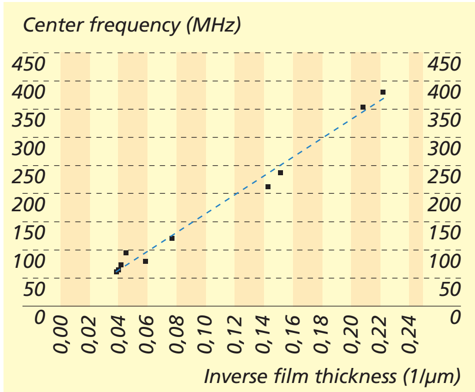


Figure 7: Realized center frequencies of ultrasound transducers by adapting the PZT thickness

In combination with a lift-off process for the platinum bottom electrode, each single element of a transducer array can independently be electrically excited and allows a swinging, focusing and the translation of the ultrasound beam.
As thin films become rougher with increasing thickness, resolution-critical lithography steps have been shifted before the deposition of the thick PZT layer. As a result, very fine electrode arrays with line widths down to 6 µm and pitches of 10 µm could be realized. The top electrode structures, consisting of a thin chromium adhesion layer and 250 nm thick gold films, were designed as large area metal electrodes with minimum requirements for the lithography on top of the rough PZT. Large area openings in the PZT to get an access to the platinum bottom electrodes were realized by a newly developed and optimized multistep PZT wet etching process. In this way, various single-element and multi-element ultrasound transducers of different center frequencies, as well as piezoelectric test structures for the PZT thin film characterization have been fabricated on 200 mm silicon substrates.

Name of project
Kolumnares Blei-Zirkonat-Titanat für leistungsstarke hochfrequente Ultraschall-Arrays, *Short name: KOLUMBUS*
Funding code
16V0202
Type of project
VIP (Validierung des Innovationspotentials wissenschaftlicher Forschung)
Project partners
Fraunhofer IBMT Fraunhofer ISIT Fraunhofer IST
Duration of project
2.5 years
Funding amount
980.025,00 €

First analyses of US transducers in combination with a newly developed and adapted multichannel control unit for digital phased array systems (DiPhS) with fre-quencies up to 100 MHz revealed a sound pressure which was a factor of 12 higher than transducers based on the piezoelectric material zinc oxide.

Author: Dirk Kaden

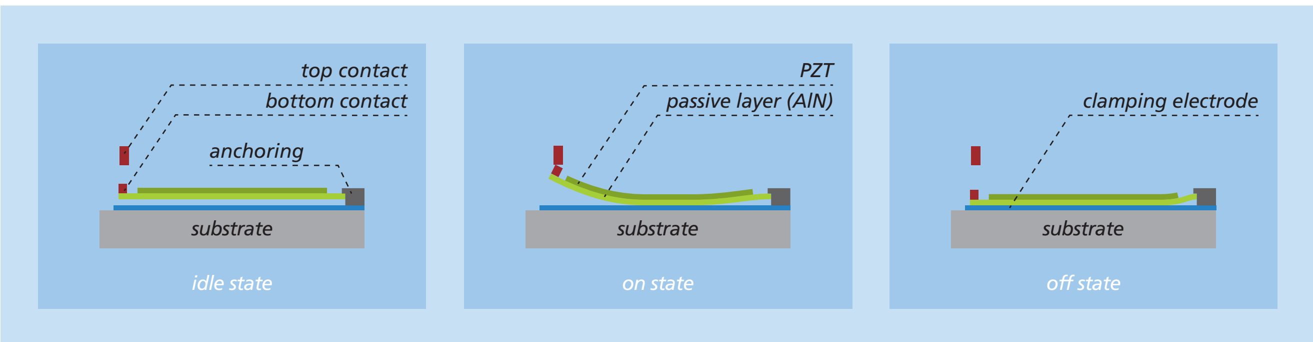
NOVEL PIEZOELECTRIC OHMIC SWITCHES FEATURING FAST SWITCHING AND HIGH CONTACT FORCES

It is increasingly challenging for RF switches fabricated in common IC technology to satisfy the rapidly growing demands of mobile communication systems. Therefore, micro mechanical (MEMS) switches are still of great interest, irrespective the fact that their breakthrough already has been predicted many years ago. Especially ohmic MEMS switches (MEMS relays) allow the transmission of signals in a wide range from DC to GHz frequencies with high isolation, excellent linearity and very low power consumption.

However, up to now sufficient reliability under load (hot switching) has not been demonstrated. Since the available forces in micro-scale actuators are typically low (< 100 µN), Gold (Au) is usually applied as contact material if a contact resistivity below 1 Ω must be met. But gold contacts stick easily, even under low load. Harder, high melting metals like Platinum (Pt), Ruthenium (Ru), Tungsten (W) or Molybdenum (Mo) decrease the sticking but presuppose significantly larger contact forces. Besides, the restoring force should be in the same range to overcome sticking effects during contact opening. To gain high forces at minimized device size has always been one of the main challenges in the realization of MEMS switches. To achieve that, a novel type of bidirectionally actuated MEMS switches has been developed at ISIT within the European ENIAC project "EPAMO".

Figure 1 illustrates the operation principle. The switch is based on a circular shaped piezo actuator consisting of PZT (active layer) on top of AlN (passive layer). In the idle state (see figure 1), the actuator is suspended above the substrate with a minimum gap. The anchoring is designed in a way that the actuator deformation, which is of spherical nature, is impeded as less as possible. If a voltage is applied, the PZT film contracts and forces the actuator to form a dome shape with increased mechanical stability. Due to the asymmetric anchoring on one side and the low gap, the dome shaped actuator becomes tilted and touches the substrate after contact closing ("on-state", figure 1). Thus, the effective

Figure 1: Illustration of the operation principle



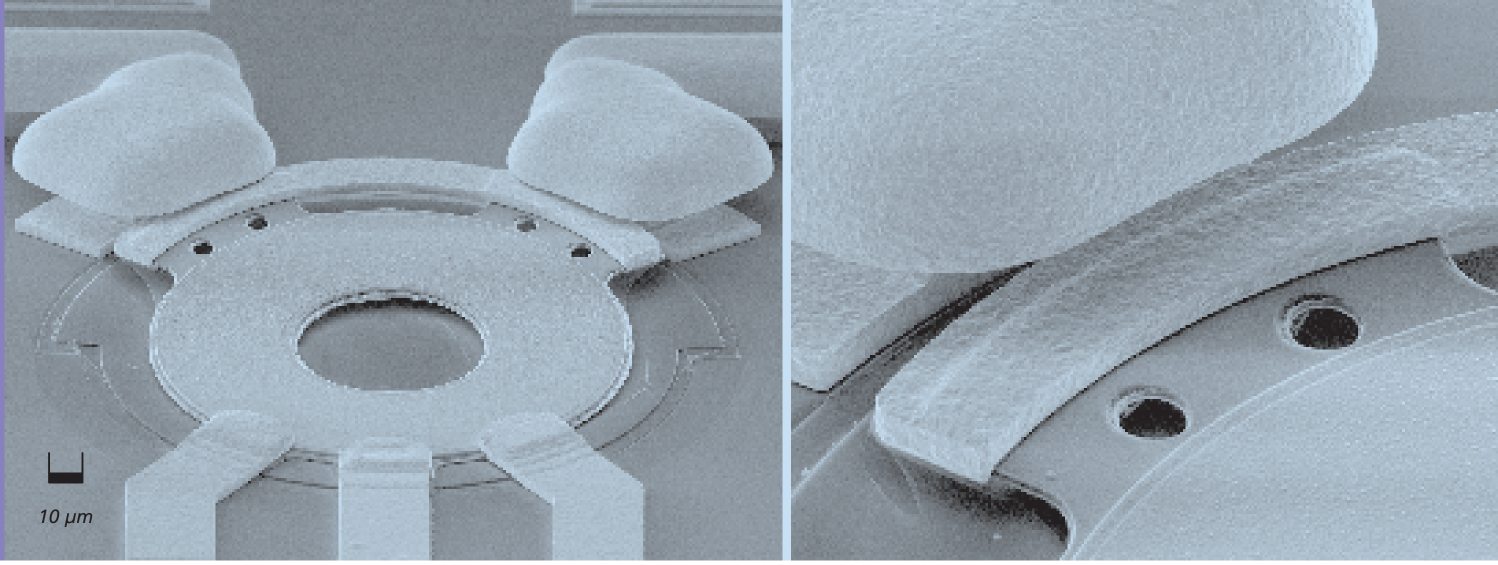


Figure 3: SEM images of a particular switch design with a ring-shaped piezo actuator (160 µm in diameter).

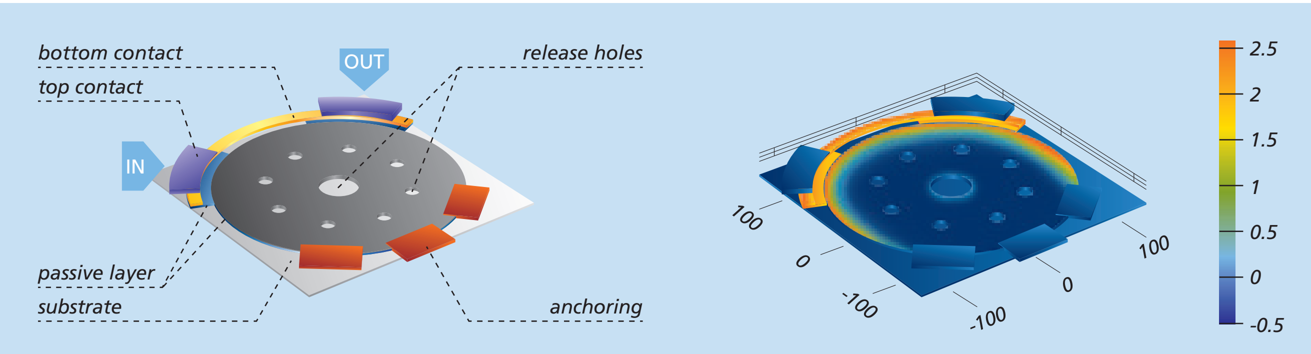


Figure 2: Schematic (left) and FEM simulated displacement field (right) of a particular switch design

leverage length is reduced significantly. Thanks to both effects high contact forces can be achieved. For particular designs, FEM simulations indicate forces well above 1 mN for actuators with a diameter of only 160 µm.

In order to achieve a high restoring force, the contact opening is supported electrostatically by applying a voltage to the clamping electrode underneath the piezo-actuator. Since the actuator is in contact with the substrate in the on state, even at low voltages high electrostatic attraction forces are created due to the zipper effect. To maintain a well-defined large gap over a certain temperature range independently from process variations, the actuator can be held clamped during off state (see figure 1).

Figure 3 presents SEM images of a first switch prototype with gold contacts. The ring-shaped actuator is only 160 µm in diameter. Reliable operation of the piezo actuator at up to 25 V driving voltage has been demonstrated. At 20 V driving voltage total resistance values below 300 mΩ were measured. At the same time the on/off-switching speed is less than 1 µs. Applying 60 V to the clamping electrode beneath the actuator has found to be an effective measure to overcome sticking caused by welding of the Au-Au contact in the case of hot switching.

Authors:
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Fabian Stoppel

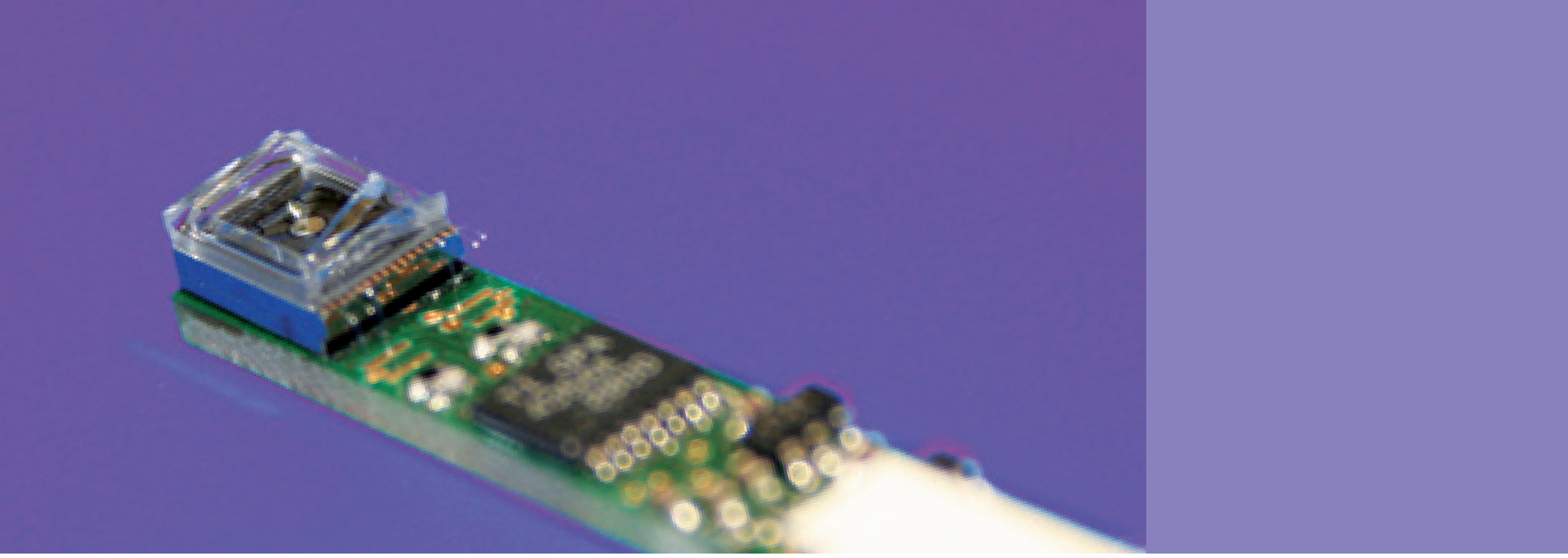


Figure 1: 2D-MEMS Scanner with tilt glass capping

SCAN APPLICATION WITH NUMERICAL DISTANCE AND RANGING ANALYSIS – SANDRA

The need for 3D imaging increases constantly in industrial applications, mainly for object recognition, terrain exploration, inspection or surveillance systems. Fraunhofer ISIT has developed a 3D-camera that uses the principle of phase difference measurement between an emitted laser beam and its reflected "echo". In contrast to other phase modulation cameras, the ISIT system operates with a resonant driven 2D scanning micro mirror (see figure 1). The mirror plate has a diameter of 1mm and deflects a modulated laser beam in a way that a solid angle of roughly 38°x 38° is illuminated. The returning light from this solid angle is collimated through a receiving lens system and an avalanche photodiode (APD) converts it to an electrical signal. A newly developed algorithm enables the camera to achieve a resolution of 450x 450 pixels. With only 17ns for a single phase measurement, the system performs roughly 60 million 3D-measurements per second.

Presently, the electronics consists of two FPGAs, one (FPGA1) operating for the closed loop control of the 2D-MEMS scanner, the other one (FPGA2) operating the sub-Nyquist sampling algorithm and additionally controlling the laser pulses and the detection circuit. Once the functionality of the

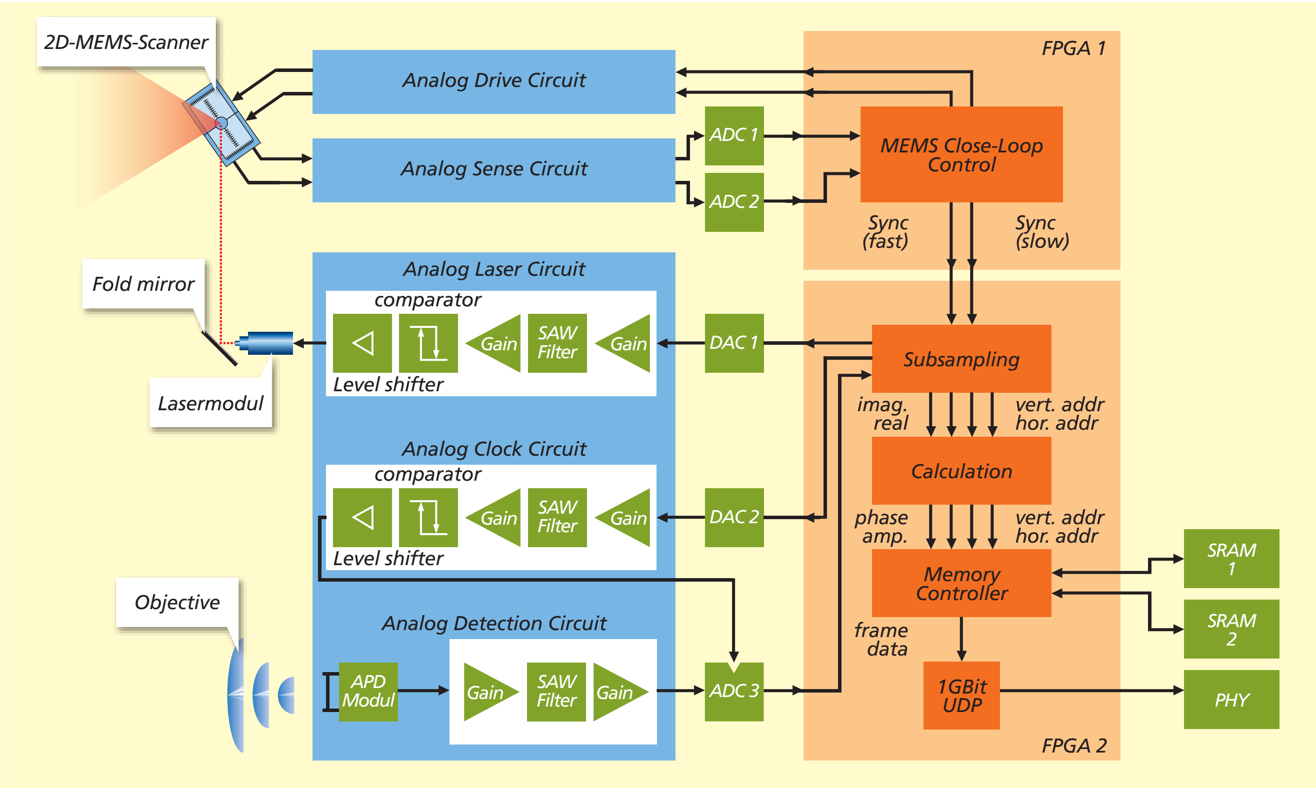


Figure 2: System block diagram

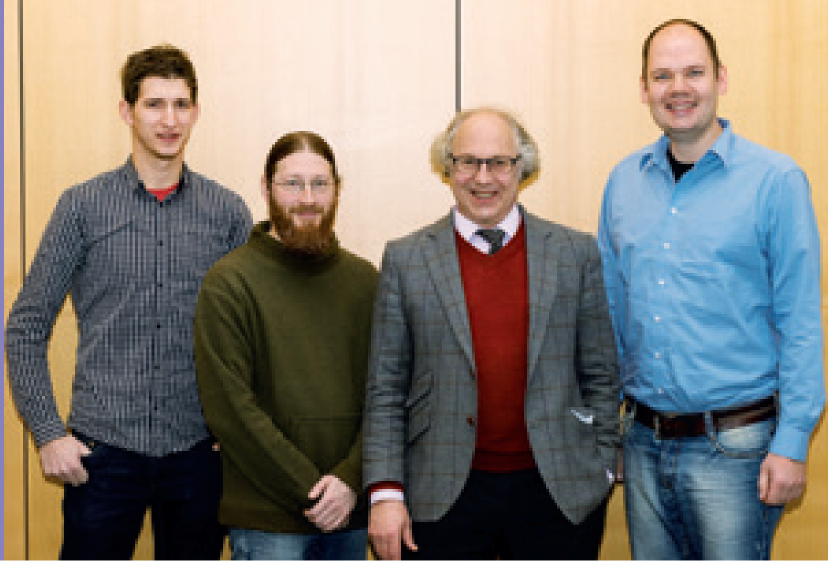


Figure 5: The team of the SANDRA project, from left to right: Lucas Weiler, Sven Grünzig, Joachim Janes, Thorsten Giese

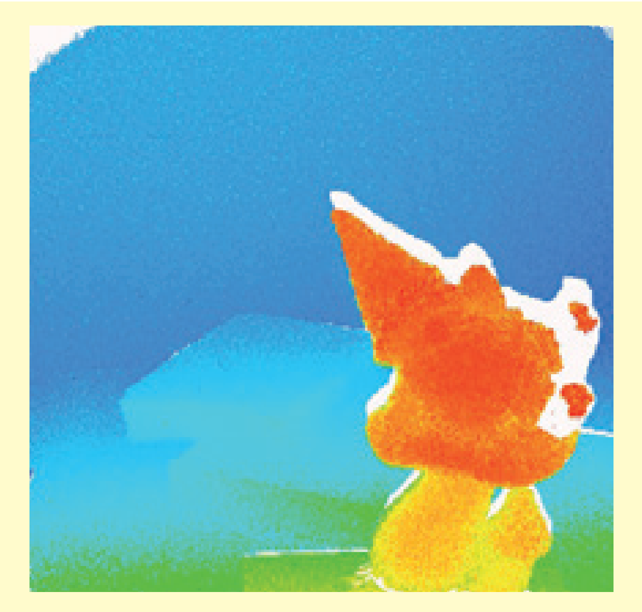


Figure 3: Phase image each with an exposure time of 0,1 sec
Figure 4: Amplitude image

electronics is proven, the two FPGAs may be merged. The synchronization signals of the two driving circuits of the two scanner axes enter the sub-sampling electronics of FPGA2. In this FPGA2 two frequencies are generated with a frequency ratio of e.g. 5/4. The higher of these frequencies is used to generate the appropriate steering signals in the analogue laser circuit (see figure 2) to operate the laser module. The lower frequency is input to the analogue clock circuit operating the ADC3 in such a way that with each rising edge the signal of the analogue detection circuit is sampled. By doing so, the sampling values are evaluated in FPGA2 in order to gain the real and the imaginary part of these values. With the real and the imaginary values the phase and the amplitude of the sampled values are calculated. With these data in addition to the x- and y-coordinates from the MEMS control loop a 3D-image is composed.

With the amplitude and the phase information relative to the originally emitted signal, the mean reflectivity and distance of the object are scanned across the whole field of vision. However, the mirror performs a Lissajous scan, which means that the random trajectory has to be assigned to the correct X- and Y-positions. For this purpose, the synchronization signals from both the fast and the slow axis of the micro mirror are used, which requires a special memory controller.

A demonstrator system at Fraunhofer ISIT allows to adapt the 3D imaging system to various sceneries, e.g. depending on the exposure time of a frame, multiple measurements of the same pixel can be averaged. The data is transmitted via UDP-Ethernet link to a Windows-PC for visualization and control of the camera (see figures 3 and 4, respectively).

Author: Thorsten Giese

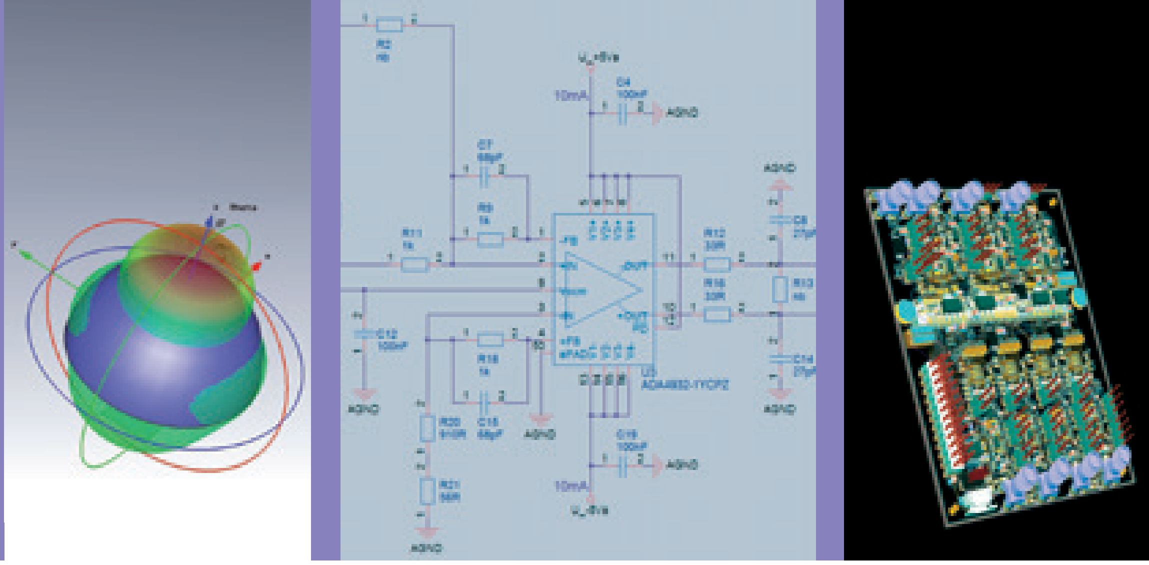


Figure 1: Cooperation areas of Fraunhofer ISIT and Fachhochschule Westküste:
Simulation > Circuit Design > PCb-Layout > Micro-Components > System Set-Up

PROJECT-GROUP: SENSORS FOR HUMAN-MACHINE-INTERACTION, FACHHOCHSCHULE WESTKÜSTE AND FRAUNHOFER ISIT

Cooperation with regional universities is one of the fundamental elements in the Fraunhofer business model, which is the promotion of the applied sciences according to the articles of the non-profit association ("Fraunhofer-Gesellschaft zur Förderung der angewandten Wissenschaften e.V."). Among the universities in proximity of Fraunhofer ISIT is the "Fachhochschule Westküste" (FHW, West Coast University of Applied Sciences) in Heide, with which a well-established student exchange and research cooperation exists for many years.

In order to strengthen the academic exchange between Fraunhofer institutes and universities of applied sciences, a new instrument recently created by Fraunhofer and the German federal and state ministries now allows a formal establishment of joint research groups. Together with the FHW, a cooperation baseline according to the new terms of collaboration was defined in 2013 and only a few months later, the final cooperation agreement was signed.
The initial work plan of the joint working group is arranged until end of 2017. In this timeframe, office and laboratory areas within ISIT and FHW are allocated for common R&D activities.

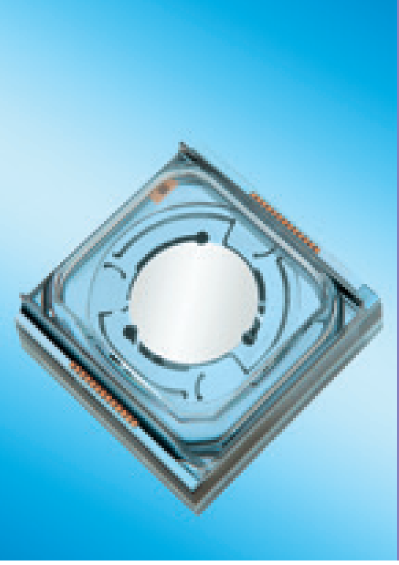
Work tasks of this group are directed towards new applications of the MEMS components and technologies that are developed and manufactured within ISIT. Following a strong trend in sensor application, the research cooperation targets the vast and complex field of "Human-Machine-Interaction" (HMI). Gesture and movement recognition are largely known as input devices for play-stations, TV-sets and smartphones, but industrial equipment suppliers take an increasing interest in these technologies to make their machines more intuitive and user-oriented.

Another environment are automotive user interfaces, like speech recognition to control driver assistance and multimedia systems while safely keeping the eyes on the traffic situation. But human-machine interaction can also operate in the background and take care of the user's needs without even being noticed: Smart, energy-efficient air conditioning systems measure the CO_2 level in the car and provide just the right quantity of fresh air to the passenger compartment. Microsleep prevention systems monitor the driver's eye blinking rate and protect the passengers from potentially dangerous situations. Many of these innovations pop into the market through a bottom-up approach: Their actual enablers are found on the component level, like a new technology or an economic manufacturing concept.

With the expertise of the Fachhochschule Westküste in the application of electronic systems, the working group can quickly provide the "early adopters" with prototypes that allow the evaluation and application-level testing of new micro-technologies developed at Fraunhofer. Initial work tasks with contributions to ISIT projects were:

- improved PCB design for miniaturized video projector control electronics (pico-projector),
- simulation of electromagnetic properties of metal micro-actuators,
- system design for a new LIDAR measurement system using micro-mirrors,
- process improvement and development for manufacturing of glass-based micro-optical components,
- set-up of a vacuum prober for characterization of IR-sensors.

The focus of the contributions from Fachhochschule Westküste is system design and PCB layout. For specific applications,



Fraunhofer employees have been trained by specialists from FHW. Up to now, eight FHW students have been engaged in ISIT projects, two of which finished their master thesis on Fraunhofer research topics.

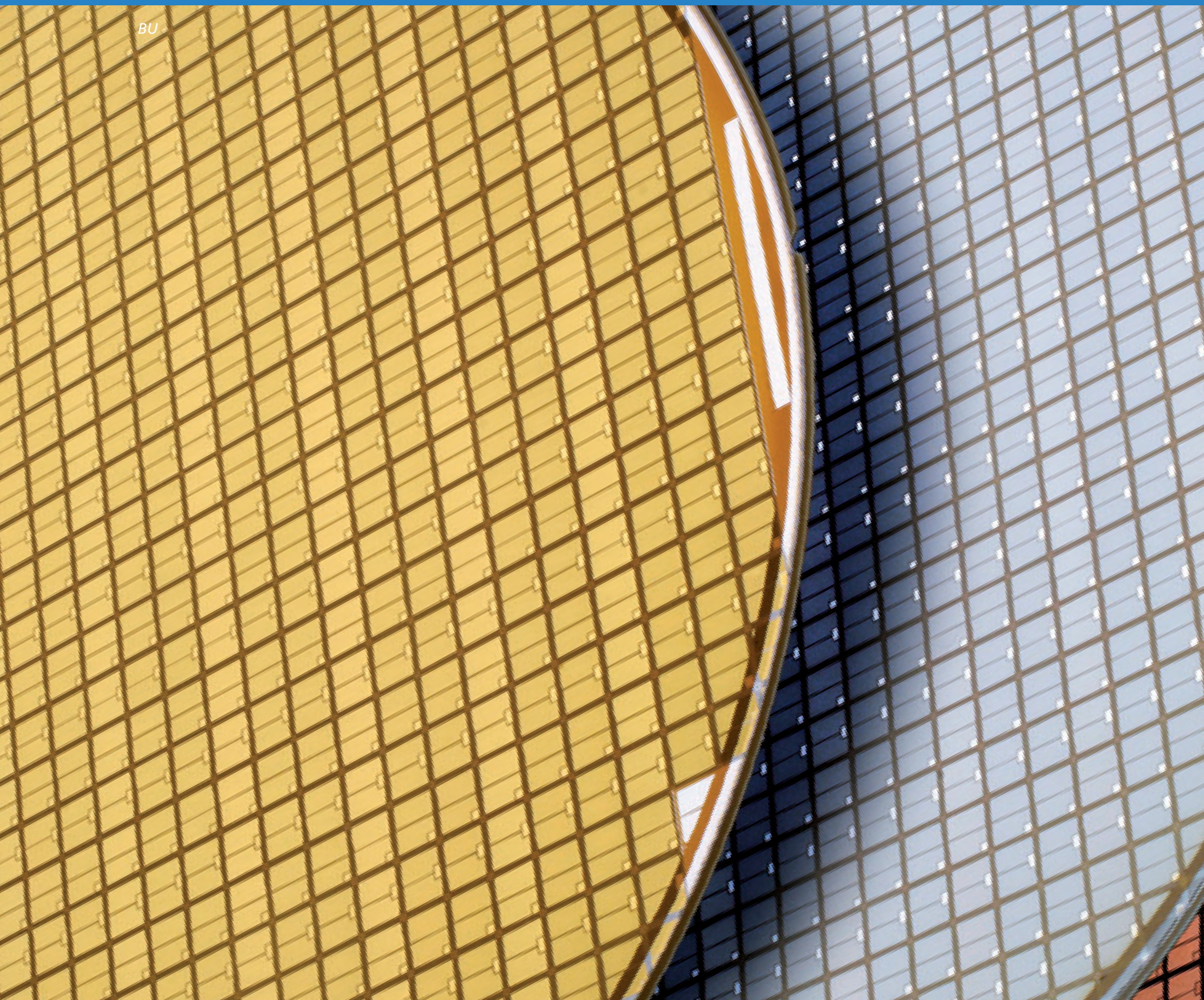
The project group will open an additional entrance to the services offered by Fraunhofer ISIT to companies that are oriented towards system- and application-level products. It is intended to organize new projects and to realize new industrial service contracts. First service offers to customers are in preparation in the areas of optical components and test of electronic components. The additional service offers of the new project group have been presented at several trade fairs like electronica 2014. For 2015, joint presentations of Fachhochschule Westküste and Fraunhofer ISIT are prepared at further exhibitions and trade fairs.

Author: Prof. Ralf Dudde

Figure 2: Joint Exhibition of ISIT and Fachhochschule Westküste at electronica 2014

REPRESENTATIVE RESULTS OF WORK

IC TECHNOLOGY AND POWER ELECTRONICS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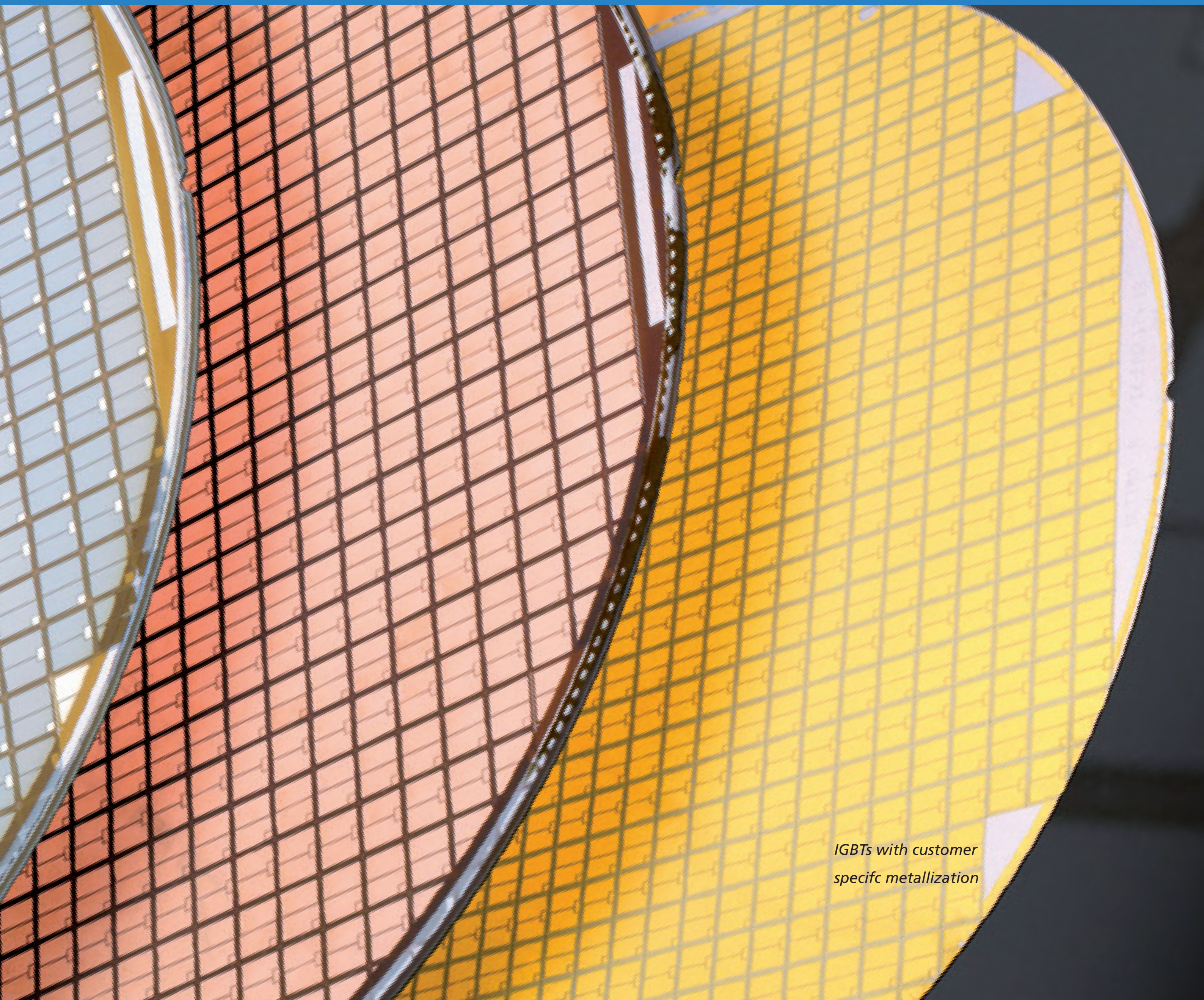


IGBTs with customer specifc metallization

FRAUNHOFER APPLICATION CENTER POWER ELECTRONICS FOR RENEWABLE ENERGY SYSTEMS IN HAMBURG

To further expand the renewable energy as a priority area in Hamburg and to combine the complementary strengths of the Fraunhofer Institute for Silicon Technology (ISIT) and the Hamburg University of Applied Sciences (HAW Hamburg), the Fraunhofer ISIT has founded an Application Center „Power Electronics for Renewable Energy Systems“ (ALR) at the HAW Hamburg as a branch office of the Fraunhofer ISIT. With the development of Application Centers, the Fraunhofer-Gesellschaft aims to facilitate the cooperation of Fraunhofer Institutes with Universities of Applied Sciences since 2012, as research and development at Universities of Applied Sciences are becoming increasingly important, often associated with a strong regional impact.

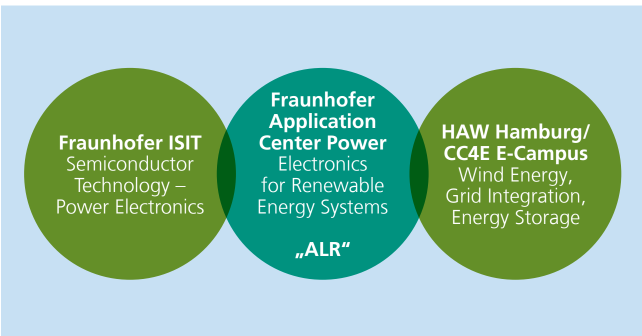


Figure 1: Combining the core competencies of Fraunhofer ISIT with University of Applied Sciences Hamburg

In the coming years, Prof. Dr. Holger Kapels, head of the Application Center, will build up a team of scientists, which will work especially in the development area of highly efficient and reliable power electronic systems. The focus of the activities lies on the design, simulation and implementation of novel circuit topologies and the assessment and prediction of power converter reliability using intelligent control methods. Systems for efficient energy storage based on new types of lithium batteries and intelligent battery sensors complete the scope of the work. From spring 2015, the Fraunhofer Application Center is located at Steindamm 94 in close proximity to the HAW Hamburg and the CC4E.

One focus area of the Application Center is the further development of high-efficiency bidirectional DC-DC converters for the integration of battery systems to DC-link.
The developed converter model adopts the non-inverting buck-boost topology that enables wide-range voltage conversion.

Furthermore, a new hybrid control scheme for achieving highly efficient power conversion is introduced. A 2.5 kW hardware prototype based on SiC-MOSFETs was fabricated and tested for performance verification. Experimental results show that the prototype achieves an efficiency of more than 97 % at 4 % load and an efficiency of more than 99% around the rated operating point.

The non-inverting buck-boost converter is often employed for these applications due to its relatively simple topology. Nevertheless, with the conventional control method, the converter has a distinct drawback, namely the low power conversion efficiency, especially during the transition phase

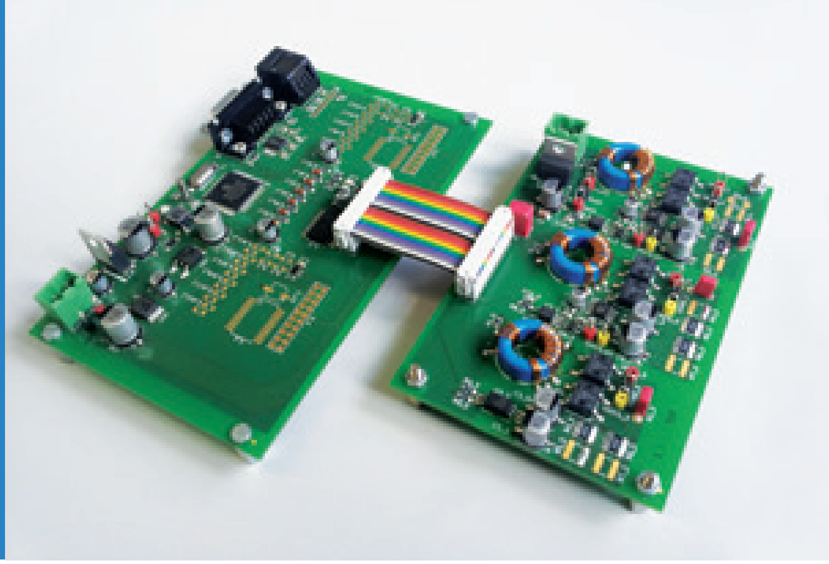


Figure 3: Microcontroller and Gate-Drivers realized in the Fraunhofer Application Center in Hamburg

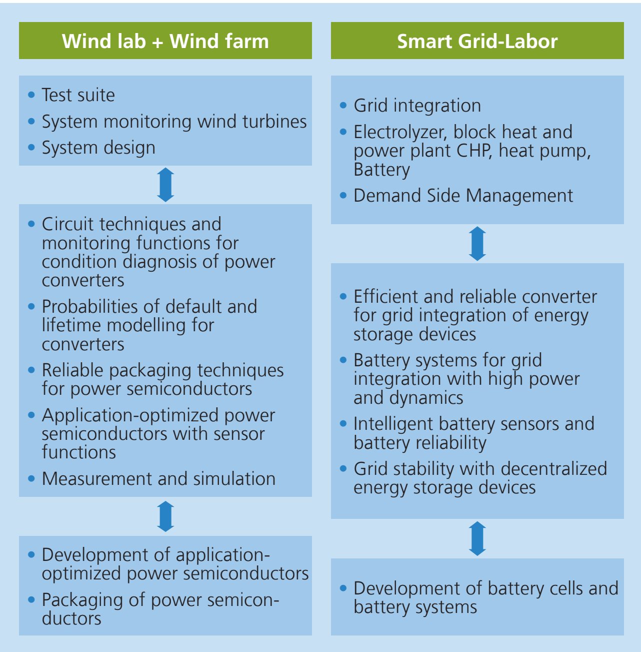


Figure 2: Synergies of Fraunhofer Application Center with Energy Campus Hamburg

between step-down and step-up mode. The non-inverting buck-boost converter is often employed for these applications due to its relatively simple topology. Nevertheless, with the conventional control method, the converter has a distinct drawback, namely the low power conversion efficiency, especially during the transition phase between step-down and step-up mode.

For the implementation of the hybrid control concept, it is not necessary to calculate optimal frequencies in real time – they can rather be calculated in advance and be stored in the microcontroller as a parameter set for each operating point. The optimal frequency is read out in real time depending on the measured input and output voltages as well as on the inductor current.

Simultaneously, the conduction losses in the power semiconductor devices and the copper and core losses in the inductor were be reduced to the lowest levels. As a result, the proposed DC-DC converter achieves extremely high efficiency over the entire load range.

Author: Prof. Dr. Holger Kapels

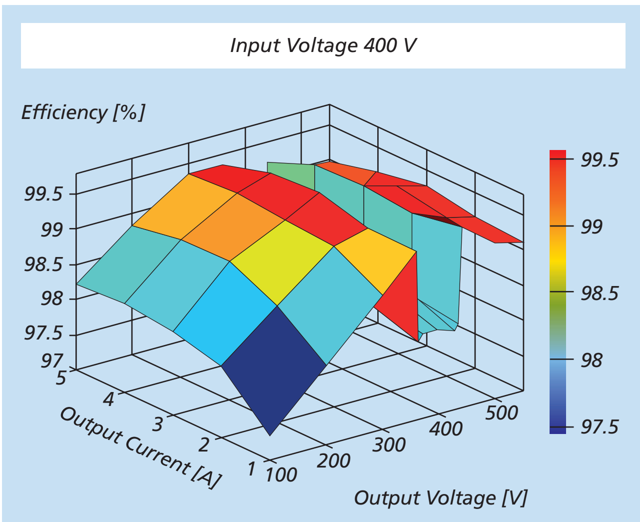


Figure 4: Conversion efficiency of the prototype

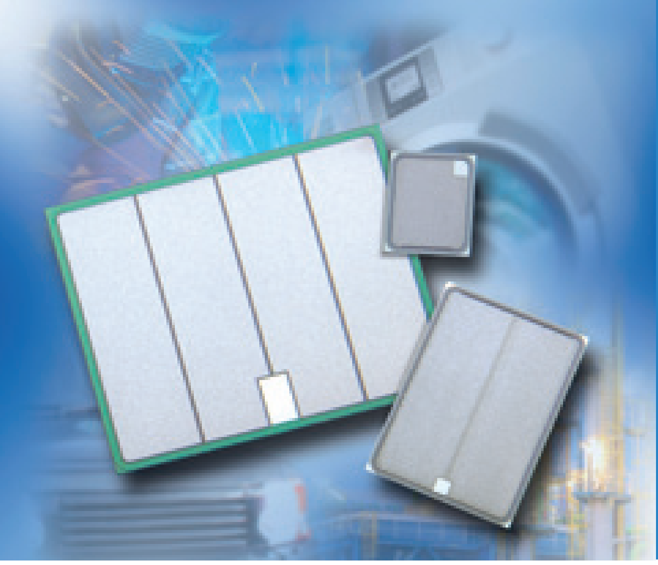


Figure 1: FS-IGBT family with nominal current range from 30 A up to 240 A

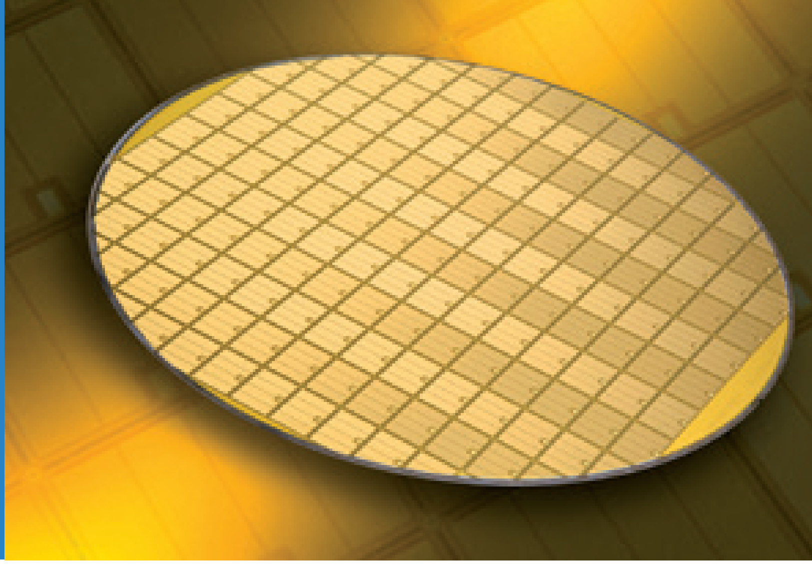


Figure 2: 8-inch wafer for application specific 1200 V / 200 A IGBTs with sinterable Ni / Au top metallisation

DEVELOPMENT AND PRODUCTION OF IGBTS IN ITZEHOE

Fraunhofer ISIT is cooperating with the industrial partner Vishay Siliconix Itzehoe GmbH in the field of Semiconductor Power Devices since 1998. Over the years an excellent technological platform for production and R&D was build up, so Itzehoe became to Vishay one of the most sophisticated semiconductor location for power devices worldwide.

Within a bilateral R&D project started in 2011, ISIT and Vishay are jointly developing so called Punch-Through (PT-IGBT) and Field-Stop IGBTs (FS-IGBT). As a result of this collaboration, first IGBT products for 600/650 V ranging from 30 A up to 240 A have been qualified (figure 1). Those high performance IGBTs are within the best of their group and on a competitive level with the market leader products worldwide.

IGBTs (Insulated Gate Bipolar Transistor) are key components for a wide range of converter applications in the mid and high power regime, being used as power switches for 600 V up to several kV. Next to the typical operational area of IGBTs in power conversion, new emerging markets with potentially high growth rates are coming up for e.g. drives control of electrical vehicles and renewable energy applications like photovoltaic and wind energy systems.

A joint ISIT and Vishay team consisting of scientists and engineers are developing new generations of 600 V and 1 200 V trench IGBTs based on a state-of-the-art front end production technology for power devices and a new technology approach for IGBT back side processing.

Some innovative technology features introduced for the new IGBT power device platform are:

- high density trench based front end technology for PT- and FS-IGBTs,
- ultra-thin IGBT devices for efficiency improvement,
- laser anneal dopant activation for the back side emitter and field stop layers,
- solderable and sinterable front and back side metallisation.

First IGBT products have been qualified in 2014, which was followed by customers sampling and production ramp up in Itzehoe. At the international exhibition "Electronica" Vishay introduced their new 600/650V IGBT family and entered to the market as a future IGBT manufacturer for mass production. Together with a new generation of Vishay Free Wheeling Diodes (FRED), specially adapted IGBT/FRED pairs are available for high performance inverter application.

Excellent opportunities for strengthening the power electronic activities at ISIT are given by the unique feature of having R&D and production of IGBTs and PowerMOS at Itzehoe. Based on qualified power devices, system specific optimisation can be offered, like IGBT trade-off adjustment for new circuit topologies. Special customer requirements for new assembly techniques can be addressed by e.g. layout adaptation or implementation of new metallisation layers. Application specific integration of gate resistors or current/temperature sensing can be applied for system performance improvement.

An important example in this context is the "Innovation Cluster Power Electronics for Renewable Energy".
This project is being funded by the Ministry of Economy of Schleswig-Holstein and the Fraunhofer-Gesellschaft with the

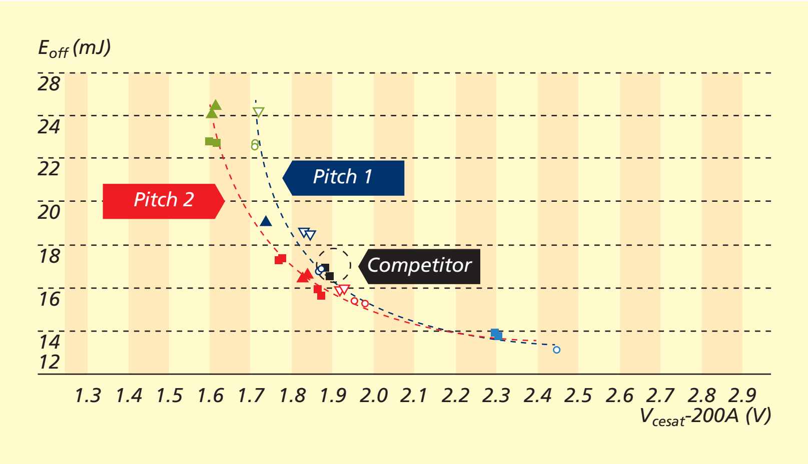


Figure 3: Trade-off curve for application specific FS-IGBTs with two different cell density values (pitch 2 < pitch 1)

goal of regional development by strengthening innovation and competitiveness in the field of power electronics.
A consortium consisting of industrial companies (Vishay, Danfoss, Senvion, Reese+Thies, FT-Cap), academic institutions (CAU, FH Kiel, FH Westküste, FH Flensburg) and Fraunhofer ISIT are developing new components for highly reliable and efficient three-level Neutral Point Clamped (NPC) power stacks for wind energy application in the MW range.

In order to comply with the specifications of the three-level power stack and the new Danfoss Bond Buffer (DBB) module assembly technique, application specific 1200 V / 200 A FS-IGBTs have been developed by ISIT and Vishay. Special layout adjustments and a sinterable Ni/Au front side metallisation were considered to fulfil the DBB requirements (figure 2).

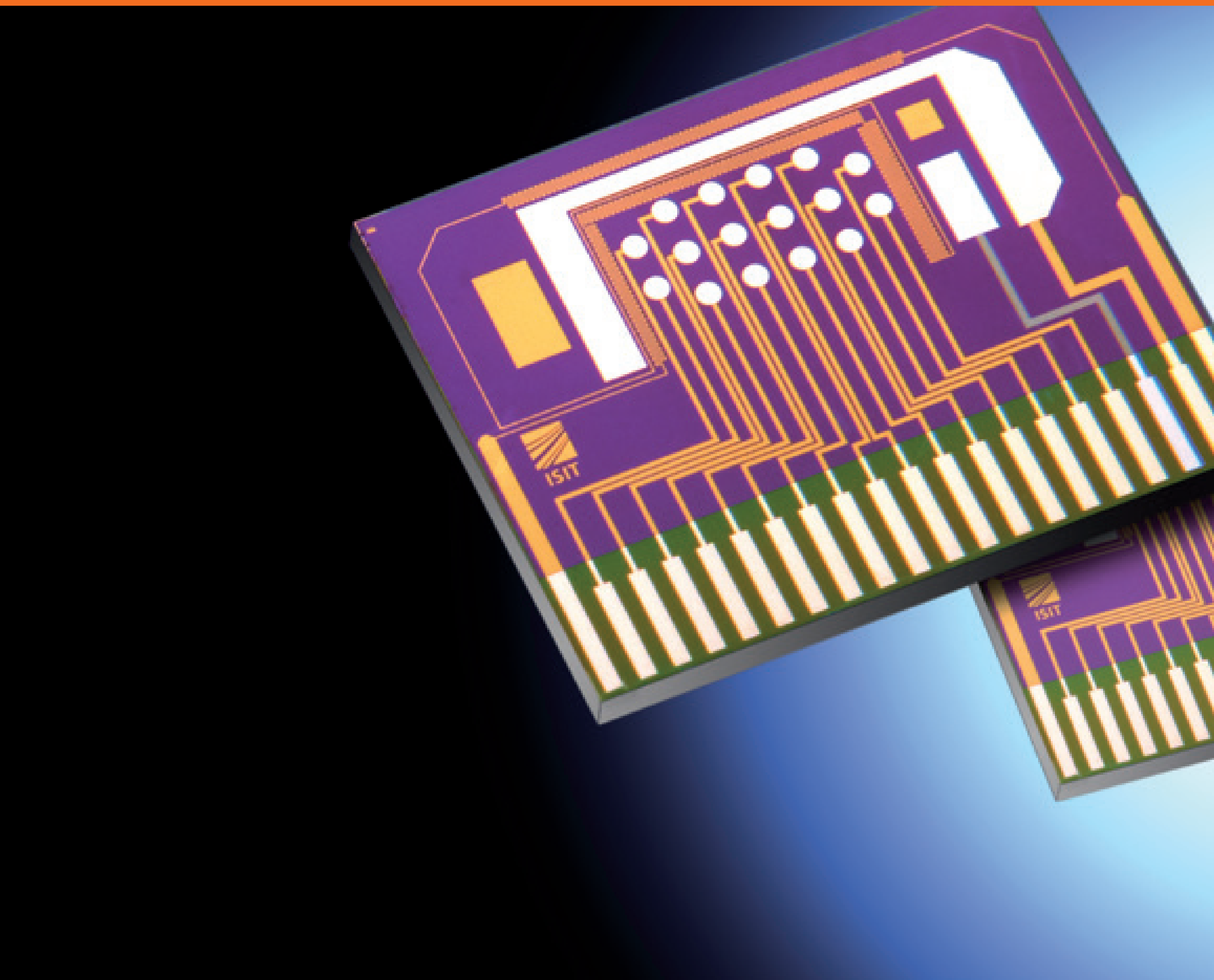
An excellent trade-off characteristic (figure 3) has been reached by varying the emitter efficiency for FS-IGBTs having two different cell densities (pitch 2 < pitch 1).
From these investigations, E_{off}/V_{cesat} values were extracted and an optimum trade-off relation could be chosen (E_{off}: energy loss off-switching, V_{cesat}: voltage drop on-state). Additionally, a short circuit capability of 10 µs has been confirmed according to the requirements for the converter. A positive temperature coefficient of V_{cesat} was ensured for easy paralleling of the IGBTs since the 1 MW power stack is specified for 600 A nominal current (three 200 A IGBTs per switch).

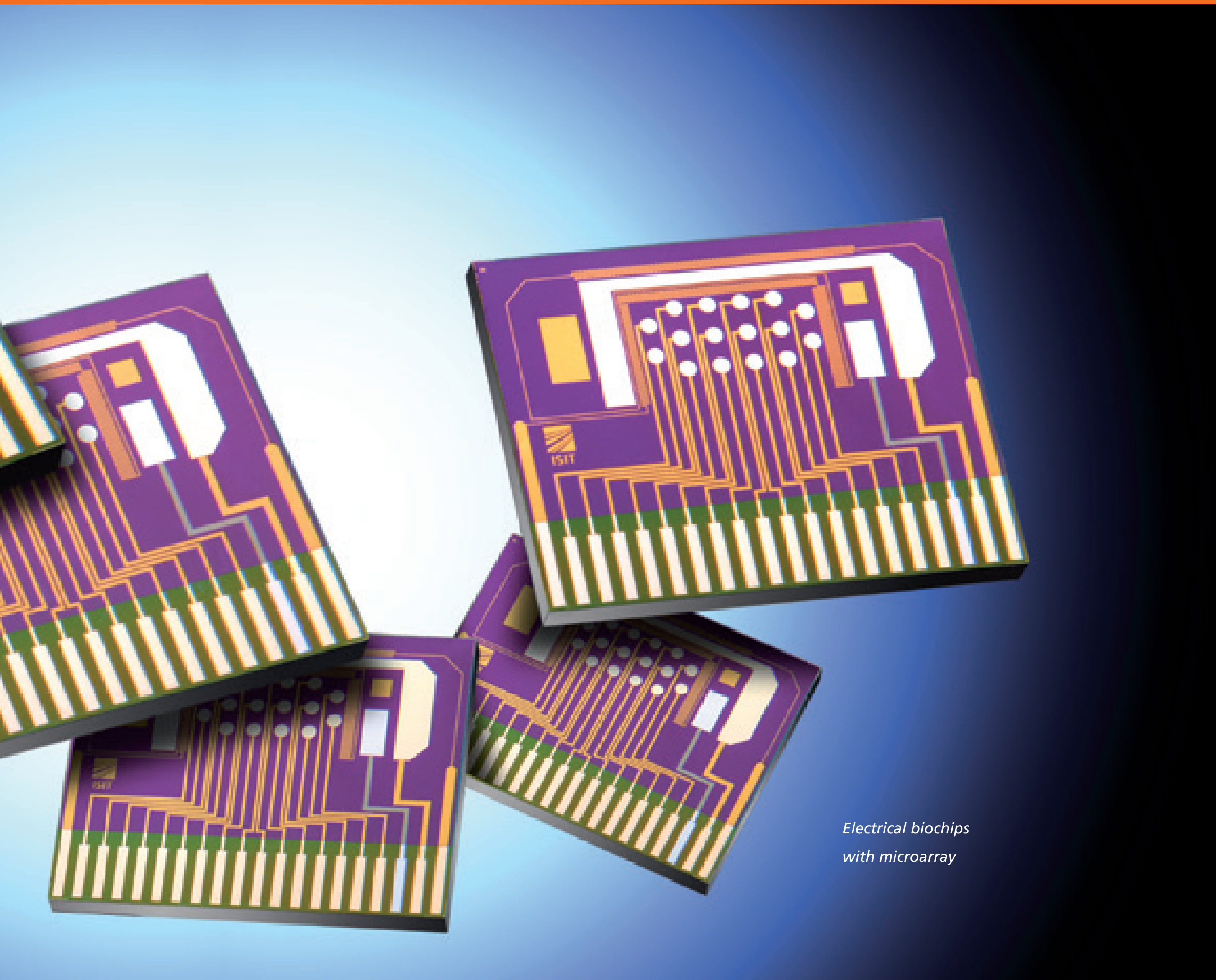
In summary, the availability of IGBT development and production in Itzehoe is a further building block for supporting power electronics activities at ISIT with an excellent future perspective.

Author: Detlef Friedrich

REPRESENTATIVE RESULTS OF WORK

BIOTECHNICAL MICROSYSTEMS





Electrical biochips
with microarray

MICRO SENSORS FOR CELL-FREE BIOPRODUCTION: MICRO PORE MEMBRANE CHIPS FOR TRANSMEMBRANE PROTEIN ANALYSIS

There is a continuously growing market for native and complex proteins, especially for pharmaceutical use and for food and cosmetics industry. Until now the industrial production of several proteins is performed in living cells. The required technology like fermenters is expensive and the yield in these systems is insufficient compared to the amount of cell culture (10 mg to 1 g output in 1 kg culture). The product extraction needs highly sophisticated separation technology, therefore the economic efficiency is sometimes limited. Furthermore, the production of pharmaceutically relevant but toxic proteins is often hindered because the cells are killed by their own product.

As an alternative to these cell-based systems, the cell-free bioproduction performed in cell lysates was established during the recent years. The synthesis of special proteins in a cell lysate driven by introduced plasmid DNA very often leads to better efficiency in an even lower amount of time.

Fraunhofer started an internal and BMBF funded project with the aim to advance cell-free bioproduction towards an on-demand scalable technology for mass production or protein fabrication screening purposes. The consortium consisted of seven Fraunhofer institutes with ICI-BB as the project leader, IZM, IPA, IPK, IME, ISI and ISIT. The Fraunhofer Gesellschaft financed the project with 6 million Euros out of its "System Research" framework. The Federal Ministry of Education and Research (BMBF) provided additional 14.5 million Euros out of the "Biotechnology 2020+" strategy process.

ISIT´s part in the project was mainly in the field of bio analytics according to its competences in sensor and microsystem technology. One part was the construction of silicon membrane chips with a varying number of micro pores. These pores were surrounded by Iridium / Iridiumoxide (IrOx) electrodes for simultaneous, sensitive pH-measurements at every single pore. The pore membranes inside the chips were

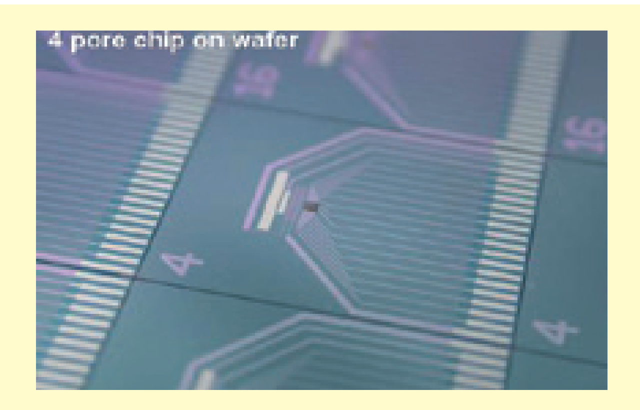


Figure 1: Wafer with pore membrane chips

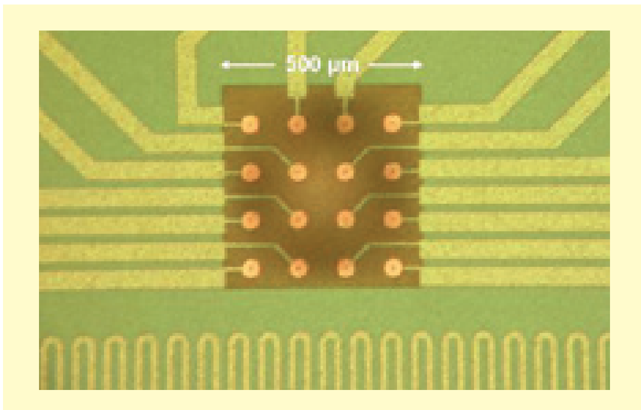


Figure 2: Detail of a pore membrane chip with 16 pores and surrounded IrOx electrodes

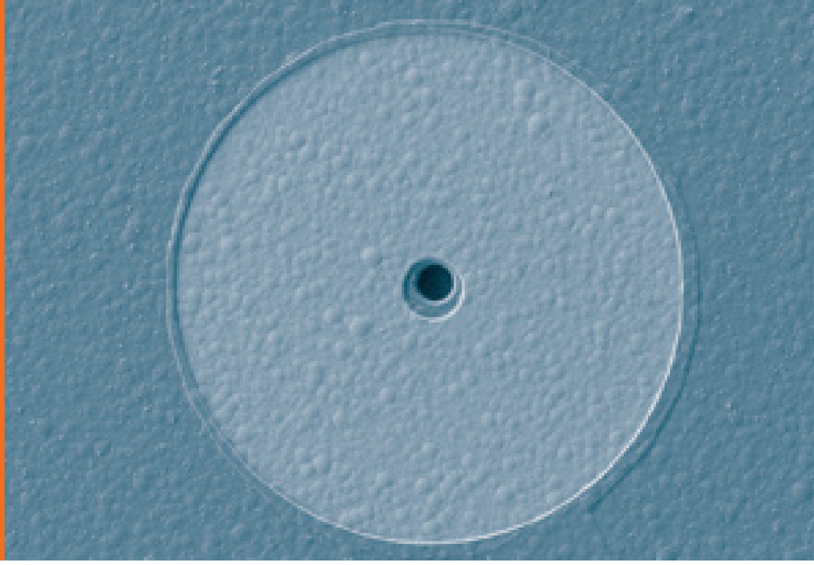


Figure 3: REM picture of a single pore with surrounded IrOx electrode

very thin (~4 µm) and equipped with 1, 4 or 16 pores with 4 µm in diameter (see figures 1 and 2). These membranes were built with Tetraethoxysilane (TEOS) resulting in stable silicon dioxide membrane structures. The pores were encircled by vapour deposited and lithographically structured Iridium by leaving a little silicon oxide edge around the pores uncovered (figure 3). On this 1 µm space, a lipid bilayer membrane could be anchored while covering the whole pore. This was done by the common "painting technology", i.e. the lipid Diphytanoyl-phosphatidylcholine (Diph-PC) dissolved in chloroform was applied with a small brush. For this purpose, the chip was clamped between two buffer reservoirs and the electrodes of the pores were connected directly to a commercial pin grid connector with 0.5 mm pitch (figure 4). This system was housed in an aluminium box for patch clamp measurements. Here, the coverage of the pores was measured with two silver chloride electrodes - one in each reservoir - connected to a potentiostat including low current measurement. We could observe "giga seal" resistances at bilayer covered pores (figure 5).

In further experiments, transmembrane proteins can be introduced into these pore covering bilayer membranes. Functional ion channels, for example, will slightly change the currents through the pores during their switching, which could be measured with the surrounded electrodes. Molecules like the ATP-synthase could be triggered by a pH-gradient, which equally could be monitored with these electrodes.

The chips were designed as a mass product suitable for disposable use. They are cheap and can be produced with high reproducibility.

Membrane chip production in ISIT´s industrial silicon production environment

A silicon wafer was used as base material with a technical membrane of TEOS-based silicon oxide. The chip size of 10x 13 mm² (figure 1) allowed handling of the membrane and its integration into fluidic test cavities with simultaneous electrical connection. The membrane size was 500 µm x 500 µm with a thickness of approximately 4 µm (figure 2). This membrane contained different pore numbers between 1 and 16 with 4 µm in diameter. IrOx micro electrodes (50 µm in diameter) around each pore (figure 3) were fabricated by deposition and lithographic structuring of Iridium, followed by electrochemical oxidation.

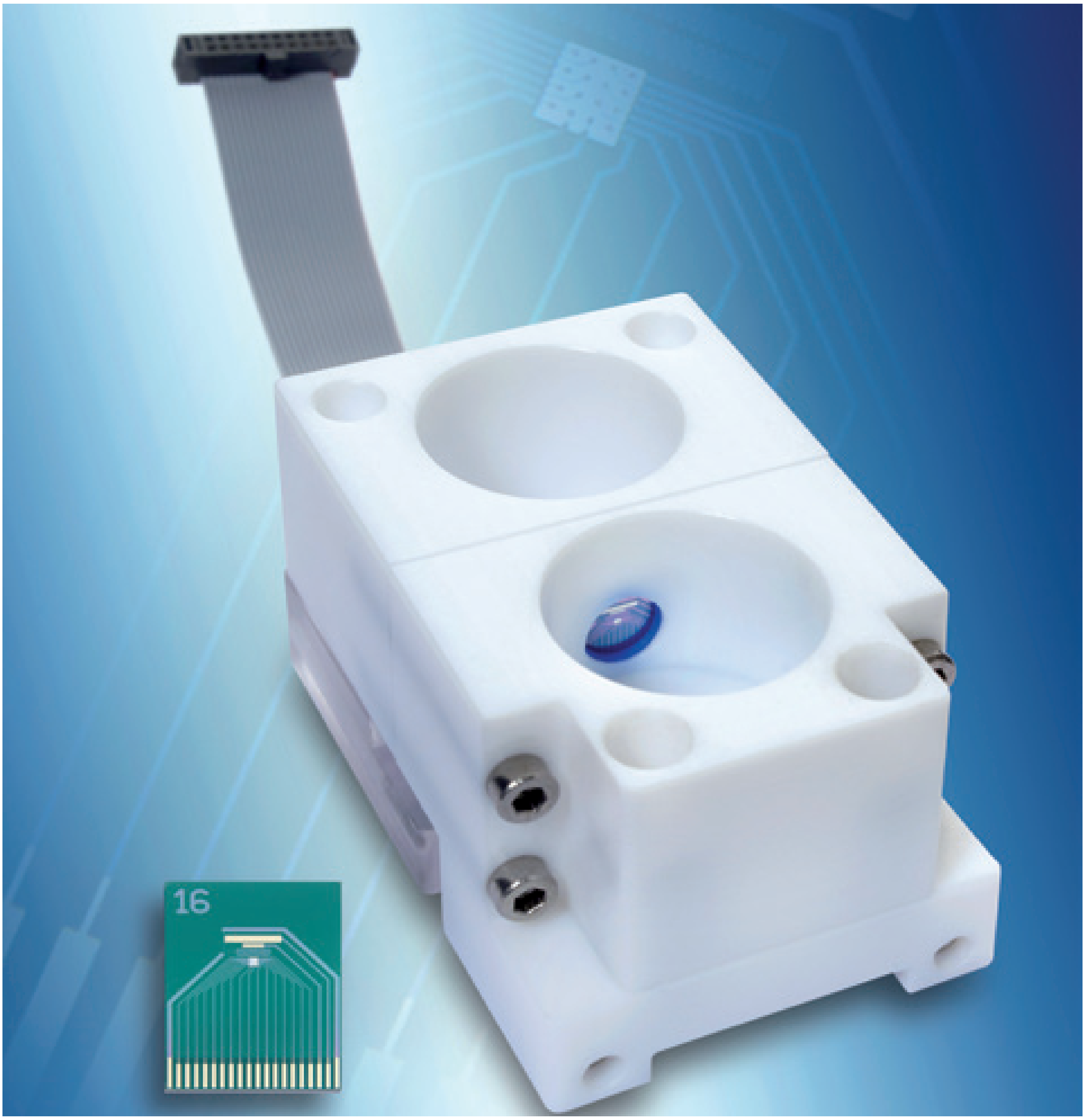
Measuring of lipid bilayer formation over the pores

An unused cleaned 1, 4 or 16 pore membrane chip was covered slightly with Diph-PC in chloroform around the membrane without covering the pores. The chip was clamped into the measuring chamber arrangement (figure 4), which then was filled with buffer solution. The current from one reservoir to the other was measured through the chip by means of two silver chloride electrodes. Painting of the second lipid (Diph-PC) was done directly during this measurement and closing of the pores with a lipid bilayer could be seen by a spontaneous current decrease. Covering all pores resulted in a "giga seal" > 100 GOhm indicating stable bilayers (figure 5).

pH-measurement with micro-electrodes

The micro-electrodes for pH-measurement were realized on silicon chips, which allow their integration into small fluidic chambers. The electrodes were made of a metal stack with Tantalum as adhesive layer, a connecting layer of Platinum and an upper active layer of Iridium. This Iridium layer was later

Figure 4: Measurement chamber for pore membrane chips



oxidized by electrochemical treatment in diluted sulphuric acid on chip level. The Iridium oxide surface works as a pH sensitive electrode by giving potentials proportional to pH-values (figure 6). This was validated in a range from pH 6.8 to 7.8 with different electrode sizes and results in the usability of electrodes down to a surface of 100 µm2 (Ø ~11 µm).

Author: Dr. Eric Nebling

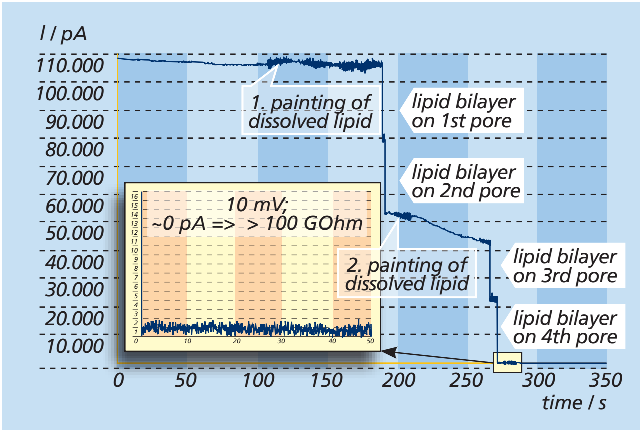
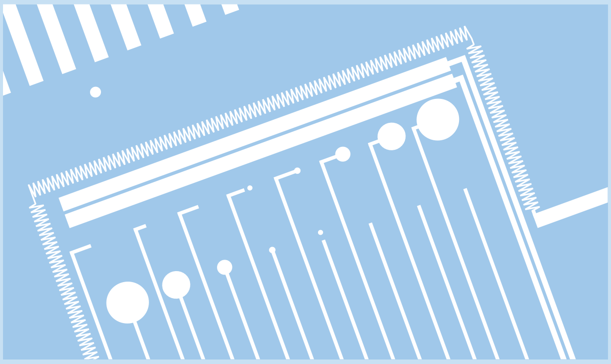
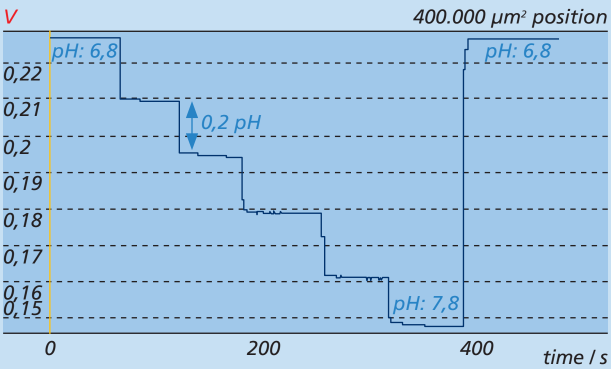


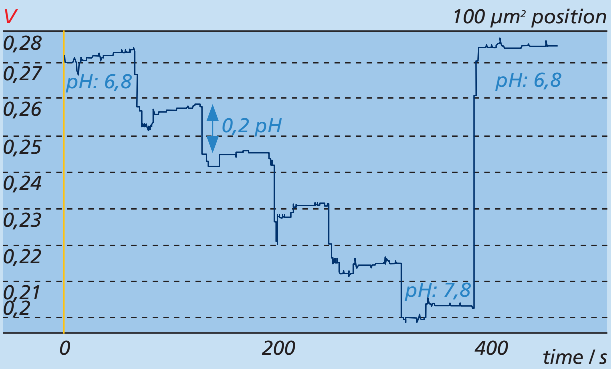
Figure 5: Lipid bilayer formation on a pore membrane chip with 4 pores

Figure 6: pH-measurements with IrOx-micro electrodes

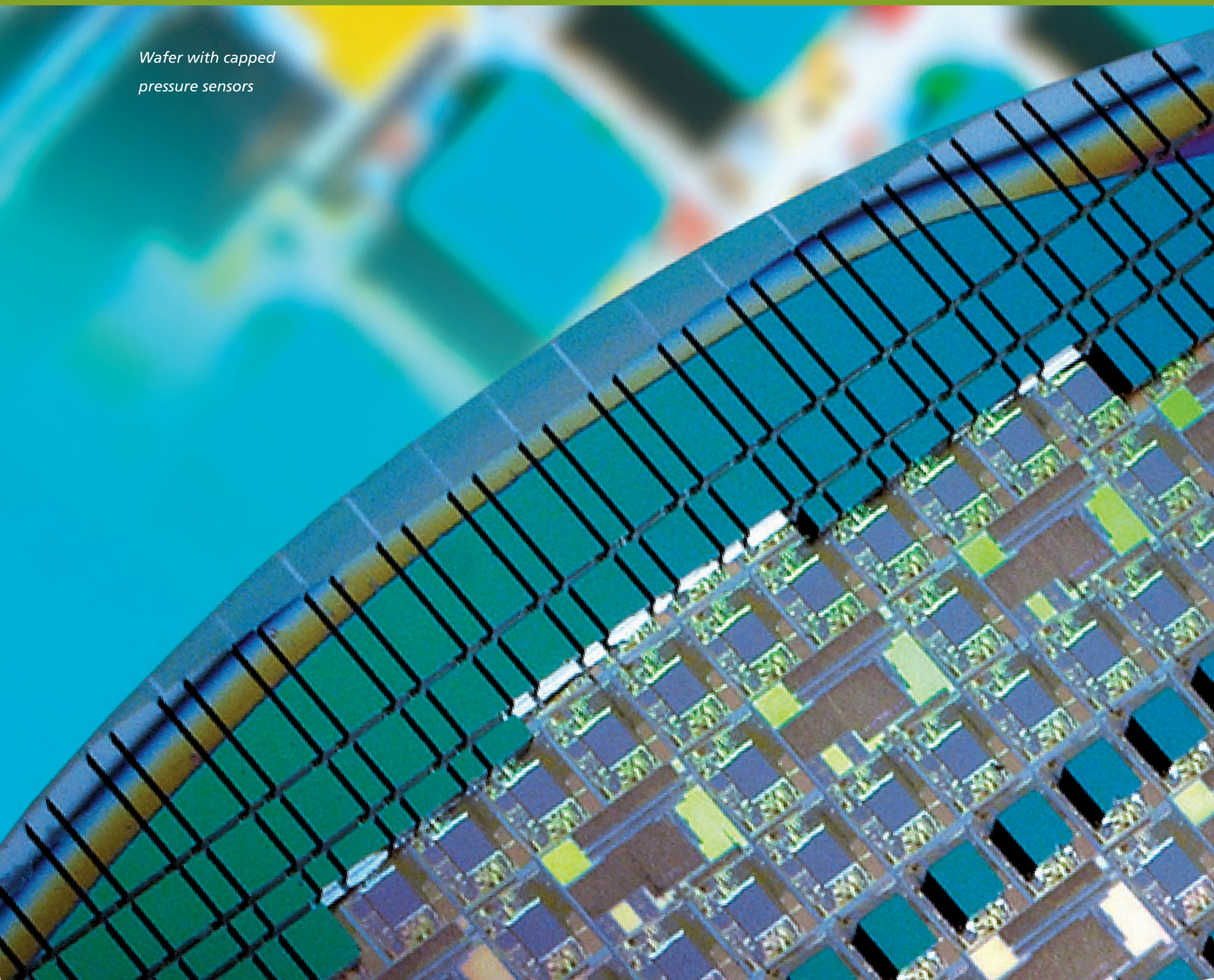


surface [µm²]	ph-step [mV/pH]	control [mV/pH]	shift [mV]
400.000	-79,247	79,222	-0,025
100.000	-79,134	79,381	0,247
25.000	-79,741	79,861	0,120
6.400	-79,889	79,794	-0,095
1.600	-77,379	77,024	-0,355
400	-77,967	78,199	0,232
100	-74,621	79,229	1,608
25	-196,356	63,778	-132,578



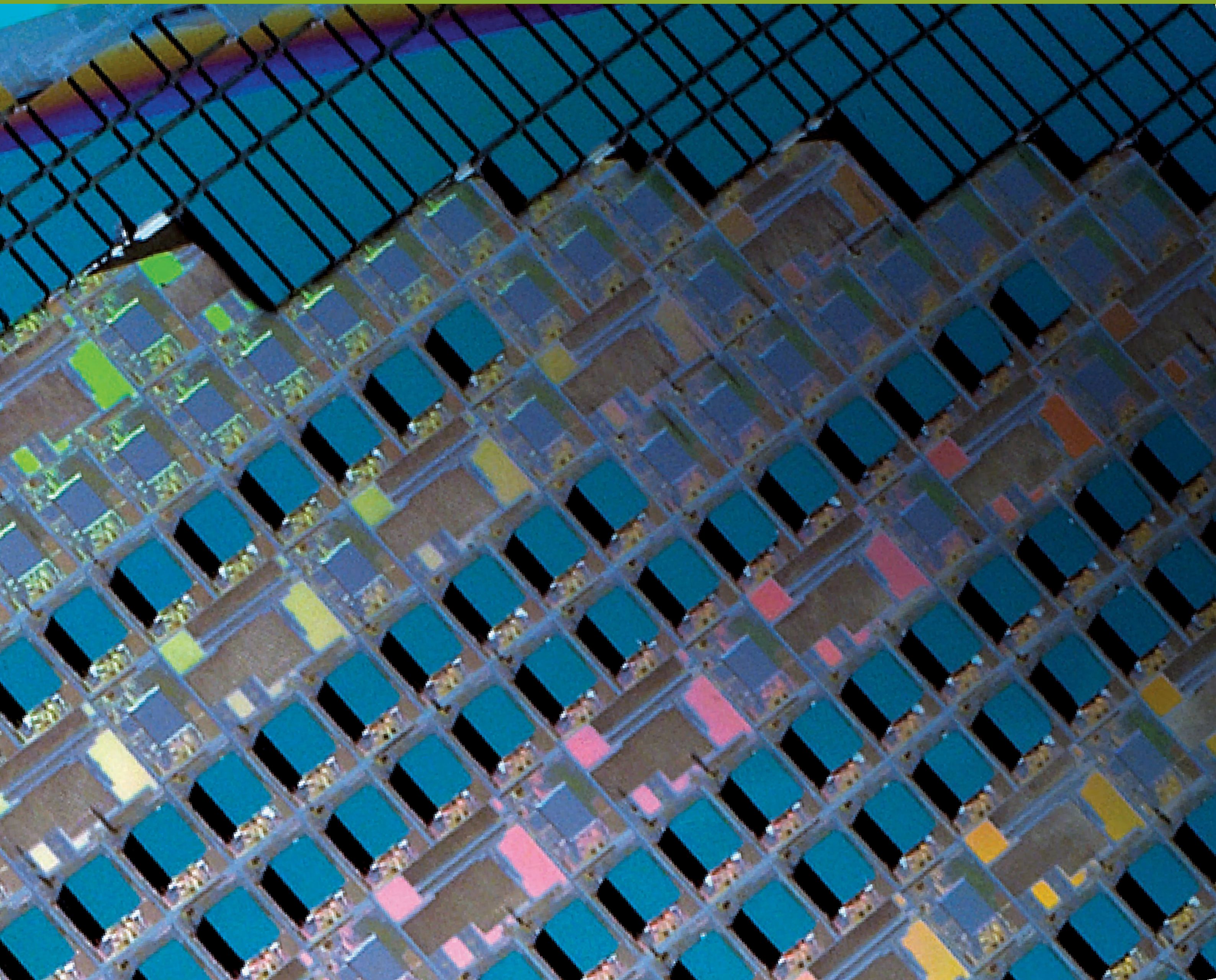


REPRESENTATIVE RESULTS OF WORK



Wafer with capped pressure sensors

MODULE INTEGRATION



BATTERY MANAGEMENT SYSTEM FOR EXCHANGEABLE BATTERY PACKS

Lithium ion accumulators are commonly used due to their high energy density. Unfortunately, they require additional care compared to other accumulator systems like lead acid, NiCd, or NiMH. Lithium ion cells are very sensitive to overcharge, deep discharge, and extreme temperatures. Battery management systems (BMS) are used to guarantee safe operation within the allowed safe operation area. Besides these basic requirements, additional features like current measurement, state of charge calculation and a communication interface are typical features of battery management systems.

The battery management system shown in figure 1 was developed for an autonomous underwater vehicle called DeDAvE (Deep Diving Autonomous Vehicle for Exploration). The DeDAvE power supply concept is based on removable battery packs, which has the following advantages:

- The vehicle availability is not affected by charging times; battery packs are simply exchanged between exploration operations.
- Battery packs are connected in parallel, which allows to add the amount of packs depending on the planned mission time. Obviously, each additional battery pack reduces the transportable payload.
- A damaged or old battery pack can simply be replaced by a fresh one.

Since the DeDAvE battery packs are charged and balanced individually outside the vehicle, we have to assume that battery packs may be added with a different state of charge. Without electronic control this would result in high equalizing currents. The developed battery management system takes care of this task on hardware level.

To reduce system complexity, the described electronics is a fixed part of the underwater vehicle, whereas the battery pack electronics consist only of cell temperature sensors and a memory chip to enable identification of individual packs. Each BMS board can handle two battery packs with up to 7 cells each. Depending on the configuration of the electronics, these two cell stacks are connected in parallel or in a row, enabling a power-bus voltage of 25 V or 50 V, respectively. The current handling capability of the system depends mainly on the cooling of the electronic switches, i.e. MOSFETs. Under laboratory conditions, a small heatsink is sufficient to enable currents up to 45 Amps per board. In case of the underwater vehicle, the electronics is potted in a watertight compound which reduces the effectiveness of the heatsink drastically, but this is no issue since the required currents are much smaller. Nevertheless, the BMS has several temperature sensors on board to monitor critical points which may get hot if the cooling is insufficient.

The described battery management system is designed as a master/slave system. The master BMS is switched on with a small low-power switch. When the power is switched on, cell voltage monitoring is started. If everything is ok, the battery pack is switched on. This voltage is used to wake up the slave modules, starting cell voltage monitoring and CAN communication. As soon as the slave modules receive a "heartbeat" from the BMS master, they hook up on the power bus. In case the BMS master stops the heartbeat signal, the slaves disconnect themselves again. The BMS master itself is switched off either by a corresponding CAN message or the aforementioned power switch. Since very low power consumption is a key issue in battery management design, the BMS boards exhibit a negligible standby current, enabling very long rest periods, e.g. during transportation, without the need to recharge the cells

Several additional features make this battery management system a smart solution for every application based on exchangeable battery packs:

- compatible to stacks with 4 … 14 cells in a row or two parallel cell stacks with 4 … 7 cells
- up to 45 Ampere with a small heatsink
- any number of parallel systems
- usable with any cell chemistry
- high precision cell voltage measurement
- high precision current monitoring
- fast electronic short circuit protection
- protection against wrong wiring of cell packs
- two I2C busses, e.g. for memory chips or temperature sensors within battery packs
- 6 precision ADC ports for NTC or PTC temperature sensors
- isolated CAN interface for CANOpen communication
- failsafe master/slave configuration
- zero standby consumption
- functionality proven at 720 bar ambient pressure

Author: Dirk Kähler

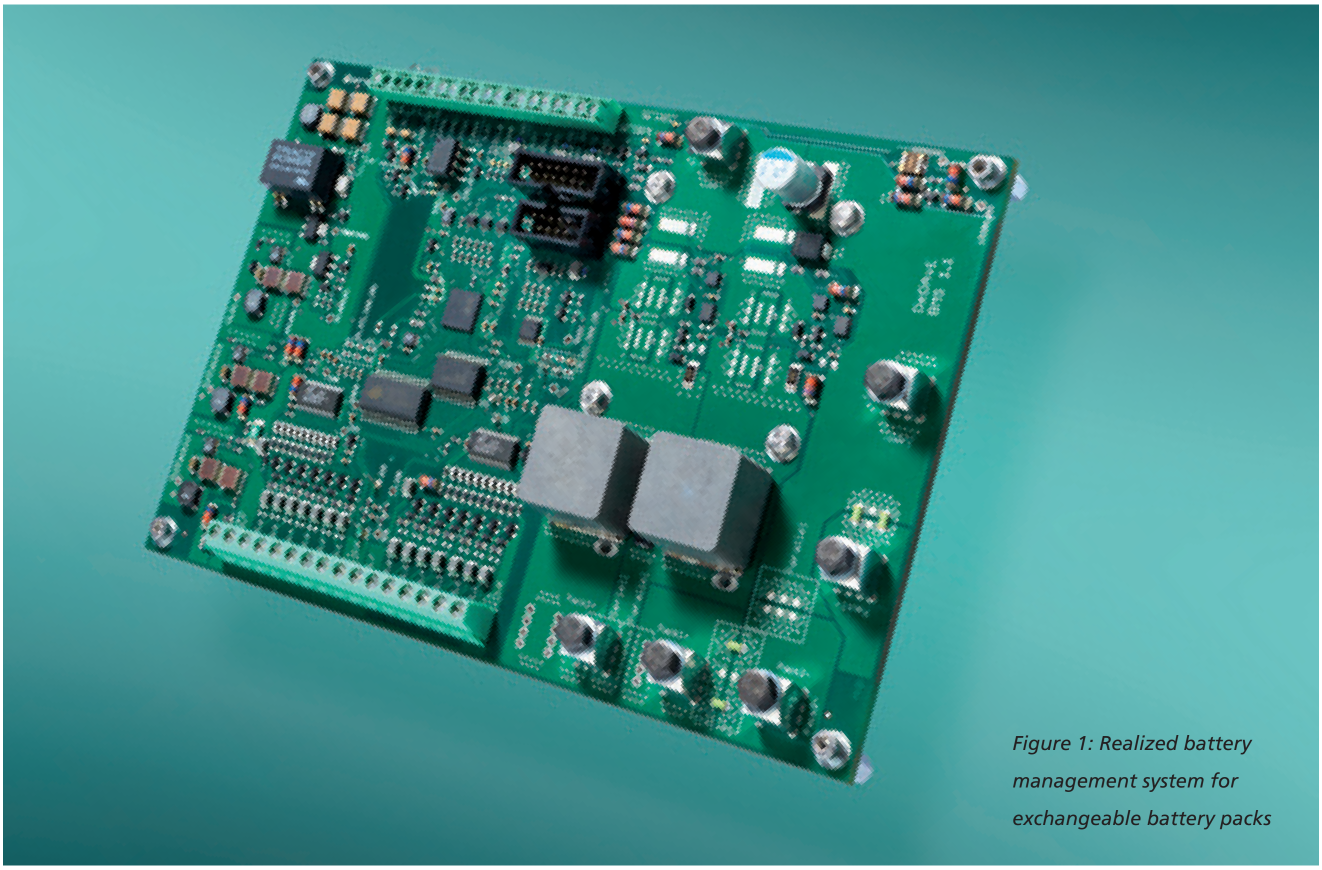


Figure 1: Realized battery management system for exchangeable battery packs

ACOUSTIC GAIT ANALYSIS: TECHNOLOGIES FOR SENSORINTEGRATION INTO A FUNCTIONAL SHOE INLAY

The project Acoustic Gait Analysis („Akustische Ganganalyse“, see also last annual report) aims at the development of a functional shoe inlay for the sonification of the gait and running behavior. The plantar pressure distribution (see figure 1) is measured and converted into an auditive feedback that enables the user to control and optimize his or her movements. Depending of the use case, the system serves for preventing injuries, for rehabilitation after disease or for improving performance in leisure and competitive sports. Moreover, it will be suited to monitor standing or walking habits of elderly persons or patients which, for example, suffer from physical nervous diseases.

During the last year, much effort was spent to find out which principles and technologies are suited for integrating sensors into a functional shoe inlay. The relevance of the specified properties is denoted in figure 2.

Three sensing principles were chosen for further evaluation:

1.) Resistive foil sensors

This technique was evaluated first and has already been presented in the last annual report; it will thus not be described here in more detail. The sensor area and circular shape were given (d = 7 mm), but can be modified by the supplier. The elements were mounted with epoxy adhesive and anisotropic conductive foil, afterwards the whole sensor matrix was covered with a second PET foil. The setup appeared to be robust and accurate enough for first tests.

2.) MEMS capacitive sensors

Micromachined capacitive sensors designed for absolute pressure measurement were obtained from Protron Mikrotechnik, Bremen, Germany (see figure 3, left). Although

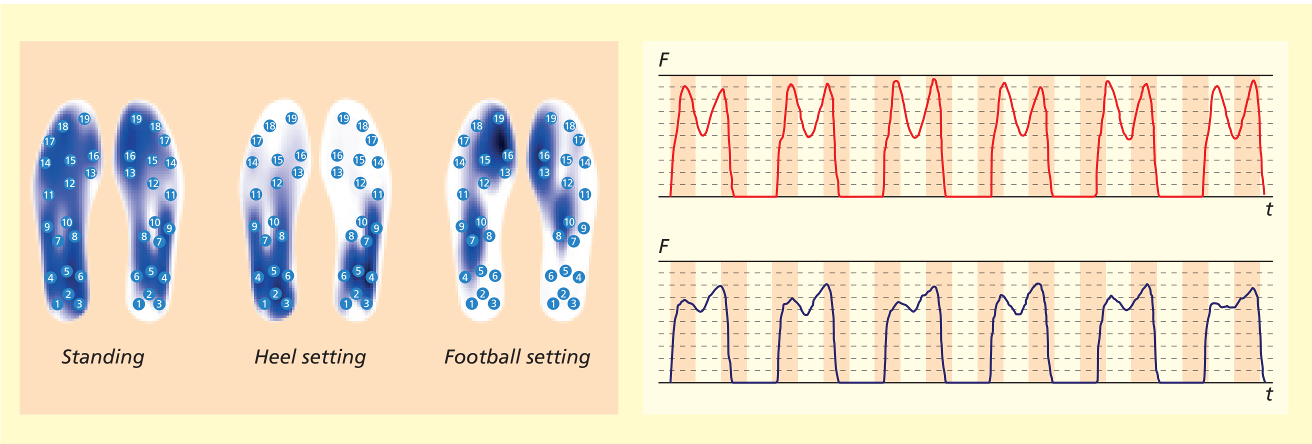


Figure 1: (Left) Graphical visualization of the relative foot pressure distribution (Right) Plantar pressure distributions, comparing typical (red) and unhealthy (blue) foot scroll

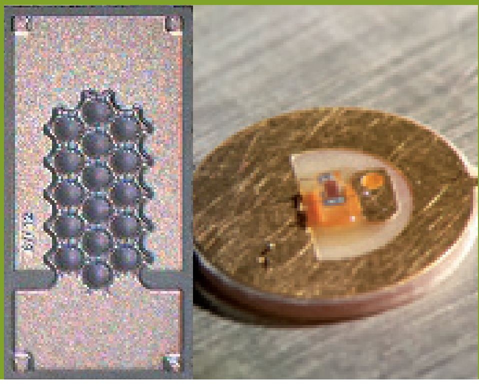


Figure 3: (Left) View from above of the pressure sensor die. (Right) Capacitive MEMS sensor bonded on a PCB interposer for integration into the flexible shoe inlay

not initially developed for this application, these MEMS sensors could recently be integrated into a few demonstrator inlays. The devices were readily available and calibrated, but the upper limit of the pressure range was slightly lower (~ 80 N) than specified (100 N). Despite this, measurements have shown that the usable range can be extended to 100 N without sensor damage.

Since the sensor will be contacted by bonding wire, a PCB interposer had to be developed and fabricated (figure 3, right). This interposer was then fixed on a perforated PET foil with printed connection and contact features. A second PET foil, again with printed lines and GND pads, was attached and the enclosed space as well as the whole system were filled and encapsulated with PDMS. The setup is illustrated schematically in figure 4. Measurements with these embedded sensors show that the signal is roughly linear but has considerable drift and hysteresis (see figure 6).

This setup represents a suitable concept but requires additional improvements like shielding against external capacitive noise, and countermeasures against humidity penetration into the silicone or PET inlay materials (e.g. caused by sweating). Water and sweat have a high dielectric constant of about 80 that will produce a considerable, presumably time dependent capacitance offset in parallel to the sensor capacitance. These effects have to be mitigated by an appropriate moisture barrier. Moreover, a point-wise measurement of the pressure distribution in the shoe inlay may require more than one sensor per sensing position, which will lead to a considerable price increase.

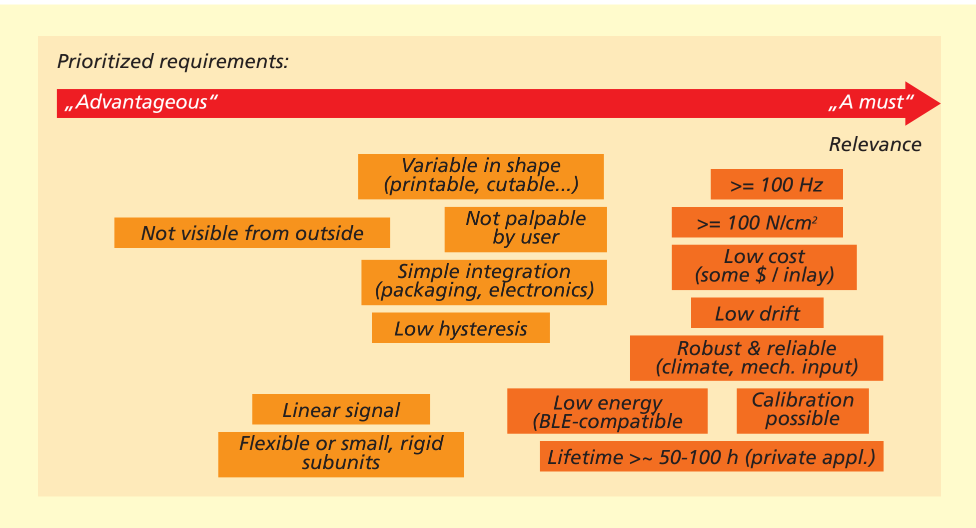


Figure 2: Priority scale for aspects of shoe inlay pressure sensing technologies in acoustic gait analysis

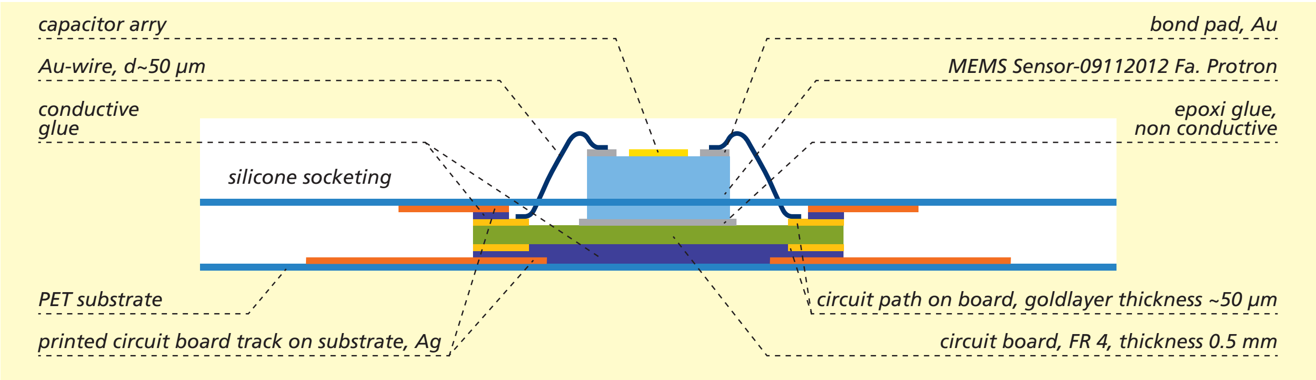


Figure 4: Schematic setup of MEMS pressure sensor integration between two PET foils and embedding in a PDMS silicone

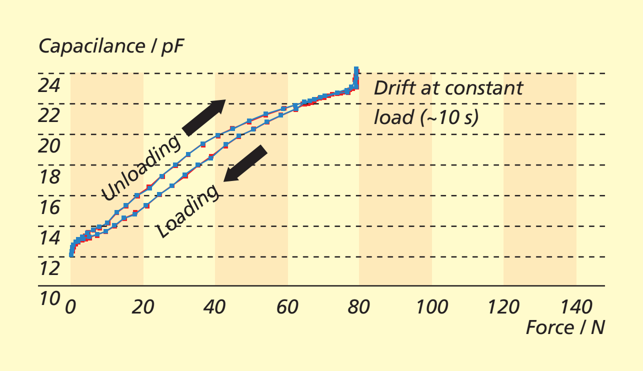


Figure 6: Characteristics of two capacitive MEMS sensors, embedded into a PET/PDMS inlay

3.) Printed piezoelectric sensors

Printed piezoelectric sensors (PPS) have many advantages like low cost, free form factor and simple fabrication once a stable process is developed. Barium-Titanate (BaTiO3) based sensors have been produced by screen printing and output voltages in the order of 1 mV/N·s were obtained; first measurements are shown in figure 7. However, in contrast to the other sensors, PPS only measure dynamic load changes rather than static pressure. In order to map the static pressure distribution, additional effort has to be spent on the data analysis hard- and software.

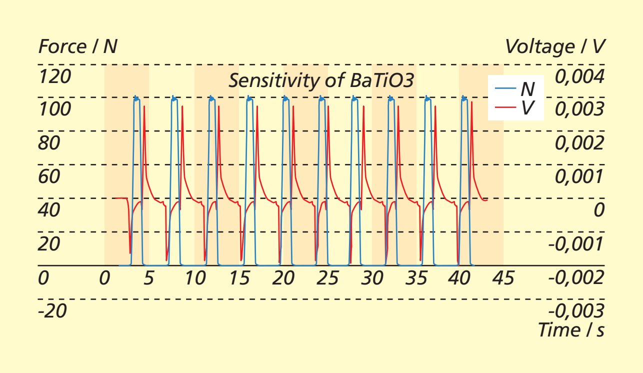


Figure 7: Force-voltage characteristics of printed $BaTiO_3$ based piezoelectric sensors. The sensing area is approx. 1 cm²

Project data:

- Project duration: 3 years (11/2014–10/2017)
- Grant: 1.6 million € by German Federal Ministry for Economic Affairs and Energy (ZIM)
- Consortium: 8 partners
- Project coordinator: Fraunhofer ISIT

Author: Dr. Thomas Knieling

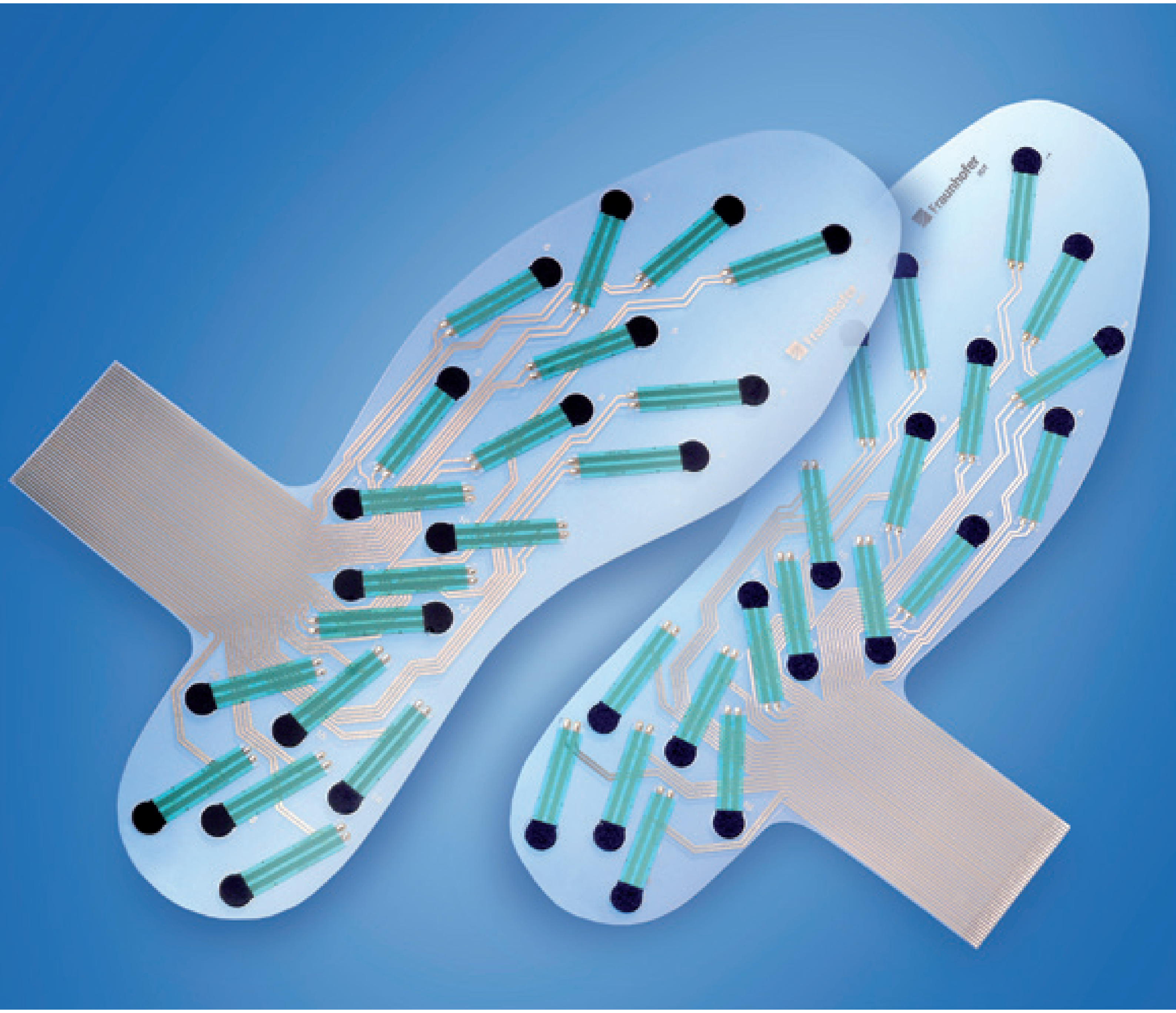


Figure 5: Functional shoe inlay with integrated foil sensors

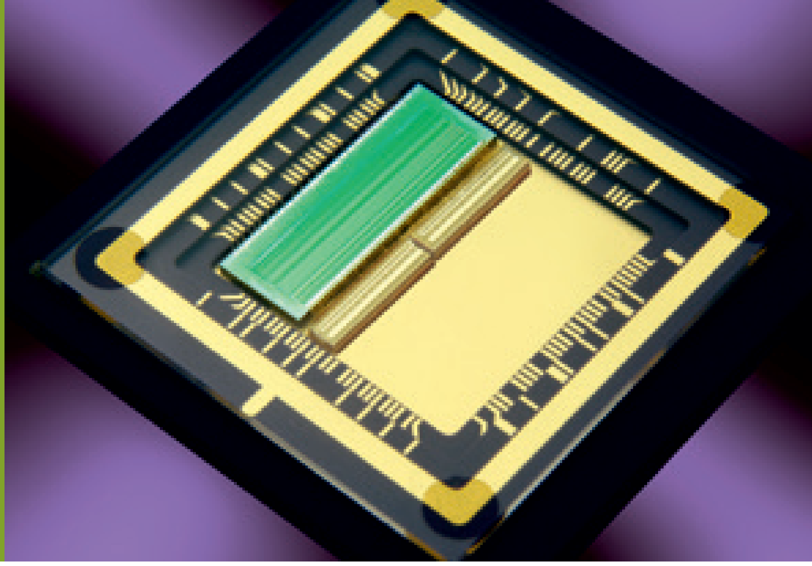


Figure 1: Assembly of two line detektor arrays (64 pixels each) next to the read-out IC

ASSEMBLY OF UV DETECTOR CHIPS IN WISA-PROJECT "AGNES"

Ultraviolet light has found many industrial applications, and powerful sources are developed to obtain increasingly high intensities for faster throughput or large-area irradiation. Within the Fraunhofer collaboration project AGNES (internally funded WISA program), tiny UV detectors with exceptional radiation hardness were developed based on the epitaxial deposition of Aluminum-Gallium Nitride (AlGaN) on sapphire. The coordinating Fraunhofer Institute for Applied Solid-State Physics in Freiburg (IAF) was responsible for the epitaxy process development. Assembly-related tasks were performed by ISIT and various application scenarios were investigated by Fraunhofer IFAM, IPM, IOSB and IGB.

Applications for radiation-hard UV detectors

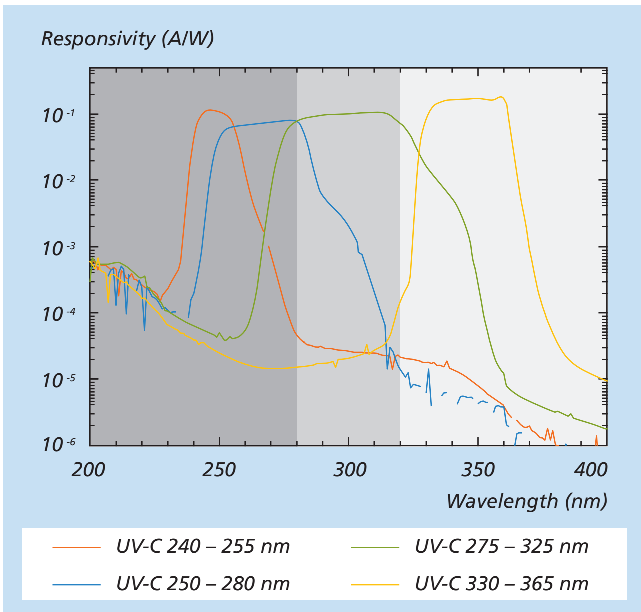
Among others, the following industrial applications were considered:

- Curing polymers and synthetic varnishes
- High gloss coating of color prints in a roll-to-roll process
- Disinfection of water, in particular ballast water of ships

The purpose of UV detectors in these applications is to reduce the energy consumption of radiation sources by monitoring the intensity of the light source. Usually, the intensity of UV sources like mercury- or excimer lamps fluctuates and decreases over lifetime. To ensure correct processing conditions, the surfaces are overexposed by a considerable safety factor to compensate for these effects. A particular difficulty lies in the specific spectrum of these sources, composed of characteristic peaks at defined wavelengths. Generally, only a narrow band of the radiation spectrum is needed for the application, but counts only for a small part of the total spectral energy. Using broadband detectors would thus not yield the desired information.

Motivations for using AlGaN as a base material are not only the extreme stability, but also the possibility to produce efficient filter layers within the epitaxial process: While depositing the layers for the photosensitive p-i-n diode, the stoichiometric composition of the layers is modified, which leads to a band gap variation. The sapphire substrate has the highest bandwidth, which means that it is generally transparent for the whole considered spectrum. It is therefore possible to build a detector that has a small bandwidth when flipped and a broad sensitivity when illuminated from the top.

Figure 2: Absorption measurement of different AlGaN layers deposited at IAF



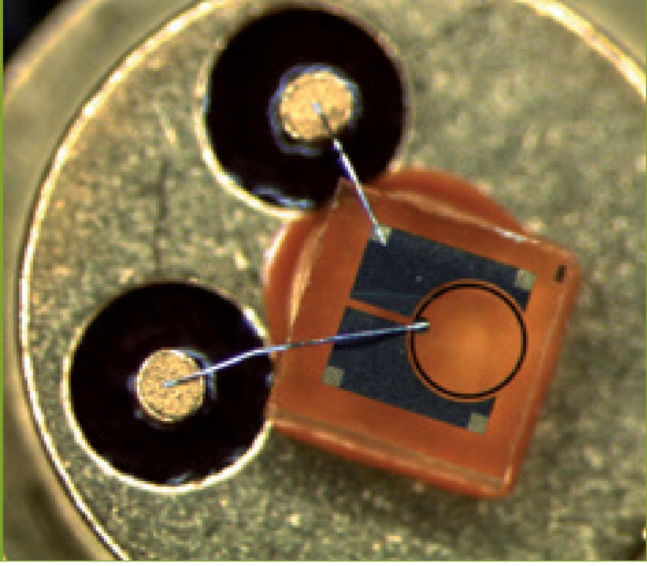


Figure 3: A UV-detector mounted on a TO-submount with conventional die attach

Figure 4: Flip-chip assembly on a silicon interposer, which is then attached to the TO submount

Throughout the project, IAF provided sensor dies with wavelength variations in the UV-A, UV-B and UV-C spectral range. A specific interest lies in a part of the spectrum called the "solar-blind" range: While natural sunlight contains a large amount of ultraviolet light, the atmosphere completely filters these wavelengths. In consequence, evolution had no need for organic life to develop a protection – cell membranes are transparent for this highly energetic radiation, which means that bacteria can easily be destroyed by this particular kind of UV light. This breach in the defense of microorganisms is exploited by "Ballast Water Treatment Systems". According to Maersk Maritime Technologies, more than 60.000 vessels have to be equipped with such systems in the next 5 years, at an expected cost level of 2 million US$ per ship. Of course, the UV detectors may only be a tiny part of such a system, but they can help save large amounts of energy throughout the coming years.

Assembly related activities at ISIT

The AGNES detectors came to ISIT in many design and process variants, which did not allow for abundant process development. Basically, single detector elements were delivered in two chip sizes with 0.6 mm and 1.4 mm edge length. To satisfy the requirements regarding yield and single device tracking, only manual sample builds were made. ISIT equally performed additional investigations on sapphire dicing and chip-soldering. In UV detector applications, TO cans are still the dominant and most versatile package. First assemblies were made by die attach on TO submounts. Open window caps were ordered for just mechanical protection purposes to allow characterization of the detector performance without any optical window.

For narrow spectral bandwidth applications, the detector is used in a flip-chip configuration. To enable this, an interposer wafer was designed and manufactured at ISIT. The wafer was diced into segments of 4 x 4 cm². A triple stack of stud bumps allowed to dip the whole segment into a silver epoxy layer, the tiny detectors were then taken from a transport carrier and placed onto the epoxy cap. An underfill was applied to provide mechanical strength.

It is evident that the high involvement of polymers in these sample builds does not allow extreme exposure to UV radiation as required in some of the applications. Therefore, IAF provided dies with a backmetal deposition that were subsequently soldered to the submounts at ISIT, using a vapor phase soldering process. Organic residues were cleaned in a Zestron bath, followed by an additional plasma treatment. For the flip-chip configuration, ISIT would propose a stud-bump silver sintering approach in order to obtain a polymer-free, robust assembly.

Other applications were equally studied, among them was a line scanning UV camera realized by Fraunhofer IOSB. Two line arrays with 64 pixels were mounted into a ceramic package, together with a commercial read-out IC. 128 pixels were connected to the ROIC, which means that gold wires of 17.5µm diameter were bonded with 100µm pitch.

In conclusion, IAF and ISIT provided packaged samples for UV-A, UV-B and UV-C sensitive detectors in single-pixel and line array configurations for evaluation in various applications. However, crack propagation in grinding and dicing is still critical for high-volume manufacturing.

Author: Norman Marenco

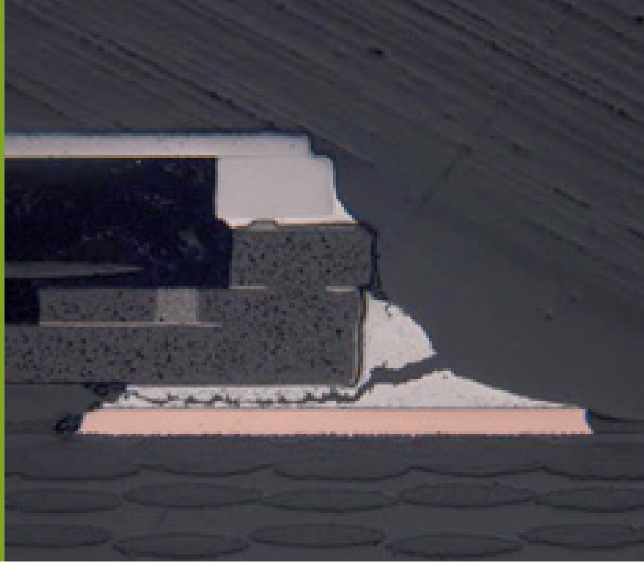


Figure 2: Component with crack in solder joint

SOLDER JOINT RELIABILITY OF CERAMIC SMD COMPONENTS ON FR4-PCB

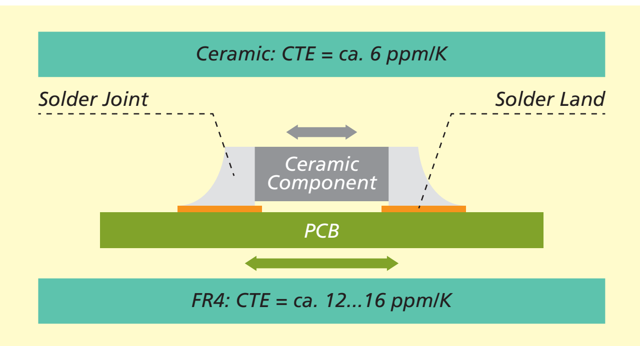
In surface-mount technology (SMT), the dominant printed-circuit board (PCB) material is still the flame-retardant FR4, a laminate made of fiberglass and epoxy resin. With a coefficient of thermal expansion (CTE) of about 12 ... 16 ppm/K, a significant mismatch with ceramic components (typically 6 ppm/K, see figure 1) exists. Pronounced thermal cycling thus leads to solder joint fatigue (figure 2) and in some cases fracture of the components, resulting in early failure of the system.

However, since these components are vital to the electronics industry, an increase in reliability is desirable. A research project was carried out by Fraunhofer ISIT with extensive involvement of an advisory committee (PA) from the German electronics industry (IGF project AiF 17405N / DVS-Nr.: 07065).

Aim of the project

The project aimed at investigating the relation between the aspects "soldering quality" and "reliability of solder joint", assuming that the process limits for an efficient production with low rework rate do not necessarily lead to an optimum product lifetime. Reliability was assessed with standard tests, e.g. up to 4 000 temperature shock cycles from -40 °C to +125 °C.

Figure 1: Ceramic on PCB



Investigated parameters were basically the solder paste amount (three different solder pastes) and land pattern layout. Monitoring the solder joint volume was an important aspect in order to draw up recommendations related to the application of additional solder and the frequently arising question whether significant solder excess can lead to component damage.

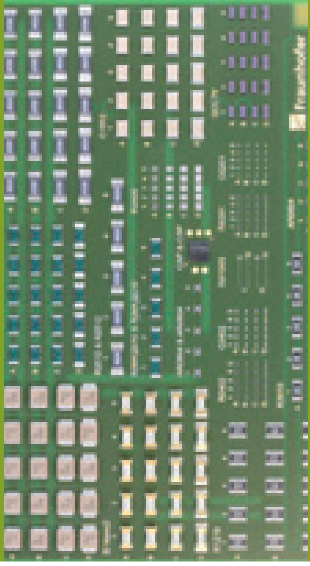
Implementation of test boards

First, relevant components were identified and two test boards were layouted accordingly. A standard FR4 material (unfilled epoxy, Tg 135) was constructed as 6-layer board with a soldering surface of NiAu. Size variations of the land patterns were recommended by manufacturers and users, resulting in 125 % pad enlargements and pad reduction down to 50 % of the nominal surface in up to 2 steps. Each type of component was placed up to 10 times per land pattern variant (A = very small, B = small, C = nominal, D = large) disposed on the printed circuit boards. Variant A required an asymmetric area reduction. On request of the industry members, following soldering alloys were studied:

- SAC305 (SAC3, „Standard", Melting point: 217–219 °C)
- SnCu0,7Ag1,0NiGe
  (SCANGe, Melting point: 217–224 °C micro alloyed)
- Bi57Sn42Ag1
  (BSA1, low-melting, melting temperature: 138–140 °C)

Equipment

The boards were printed on a DEK Horizon 2. We used stepped stencils (stainless steel, electro-polished, plasma



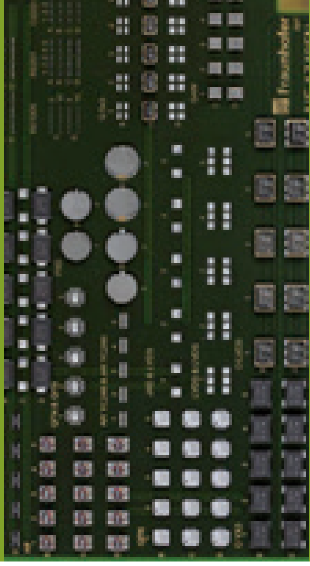


Figure 3, Figure 4: Assembled PCBs

Figure 5: Crack growth SAC3 after 2000 temperature cycles

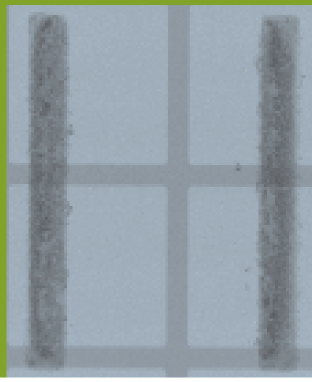


Figure 6: Crack growth BSA1 after 2000 temperature cycles

coated) to meet different requirements of solder paste amount to different component types on the board. A 3D solder paste inspection system (3D SPI) from Parmi, type HS70, was used. The system works with a two-laser-triangulation, achieving a lateral resolution of about 7 microns which is sufficient to quantify the smallest solder paste volumes for component size 01005. The samples were soldered under nitrogen atmosphere with a Rehm convection reflow system, type V8. In order to achieve many results at reasonable cost, a shear test analysis of the components was performed with a pull-shear tester from XYZTEC.

Investigation of solder amount

In our studies, the effective amount of solder depends on two parameters, the layout pattern types A…D and variations of applied solder paste ranging from 50 % to 400 %. Solder amount reduction was focused on small components, while increased quantities were essentially applied to larger components. Printing parameters were set according to data sheet specification of the solder pastes, with particular care to center the parameters within the recommended process window. For each solder paste, optimal reflow temperature-time profiles were measured, leading to peak temperatures of 180 °C for BSA1 and 240 °C for the other two solder alloys. Again, the temperature-time curve was carefully adjusted to the process window specified by the material suppliers.

For effectivity reasons, the experiment could not be run as a complete matrix. However, more than 47 000 components were supplied by the PA and placed on approximately 380 printed circuit boards (figures 3 and 4). The study covered ceramic chip components of sizes 01005 up to 2220 with two and more terminations as well as functional ceramic components, including oscillators, pressure sensors and RF power couplers with edge lengths up to 8 mm. All soldered components were inspected visually for solder defects such as tombstoning, solder balls, solder bridges, missing components, billboarding, offset and rotation, followed by a 100 % X-Ray analysis.

Reliability testing

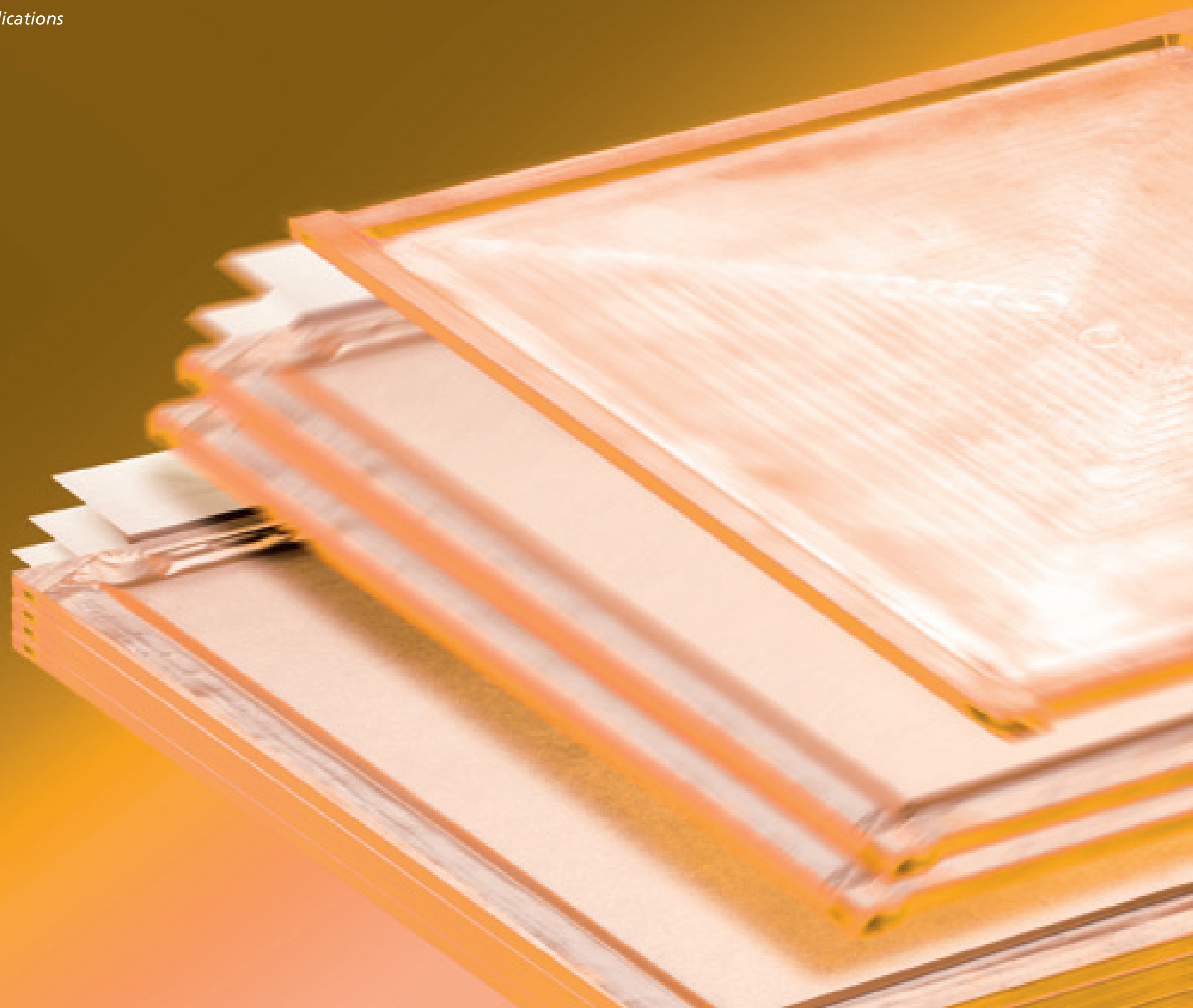
Reliability tests were carried out with standard industry-temperature shock tests, i.e. 15 minute load changes from -40 °C to + 125 °C in up to 4000 cycles. At appropriate intervals (250 or 500 cycles depending on component type), samples were taken for analysis. In addition to cycle tests, shear tests were performed. Shear forces relative to the initial state were calculated and a general limit for an intact connection was fixed at 50 % as a criterion for a possible further cycling.

The most important results are shown below:

- SCANGe alloy / 0201 resistors / 3000 cycles: Shear strengths are reduced to 75 % with B, C and D land patterns and 65 % with pattern variant A.
- SAC3 and SCANGe solder alloy / 01005 resistors / 3000 cycles: C and D land pattern variants show shear strengths of at least 77 %. Smaller pads were omitted since printing with aperture area ratio significantly less than 0.62 would be inherently instable.
- SAC3 and BSA1 solder / R1218 components / 2000 cycles: X-Ray analysis shows crack growth in the SAC3 (figure 5) and BSA1 (figure 6) solder joints. BSA solder generally shows a spongy structure and significant crack growth already after 250 cycles. With the maximum solder amount, this is not observed until 500 cycles.

Authors: Helge Schimanski, Saskia Schröder

Lithium polymer secondary batteries for stationary power applications



INTEGRATED POWER SYSTEMS

Figure 1: 25 Ah Li-ion cell (LMFP/LTO) in size comparison with a 2 € coin

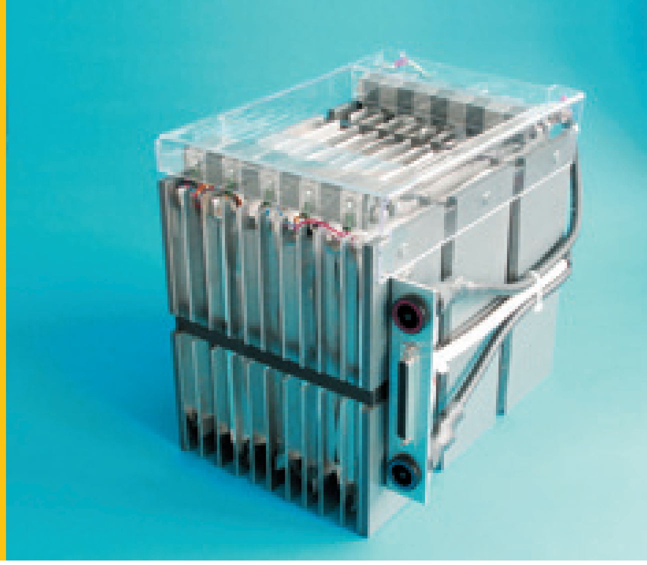


Figure 2: Single battery module used for construction of a 5 kWh storage system

HYBRID ENERGY STORAGE SYSTEM FOR URBAN USE

Since the "Energiewende" was issued by the German government in 2011 for a safe, reliable and sustainable future of the national energy economy, the "renewables" have greatly gained in significance. According to the Federal Ministry for Economic Affairs and Energy (BMWi), the share of renewable energies - water, photovoltaics, wind parks and biomass - in gross electricity consumption was 25.8 % in 2014.

As a consequence of the strong fragmentation of energy sources, a modern power grid architecture needs to take into account a variety of geographic and temporal constraints. In the past, electricity was generally supplied by big power plants located in proximity of major consumers like cities and manufacturing areas. The energy need throughout the day was well known on a statistical base, which allowed to power up gas- or coal turbines on demand while providing a stable base supply through nuclear power plants.

Today, wind turbines and solar cells are spread across the whole country. Their size varies between few-kilowatt household installations and power plants well above 100 megawatt. Mostly, the large wind parks or solar farms are far from urban areas, which is especially true for offshore wind parks that promise a relatively steady energy supply.

With an increasing amount of fluctuating energy sources like wind and solar power, the pressure rises to dynamically balance generation and consumption, in order to ensure continuous power supply. Managing the power grid will rely on dense information and remote control mechanisms. But not only the technical structure of the power grid will change - also economic aspects like cost models and profitability of infrastructures need to be revisited.

The idea of the project "Hybrid energy storage system for urban use" (hereinafter referred to as "hybrid urban storage") is to mitigate the problems of a disruptive change by promoting a smooth transition on a regional level. If, in the coming years, the cities installed sufficient energy storage capacity within their local power grids, a smart load- and generation management would put an aggregated "hybrid virtual storage" at the upstream grid operator's disposal.

By combining different storage- and load-balancing possibilities, the hybrid urban storage would offer both positive and negative balancing power. Grid balancing could be based on the five following elements:

1. Additive loads, e.g. short term electric heating of local heat grids
2. Dispatchable loads, e.g. use of heat pumps with combined thermal storage

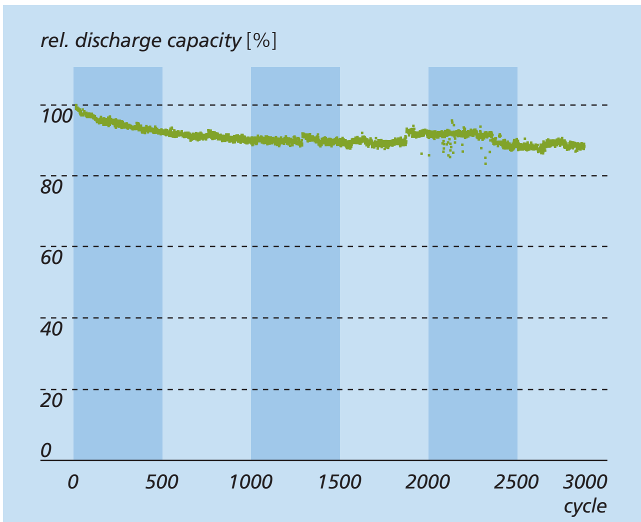


Figure 3: Cycle behavior of a LMFP/LTO cell (1C, 100% DOD) at 20 °C

3. Electric energy storage, e.g. Li-ion battery system or redox-flow battery
4. Dispatchable generation, e.g. combined heat and power plant (BHKW) driven by power demand through additional thermal storage capability
5. Additive generation, e.g. additive power input of emergency generators in data centers or hospitals.

The hybrid urban storage concept would use a 24h forecast on generation and demand for optimizing all of its components on a quarter-of-an-hour schedule to take full advantage of the virtual storage.

An essential element in prospective grid balancing are decentralized battery systems for electrical energy storage, which was the aim of the "hybrid urban storage" project. Real energy storage systems that exploit load-shifting potentials and adjust power- and heat generation could create predictable cluster units and thus become an important contribution to the future power grid balance. Integrated into buildings, these storage systems must be safe and reliable; excellent durability is necessary both in terms of lifetime and compatibility to future technologies.

In order to meet these requirements, Fraunhofer ISIT's department "Integrated Power Systems" developed a cost efficient, long-lasting and inherently safe 5 kWh Li-ion battery system for stationary applications. The innovative approach was realized in close collaboration with Fraunhofer ISE: Cells with a capacity of 25 Ah were developed and manufactured at ISIT (figure 1). Fraunhofer ISE developed the battery management system (BMS) and assembled the modules as shown in figure 2.

The performance and the safety of Li-ion cells are mainly affected by the choice of both positive and negative electrode materials. For storage applications, Lithium-Titanate (LTO) is an ideal anode material that offers high cycle stability and is inherently incombustible. For these applications, the advantages of Lithium-Titanate effectively counterbalance the drawbacks of its lower energy density compared to graphite.

Combined with the olivine-type cathode material Lithium Manganese Iron Phosphate (LMFP), the cell achieved excellent cycle life (figure 3). Compared to Lithium iron phosphate (LFP), LMFP offers increased cell voltage and thus 25% better energy density. However, it meets the same high safety requirements, as shown by Fraunhofer ICT: None of the safety tests performed in accordance with UN recommendations resulted in fire or explosion.

In summary, the objective of the project "Hybrid energy storage system for urban use" was the development of a self-sustained electrical storage system for stationary applications. Based on a future scenario of a widespread use in city buildings, such a system would become a locally managed resource to balance energy availability and consumption. For this purpose, Fraunhofer ISIT developed an intrinsically safe, long-lasting Lithium-ion cell that was integrated in a system concept by Fraunhofer ISE. The cell successfully passed all recommended safety tests as performed by Fraunhofer ICT.

DER HYBRIDE STADTSPEICHER®

Author: Jannes Ophey

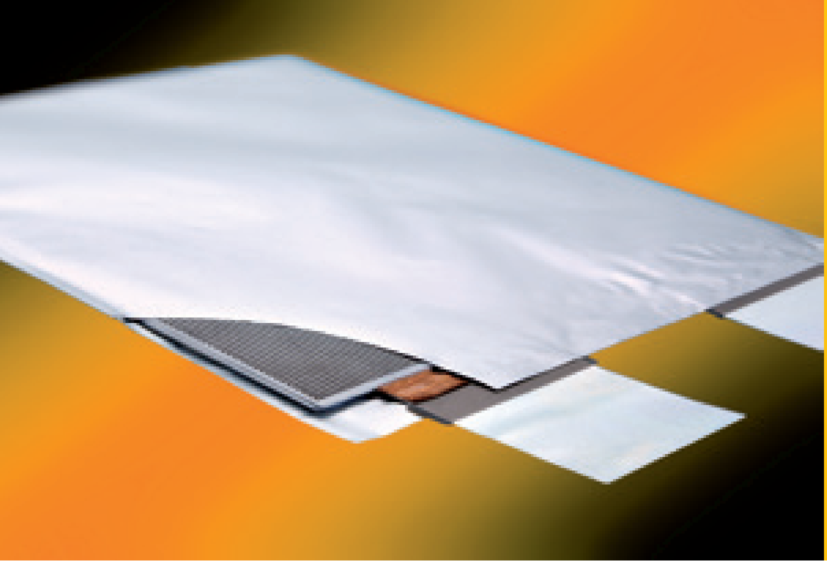


Figure 1: 3.3 Ah Li-Booster high power cell

LI-BOOSTER-BATTERY SYSTEM

Challenges for Electric Mobility

During most of the operating time road vehicles run in the partial-load operational range. For short term „power-hungry" activities such as overtaking, pulling out into traffic on the highway etc. significant additional power reserves must be held available. For pure combustion vehicles this results in a trade-off between performance and range, leading to significant losses of efficiency. In battery-electric vehicles, the energy storage systems are designed for maximum range. Regularly occurring periods of high power rates accelerate the aging of this energy-density-optimized type of battery. Both conflicts of aims are addressed within the scope of the Fraunhofer system research project "FSEM II" by using a special high-performance battery („Li-Booster").
This type of accumulator is always used if short-duration power spikes (<1 min) occur. Additionally, its load characteristic supports efficient recovery of braking energy (recuperation) in the drive system.

Requirements for high-performance batteries

In order to ensure the required functionality, the use of lithium rechargeable batteries with high power density is necessary. High intrinsic safety, cycle stability and low aging should be ensured across the wide temperature range that is typical for automotive products. Another challenge for the battery electronics is the required capacity for rapid charging of the system. On one hand, a very high response and thus measurement time is required. On the other hand, power handling at peak values of more than 10 kW with currents up to 100 A cannot be achieved with traditional methods for cell balancing. The research for the booster development mainly focuses on two main objectives, the cell development including assembly, and the electronics for battery management.

Cell development

The properties of high-performance Lithium cells are significantly influenced by material and process parameters. Electrochemical storage with Lithium Titanate ($Li_4Ti_5O_{12}$) as an anode material generally fulfills the desired characteristics like long life, high safety and the potential for a very good rate capability.
Previous works at Fraunhofer ISIT have shown that Lithium Titanate anodes comply much better to these requirements than graphite-based systems.

In the current project, ISIT further developed and optimized the materials and processes as well as the cell design in order to maximize the power density while maintaining the aforementioned characteristics.

The high power cells (figure 1) were designed with a capacity of 3.33 Ah and a maximum rate capability of 30 °C.
In order to reach these parameters, a high-power Lithium Manganese Oxide (LMO) is used as cathode material and a thin separator consisting of olefin polymers. As can be seen in figure 2, these cells can even provide up to 50 °C at 20 °C with a residual capacity of 20 % (50 % at 30 °C). Cycle tests (figure 3) show a very good stability with 100 % discharge capacity after 490 cycles.

The fully developed cells are now produced at ISIT in a small series of 150 pieces, with 132 needed for the booster battery system. In this system, each sub-module consists of 12 cells; 11 sub-modules are connected in series in order to obtain a working voltage of 240 V to 370 V with a maximum current of 100 A. For the battery, a liquid cooling system will be used to minimize the temperature increase during times of peak power output.

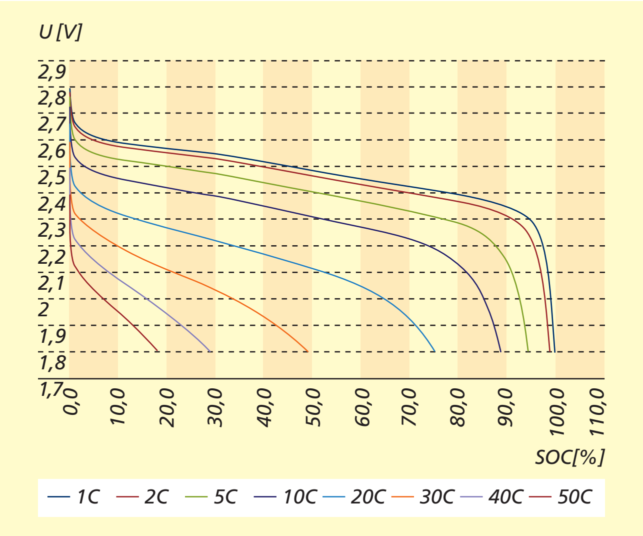


Figure 2: Discharge behavior of the ISIT Booster cell at 20 °C

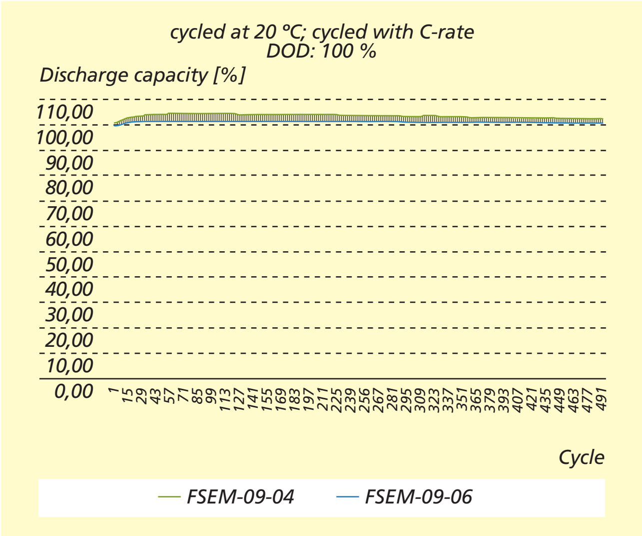


Figure 3: Cycle stability of the ISIT Booster cell at 20 °C

Battery management system

The second priority of the project is the battery management system (BMS). For this, a special concept was developed which combines a balancing of the charge states in the resting phase with the complete shutdown of aged low-power cells.

In the Li-booster concept, the overall functionality is split into three independent hardware modules:

- Central control board (interface to the vehicle, energy management)
- BMS electronics (cell voltage measurement, short circuit and overload protection)
- BMS cell (cell temperature monitoring, SOH, cell balancing)

The work that has been done in this project by Fraunhofer ISIT shows, that it is possible to devolp Lithium accumulators with a very high power density in combination with a long lifetime and cycle stability as well as an high intrinsic safety. It is also increased significantly the knowhow of the institute regarding battery design and construction.

Our Offer

- Optimization of electrode formulations and manufacturing procedures in regard to a high load capacity.
- Development and production of high-line storage battery prototypes for use in vehicles
- Characterization of batteries for the automotive industry

Author: Dr. Andreas Würsig

IMPORTANT NAMES, DATA, EVENTS

LECTURING ASSIGNMENTS AT UNIVERSITIES

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

R. Dudde
Mikrotechnologien (8168), Fachbereich Technik, FH Westküste, Heide

H. Kapels
Elektrotechnik, Elektronik Fakultät Technik und Informatik, HAW Hamburg

O. Schwarzelbach
Mikrotechnologien (8168), Fachbereich Technik, FH Westküste, Heide

O. Schwarzelbach
Mikroelektromechanische Systeme (MEMS), Institut für elektrische Messtechnik und Mess-Signalverarbeitung, Technische Universtität Graz, Austria

B. Wagner
Lehrstuhl Prozesse und Materialien der Nanosystemtechnik, Micro- and Nanosystem Technology, Technische Fakultät, Christian-Albrechts-Universität zu Kiel

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*

W. Benecke
Member of Editorial Boards
- *'Sensors & Acutuators'*
- *Microsystem Technologies (MST)*

J. Eichholz
Member of GMM / GI-Fachausschuss EM „Entwurf von Mikrosystemen", VDE / VDI-Gesellschaft für Mikroelektronik, Mikro- und Feinwerktechnik

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

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

D. Kähler
Nanotechnik S-H

D. Kähler
OE A (VDMA)

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

T. Knieling
Member of Organic and Printed Electronics North (OPEN)

T. Knieling
Member of Verband der Elektrotechnik Elektronik Informationstechnik e.V. (VDE)

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

M. Kontek
Member of AG 2.4 Drahtbonden, DVS

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

J. Lähn
Member of Hamburger Lötzirkel

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

K. Pape
Member of BVS, Bonn

K. Pape
Member of FED

K. Pape
Member of VDI

H.-C. Petzold
Member of Netzwerk „Qualitätsmanagement" of the Fraunhofer Gesellschaft

M. H. Poech
Member of Arbeitskreis „Systemzuverlässigkeit von Aufbau- und Verbindungstechnologie" des Fraunhofer IZM

W. Reinert
Member of Arbeitskreis A2.6, "Waferbonden", DVS

W. Reinert
Member of „DVS-Fachausschuss Mikroverbindungstechnik"

W. Reinert
Member of Technical Committee of Electronics Packaging Technology Conference (EPTC)-Singapore

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

W. Reinert
Member of FA10 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

H. Schimanski
Member of VDE/VDI Arbeitskreis „Prüftechniken in der Elektronikproduktion“

H. Schimanski
ZVEI Fachverband Arbeitsgruppe „Zuverlässigkeit von Leiterplatten“

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

H. Schimanski
Member of Hamburger Lötzirkel

H. Schimanski
FED Arbeitskreis „Zukunftsweisende Baugruppenfertigung“

H. Schimanski
Member of FED Regionalgruppe Hamburg

C. Wacker
Member of Messebeirat of Husum Wind and WindEnergy Hamburg

B. Wagner
Member of GMM-Fachausschuss 4.1 „Grundsatzfragen der Mikrosystemtechnik und Nanotechnologie“, VDE/VDI-Gesellschaft für Mikroelektronik, Mikro- und Feinwerktechnik

A. Würsig
Member of Allianz Batterien of the Fraunhofer-Gesellschaft

A. Würsig
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)

G. Zwicker
Head of Fachgruppe Planarisierung / Fachausschuss Verfahren / Fachbereich Halbleitertechnologie und –fertigung der GMM des VDE/VDI

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

Capetown University, *South Africa*

Technische Universität Dresden, Institut für Aufbau- und Verbindungstechnik

Technische Universität Dresden, Institut für Halbleiter- und Mikrosystemtechnik

Fachhochschule Flensburg

Hochschule für Angewandte Wissenschaften, *Hamburg*

Helmut-Schmidt-Universität Hamburg

TU Hamburg Harburg

Fachhochschule Westküste, *Heide*

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

Fachhochschule Kiel

Acreo Swedish ICT, *Kista, Sweden*

Fachhochschule Lübeck

University of Naples Frederico II, *Naples, Italy*

Sydansk Universitet, *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

P. F. Hanßen
Distinction of being best apprentice as „ Mikrotechnologe - Mikrosystemtechnik „ at IHK Kiel for which he was awarded by the Fraunhofer-Gesellschaft, München, 2014

S. Queck
Distinction of being best apprentice as „Werkstoffprüfer" at IHK Kiel for which he was awarded by the Fraunhofer-Gesellschaft, München, 2014

M. Schröder
Distinction of being best apprentice as „Mikrotechnologe - Mikrosystemtechnik" at IHK Kiel for which he was awarded by the Fraunhofer-Gesellschaft, München, 2014

F. Stoppel, T. Lisec, B. Wagner
Outstanding Poster Award for: Novel Design Concepts for Piezoelectrically Driven Ohmic Switches
Eurosensors 2014, September 07–10, Brescia, Italy

TRADE FAIRS AND EXHIBITIONS

Battery Japan 2014
International Rechargeable Battery Expo, in Cooperation with Fraunhofer Netzwerk Batterien,
February 26–28, 2014, Tokyo, Japan

Battery University 2014
Developer Forum Accumulator Technologies
March 25–27, 2014, Aschaffenburg

Analytica 2014
International Trade Fair for Laboratory Technology, Analysis, Biotechnology and Analytica Conference,
April 01–04, 2014, München

Hannover Messe 2014
Integrated Industry – NEXT STEPS
April 7–11, 2014, Hannover
SMT/Hybrid/Packaging 2014

Hybrid *Packaging System Integration in Micro Electronics,*
May 06 – 08, 2014, Nürnberg

Optatec 2014
International trade fair for optical technologies, components and systems,
May 20 – 22, 2014, Frankfurt

PCIM Europe 2014
International Exhibition & Conference, Power Conversion Intelligent Motion,
May 20–22, 2014, Nürnberg

LOPE-C 2014
International Conference and Exhibition for the Organic and Printed Electronics Industry,
May 26 – 28, 2014, München

Intersolar Europe 2014
The world's leading exhibition for the solar industry and its partners,
June 04–06, 2014, München

microtec nord 2014
September 08, 2014, Hamburg

AzubIZ 2014
Regional Training Fair,
September 19, 2014, Itzehoe

WindEnergy 2014
International Trade Fair for Wind Industry,
September 23–26, 2014, Hamburg

Electronica 2014
International Trade Fair for Electronic Components, Systems and Applications,
November 11–14, 2014, München

Compamed 2014
High Tech Solutions for Medical Technology International Trade Fair,
November 12–14, 2014, Düsseldorf

Jobaktiv Metropolregion 2014
Akademiker im Norden,
November 19, 2014, CCH, Hamburg

IMPORTANT NAMES, DATA, EVENTS

MISCELLANEOUS EVENTS

Aspekte moderner Siliziumtechnologie
Public lectures, monthly presentations, 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 11, 2014, Fraunhofer ISIT, Itzehoe

Die beherrschbare Baugruppenfertigung
Herstellungsqualität, Fehleranalyse und Prozessoptimierung
Seminar: February 25–27 and September 23–25, 2014, Fraunhofer ISIT, Itzehoe

Information Visit on „Herausforderung der Energiewende“
Speakers:
Frank Horch, *Economics Senator from Hamburg*
Reinhard Meyer, *Minister for Economic Affairs in Schleswig-Holstein*
Prof. Wolfgang Benecke
Press conference: March 23, 2014, Fraunhofer ISIT, Itzehoe

Der optimierte Rework-Prozess
Lernen Sie Ihren Reparaturprozess sicher zu beherrschen
Seminar: April 02–04, 2014, Fraunhofer ISIT, Itzehoe

ISIT Participation in “Deutsche Biotechnologietage”
April 09–10, 2014, Congress-Centrum, Hamburg

31. CMP Users Meeting and 2. Wet Users Meeting
April 10, 2014, Pettenasco, Italy

Opening ceremony of the new ISIT Cleanroom building
Speakers:
Reinhard Meyer, *Minister for Economic Affairs in Schleswig-Holstein*
Prof. Alfred Gossner, *Senior Vice President of the Fraunhofer-Gesellschaft*
Dr. Andreas Koeppen, *Mayor of the City of Itzehoe*
Hans-Jürgen Straub, *X-Fab*
Frédéric Breussin, *Yole Développement*
May 28, 2014, Fraunhofer ISIT, Itzehoe

ISIT Participation in „Hochleistungsbatterien für die Elektromobilität Entwicklungen und Perspektiven“
Workshop Speichertechnologie, June 25, 2014, Aachen

ISIT Participation in „MedTechPharma-Kongress“
July 02–03, 2014, Messe, Nürnberg

Fraunhofer ISIT gründet Außenstelle an der Christian Albrechts Universität Kiel
Speakers:
Prof. Karin Schwarz, *CAU Vice President*
Prof. Bernhard Wagner, *Member of ISIT-Board*
Press conference: July 09, 2014, CAU Kiel

Information Visit of Reimer Böge, MdEP
Speakers:
Prof. Wolfgang Benecke
Prof. Holger Kapels
August 11, 2014, Fraunhofer ISIT, Itzehoe

ISIT Participation in „Heiligenstädter Kolloquium“
September 22–24, 2014, IBA, Heilbad Heiligenstadt

ISIT Participation in “Low Flow in MEDICAL Technology”
Workshop, September 23–25, 2014, Lübeck

32. CMP Users Meeting and 3. Wet Users Meeting
October 09, 2014, Bernin, France

Innovation Cluster Power Electronics for Renewable Energy
2. Workshop, November 27, 2014, Fraunhofer ISIT, Itzehoe

Fraunhofer ISIT gründet neues Anwendungszentrum an der HAW Hamburg
Speakers:
Dr. Dorothee Stapelfeldt, *Senator of Economics and Research from Hamburg*
Prof. Jacqueline Otten, *President of HAW Hamburg*
Prof. Wolfgang Benecke
Dr. Patrick Hoyer *Member of Administrative Department of the Fraunhofer-Gesellschaft*
Press conference: December 05, 2014, Town Hall, Hamburg

Wellenlöten und Selektivlöten Technologien, Fehlervermeidung durch Prozessoptimierung,
Qualitätsbewertung
Seminar: December 09– 10, 2014, Fraunhofer ISIT, Itzehoe

JOURNAL PAPERS, PUBLICATIONS AND CONTRIBUTIONS TO CONFERENCES

L. Blohm, C. Püttmann, S. Holz, G. Piechotta, J. Albers, C. Dammers, M. Kleines, A. Krüttgen, G. Melmer, J. Nähring, S. Barth, E. Nebling
Rapid Detection of Different Human Anti-HCV Immunoglobulins on Electrical Biochips. Antibody Technology Journal 2014:4, 23–32

S. Gu-Stoppel, J. Janes, H.-J. Quenzer, U. Hofmann, W. Benecke
Two-Dimensional Scanning Using two Single-Axis Low-Voltage PZT resonant Micromirrors. Proceedings of SPIE Vol. 8977, 897706: MOEMS and Miniaturized Systems XIII, March 7, 2014

S. Gu-Stoppel, J. Janes, H.-J. Quenzer, W. Benecke
High frequency 1D Piezo-electric resonant Micro-scanners with Large Displacements. Eurosensors 2014, Brescia, Italy, September 7–10, 2014

U. Hofmann, M. Aikio, J. Janes, F. Senger, V. Stenchly, J. Hagge, H.-J. Quenzer, M. Weiss, T. von Wantoch, C. Mallas, B. Wagner, W. Benecke
Resonant Biaxial 7-mm MEMS Mirror for Omni-directional Scanning. J. Micro/Nanolith. MEMS MOEMS 13(1), 011103:1–12 (Jan–Mar 2014)

U. Hofmann, F. Senger, J. Janes, C. Mallas, V. Stenchly, T. von Wantoch, H. J. Quenzer,M. Weiss
Wafer-Level Vacuum-Packaged Two-Axis MEMS Scanning Mirror for Pico-Projector Application. Proceedings of SPIE Vol. 8977, 89770A: MOEMS and Miniaturized Systems XIII, March 7, 2014

R. Jahns, S. Zabel, S. Marauska, B. Gojdka, B. Wagner, R. Knöchel, R. Adelung, F. Faupel
Microelectromechanical Magnetic Field Sensor Based on ΔE Effect Applied Physics Letters 105, 052414:1-3 (2014)

T. Knieling, C. Deusen
Kleine Ursache – Große Wirkung: Schadensanalyse an elektronischen Bauteilen. Zeitschrift QZ, Nr. 11, 2014, Carl Hanser Verlag, München

P. Lange, M. Weiss, S. Warnat
Characteristics of a Micro-Mechanical Thermal Flow Sensor Based on a Two hot Wires Principle with Constant Temperature Operation in a Small Channel. J. Micromech. Microeng. 24 (2014) 125005

M. H. Poech
Power Modules with Increased Power Density and Reliability Using Cu Wire Bonds on Sintered Metal CIPS 2014, VDE Verlag GmbH, Nuremberg, February 25–27, 2014

H.-J. Quenzer, V. Stenchly, S. Schwarzelbach, M. Kampmann, B. Wagner and R. Dudde
Precision Micro-Optical Elements for Manufacturing of Gas Sensors using IR-Absorption. Proceedings of Nanotech 2014, Washington, MD

H. Rathmann, C. Weber, W. Benecke, J. Eichholz, D. Kähler
Novel Method of State-of-Charge Estimation using In-Situ Impedance Measurement. IECON 2014, online eingereicht April 24, 2014

K. Ronge, M. Loske, P. Spies, H. Kapels, D. Kähler, J. Molter
Semiconductor Technologies for Smart Cities. CATRENE Scientific Committee, Chapter 3.4 Energy, 2014

H. Schimanski
Einfluss der Nutzentrennung auf die Baugruppenqualität - Nutzentrennverfahren und Möglichkeiten zur Design-optimierung. Konferenzband, 22. FED-Konferenz, pp. 485–500, Bamberg, September 18–20, 2014

H. Schimanski
Surface Insulation Resistance (SIR) measurement of jetted solder paste. EPP Europe, pp. 42-43, October, 2014

V. Stenchly, F. Lofink, W. Reinert
AR-Concepts for Hermetic Wafer Level Packaging of Uncooled FIR Bolometer Arrays. ESTC 2014, Helsinki, Finland, September 16 –18, 2014

F. Stoppel, T. Lisec, B. Wagner
Novel Design Concepts for Piezoelectronically Driven Ohmic Switches. Procedia Engineering Vol. 87, p. 416-419, September, 2014

T. von Wantoch, C. Mallas, J. Janes, B. Wagner, W. Benecke
Analysis of Capacitive Sensing for 2D-MEMS Scanner Laser Projection Proceedings SPIE 8977, MOEMS and Miniaturized Systems XIII, 897707 March 7, 2014

T. von Wantoch, H. Roeck, F. Koschmieder, W. Benecke
Adaptive Phasor Control of a Duffing Oscillator with Unknown Parameters. Proceedings of the 19th IFAC World Congress, 2014

TALKS AND POSTER PRESENTATIONS

L. Blohm
Microfluidics for Electrical Biochip Technology. 8th Workshop Low Flows in Medical Technology, Lübeck, September 24, 2014

R. Dudde
Precision Micro-Optical Elements for Manufacturing of Gas-Sensors using IR-Absorption. Nanotech 2014, Washington, DC, June 15–18, 2014

R. Dudde
Development of new Technologies-Industrial Production Services. INC10, Gaithersburg, Maryland, USA, May 13–15, 2014

D. Friedrich, F. Dietz, J. Hinz, H. Hanssen
Entwicklung und Herstellung einer Si Fast-Recovery Hochvolt Diode. DLR-Bauteilekonferenz, Freiburg, April 9–10, 2014

D. Friedrich
Innovationscluster Leistungselektronik Regenerative Energieversorgung in Schleswig-Holstein. Veranstaltung Innovationscluster Niedersachsen, Hannover, July 17, 2014

D. Friedrich
Robuste Hochvolt Bauelemente. MicroTech Nord, Hamburg, September 08, 2014

D. Friedrich
IGBT Entwicklung und Produktion in Itzehoe. Workshop Innocluster, ISIT, Itzehoe, November 27, 2014

D. Friedrich
Innovationscluster Leistungselektronik Regenerative Energieversorgung. Workshop Innocluster, ISIT, Itzehoe, November 27, 2014

P. Gulde
Lithium Secondary Battery Technology with LTO-Anode – a System with Inproved Safety Features. HYDRAIL 2014, Neumünster, June 16–18, 2014

S. Gu-Stoppel, J. Janes, H.-J. Quenzer, U. Hofmann, W. Benecke
Two-Dimensional Scanning Using two Single-Axis Low-Voltage PZT resonant Micromirrors. SPIE, March 7, 2014

S. Gu-Stoppel, J. Janes, H.-J. Quenzer, W. Benecke
High frequency 1D Piezoelectric resonant Microscanners with Large Displacements. Eurosensors 2014, Brescia, Italy, September 7–10, 2014

J. Hinz
Elektrische Simulation moderner Leistungsbauelemente. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, September 3, 2014

U. Hofmann, F. Senger, J. Janes, C. Mallas, V. Stenchly, T. von Wantoch, H.-J. Quenzer, M. Weiss
Wafer-Level Vacuum-Packaged Two-Axis MEMS Scanning Mirror for Pico-Projector Application. SPIE, March 7, 2014

B. Jensen
Silizium Germanium basierte Energyharvester (Thermogeneratoren) für Hochtemperaturanwendungen auf 8"-Wafern. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, November 5, 2014

H. Kapels
Trends in Strukturen und Technologien für Leistungshalbleiterbauelemente. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, March 5, 2014

T. Knieling
Flexible Insoles Preparation with Inkjet Printing Technology and Pressure Sensors as a part of Acoustic Gait Analysis. Manufacturing for Printed Electronics Conference, Cambridge, March 20, 2014

T. Knieling
Stability, Reliability and Promises of Organic Systems. ThinFace Summer School, Sønderborg, Denmark, August 18–22, 2014

T. Knieling
Hybrid Electronics for Healthcare and Sports applications. OE-A 10th Annual General Assembly and 33rd Working Group Meeting, Janssen Pharmaceutica, Beerse, Belgium, October 28–29, 2014

T. Knieling
Herstellung einer funktionellen Sohleneinlage für die akustische Ganganalyse in Sport, Medizin und Rehabilitation. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, December 3, 2014

J. Lingner
Untersuchungen zur Qualität und Zuverlässigkeit in der Leistungselektronik – das ISIT-Dienstleistungsangebot. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, February 5, 2014

J. Molter, J. Ophey
Technologie-Trends in der Li-Ionen Batteriezellenfertigung. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, May 7, 2014

E. Nebling
Siliziumbasierte Biosensoren als integraler Bestandteil mikrofluidischer Systeme. 17. Heiligenstädter Kolloquium, Heilbad Heiligenstadt, September 22–24, 2014

TALKS AND POSTER PRESENTATIONS

E. Nebling
Diagnostik mittels silizium-basierter Chiptechnologie. Bernhard-Nocht-Institut, Hamburg, Oktober 07, 2014

M. H. Poech
Fehlermechanismen. ECPE Cluster-Schulung „Aufbau- und Verbindungs-technik in der Leistungs-elektronik“, Regensburg, February 13–14, 2014

M. H. Poech
Werkstoffe der AVT 1. ECPE Cluster-Schulung „Aufbau- und Verbindungs-technik in der Leistungs-elektronik“, Regensburg, February 13–14, 2014

M. H. Poech
Werkstoffe der AVT 2. ECPE Cluster-Schulung „Aufbau- und Verbindungs-technik in der Leistungs-elektronik“, Regensburg, February 13–14, 2014

M. H. Poech
Passive Bauelemente, Schaltungsträger, Kühlkörper. ECPE Cluster-Schulung „Aufbau- und Verbindungs-technik in der Leistungs-elektronik“, Regensburg, February 13–14, 2014

M. H. Poech
AVT für Systeme kleiner und mittlerer Leistung. ECPE Cluster-Schulung „Aufbau- und Verbindungs-technik in der Leistungs-elektronik“, Regensburg, February 13–14, 2014

M. H. Poech
Zuverlässigkeit von Baugruppen. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27 and September 23–25, 2014

M. H. Poech
Das Verhalten der Lötstelle, der Einfluss ihrer Geometrie und die Erwartung an den Lotwerkstoff. 26. BFE-Jahrestreffen, Greifswald, March 25–26, 2014

M. H. Poech
Selektivlöten in der Leistungselektronik. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27 and September 23–25, 2014

M. H. Poech
Das Reflow-Lötprofil bei eingeschränktem Prozessfenster. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27 and September 23–25, 2014

M. H. Poech
Solder Joint Reliability – Modelling might help. IPC Europe High Reliability Forum, Düsseldorf, October 14–15, 2014

M. H. Poech
Power Cycling Failures explained by Modelling the Materials Behaviour. ECPE Workshop “Intelligent Reliability Testing”, Nuremberg, December 2–3, 2014

H.-J. Quenzer
Miniaturisierte Optiken für die Gassensorik. Aspekte moderner Silizium-technologie, Fraunhofer ISIT, Itzehoe, October 1, 2014

H.-J. Quenzer, V. Stenchly, S. Schwarzelbach, M. Kampmann, B. Wagner and R. Dudde
Precision Micro-Optical Elements for Manufacturing of Gas Sensors using IR-Absorption. Nanotech 2014, Washington, May 12–15, 2014

W. Reinert
Hermetische Verkappung von Mikrosensoren auf Waferebene. Aspekte moderner Silizium-technologie, Fraunhofer ISIT, Itzehoe, April 2, 2014

M. Reiter
Baugruppen- und Fehler-bewertung. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27 and September 23–25, 2014

H. Schimanski
Lötqualität und Reflow-Lötverfahren. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27, 2014

H. Schimanski
Einflussfaktoren im Lotpastendruck. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27, 2014

H. Schimanski
Prozessfenster und Zuver-lässigkeit manuell reparierter Lötstellen. ISIT-Seminar: Die beherrsch-bare Baugruppenfertigung, ISIT, Itzehoe, February 25–27, 2014

H. Schimanski
(Bleifrei) Reparaturlöten. ISIT-Seminar: Der optimierte Rework-Prozess, ISIT, Itzehoe, April 02–04, 2014

H. Schimanski
Baugruppen schonende Reparatur komplexer SMT-Baugruppen. ISIT-Seminar: Der optimierte Rework-Prozess, ISIT, Itzehoe, April 02–04, 2014

H. Schimanski
Baugruppen- und Fehlerbe-wertung. ISIT-Seminar: Der optimierte Rework-Prozess, ISIT, Itzehoe, April 02–04, 2014

H. Schimanski
Einfluss der Nutzentrennung auf die Baugruppenqualität. 22. FED-Konferenz, Bamberg, September 18–20, 2014

H. Schimanski
Lötqualität und Reflow-Lötverfahren. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, September 23–25, 2014

H. Schimanski
Einflussfaktoren im Lotpastendruck. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, September 23–25, 2014

H. Schimanski
Einfluss der Nutzentrennung auf die Baugruppenqualität. ISIT-Seminar: Die beherrschbare Baugruppenfertigung, ISIT, Itzehoe, September 23–25, 2014

H. Schimanski
Lötprofiloptimierung und Qualitätsbewertung. ISIT-Seminar: Wellenlöten und Selektivlöten, ISIT, Itzehoe, December 09–10, 2014

F. Senger
MEMS-Scanner für Anwendungen in der Laser-Materialbearbeitung. Aspekte moderner Siliziumtechnologie, Fraunhofer ISIT, Itzehoe, June 4, 2014

V. Stenchly, F. Lofink, W. Reinert
AR-Concepts for Hermetic Wafer Level Packaging of Uncooled FIR Bolometer Arrays. ESTC 2014, Helsinki, Finland, September 16–18, 2014

F. Stoppel, T. Lisec, B. Wagner
Novel Design Concepts for Piezoelectronically Driven Ohmic Switches. Procedia Engineering, September, 2014

T. von Wantoch, C. Mallas, J. Janes, B. Wagner, W. Benecke
Analysis of Capacitive Sensing for 2D-MEMS Scanner Laser Projection. SPIE, March 7, 2014

T. von Wantoch, H. Roeck, F. Koschmieder, W. Benecke
Adaptive Phasor Control of a Duffing Oscillator with Unknown Parameters. 19th IFAC World Congress,Cape Town, South Africa, August 24–29, 2014

A. Würsig
Cell Design and Production – Quality and Safety Aspects. Automotive Battery Safety 2014, Berlin, December 01–03, 2014

DIPLOMA, MASTER'S AND BACHELOR'S THESES

Subhasis Chakraborty
Optimization of Double Pulse Measurements for Fast Switching Power Transistors by Reduction of High Frequency Overshoot.
Master's thesis, TU Hamburg-Harburg, April 2014

Martin Günther
Modellierung und Regelung eines biaxialen MEMS Scanners mit piezoelektrischen Aktuatoren.
Bachelor's thesis, CAU Kiel, September 2014

Thomas Kock
Entwicklung einer Messvorschrift zur Erfassung charakteristischer Zelldaten von Lithium-Polymer Batterien mit Hilfe eines elektronischen Modells basierend auf impedanzspektroskopischen Messungen.
Master's thesis, HAW Hamburg, July 2014

Fabian Köster
Entwicklung eines aktiven Cell-Balancing-Systems als Erweiterung eines vorhandenen Batterie-Management-Systems.
Bachelor's thesis, FH Westküste, June 2014

Dennis Knobbe
Entwicklung automatisierter Pumpenantriebe für ein integriertes Biochip-Kartuschensystem für die Point-of-Care Diagnostik
Bachelor's thesis, CAU Kiel, April 2014

Marcel Reher
Entwurf einer Regelung zur Ansteuerung eines biaxialen MEMS Scanners in Resonanz.
Bachelor's thesis, CAU Kiel, August 2014

Thomas Reich
Modellierung und Identifikation der analogen Signalverarbeitung eines kapazitiven MEMS Scanners.
Bachelor's thesis, CAU Kiel, September 2014

Mohamed Zied Sadfi
Entwicklung eines Verfahrens zur Extraktion von Modellparametern zur Modellierung der Zellen mit einem Kalman-Filter.
Bachelor's thesis, HTW Berlin, October 2014

Georg Schönweger
Herstellung und Untersuchung von AlScN-Dünnfilmen für piezoelektrische Anwendungen.
Bacherlor's thesis, CAU Kiel, 2014

Leslie Schröder
Entwicklung eines integrierten Biochipkartuschensystems in Verbindung mit Assayoptimierungen für die Point-of-Care–Diagnostik.
Master's thesis, HAW Hamburg, November 2014

Jan Philip Wilner
Entwicklung, Aufbau und Test eines Hochvolt-Slaves eines Batteriemanagementsystems für einen Lithium-Akkumulator mit Li4Ti5O12-Anode für ein Hybridfahrzeug.
Bachelor's thesis, FH Kiel, March 2014

PATENTS

Supplement 2013
U. Hofmann, L. Ratzmann, J. Janes, M. Weiß, S. Mühlmann
Ablenkeinrichtung für eine Projektionsvorrichtung, Projektionsvorrichtung zum Projizieren eines Bildes und Verfahren zum Ansteuern einer Ablenkeinrichtung für eine Projektionsvorrichtung
EP 2514211 B1

L. Blohm, E. Nebling, J. Albers, G. Piechotta
Integriertes Einweg-Chipkartuschensystem für mobile Multiparameteranalysen chemischer und/oder biologischer Substanzen
DE 102012205171 B3

2014
P. Merz, M. Weiß
Mikromechanischer Inertialsensor zur Messung von Drehraten
DE 10 2007 017 209 B4
JP 5552420

U. Hofmann, M. Oldsen
Micro-mirror actuator having encapsulated capability and method for the production thereof
JP 5486312
KR 10-1437193

N. Marenco
Method of manufacturing a multitude of micro-opto-electronic devices, and micro-optoelectronic device
JP 5507585

H.-J. Quenzer, G. Zwicker
Verfahren zur Oberflächenbehandlung einer elektrisch leitfähigen Substratoberfläche. Method for treating the surface of an electrically conducting substrate surface
EP 2058075 B1
JP 5484538
US 8,758,590 B2

U. Hofmann, M. Oldsen, B. Wagner
An electrostatic comb-drive micromechanical actuator
JP 5528466

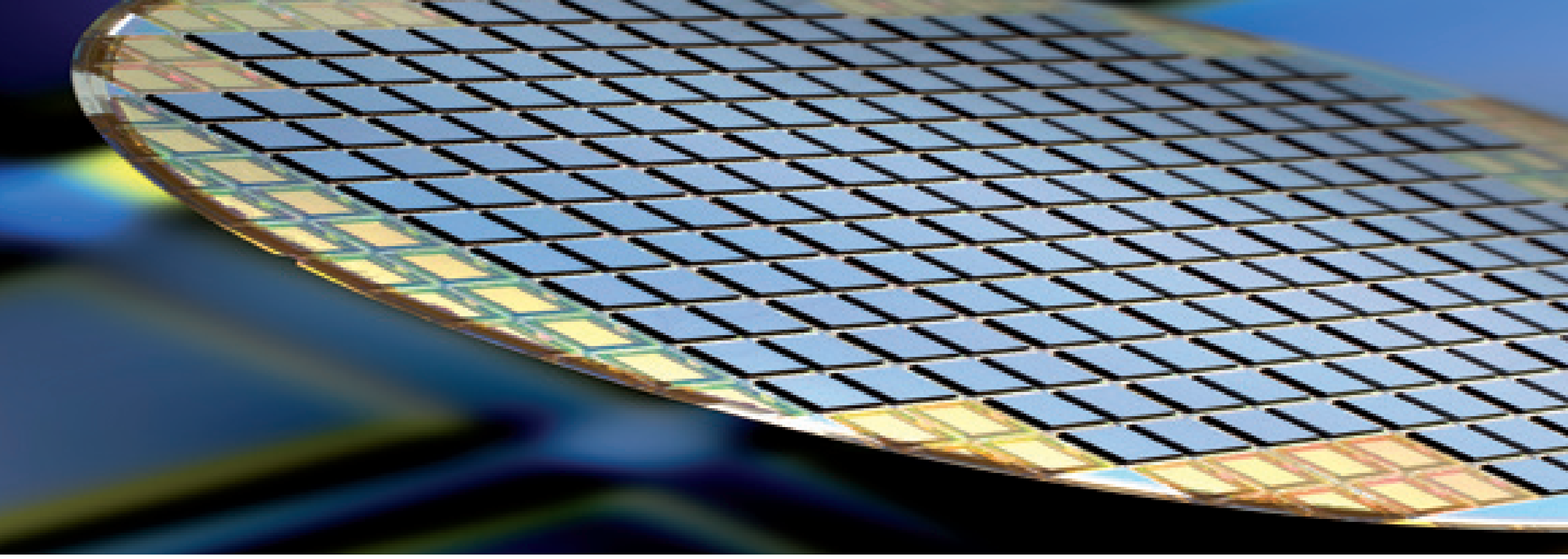
P. Merz, M. Weiss
Micromechanical Coriolis rate of rotation sensor
US 8,794,066,B2

O. Schwarzelbach, M. Weiß, V. Kempe
Sensor for detecting acceleration
KR 10-1413352

M. Oldsen, W. Reinert, P. Merz
Cover wafer of component cover, wafer part or component that can be inserted using microsystems technology, and soldering method for connecting corresponding wafer or component parts
KR 10-1416773

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
JP 5502465

N. Marenco
Method of manufacturing a multitude of micro-optoelectronic devices, and micro-optoelectronic device
US 8,900,904 B2



OVERVIEW OF PROJECTS

- *Integration von GaN mit CMOS-Technologie*
- *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*
- *Advanced Metallization for PowerMOS*
- *Entwicklung Epitaxie für Hochvolt PowerMOS*
- *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 256 k 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*
- *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*
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- *MiChroChip (MEMS-Chromatographiechip) intern*
- *F&E-Projekt mit LightStat LLC (Bioproject Phase 2)*
- *Zuverlässige Kontaktierung von Höchstleistungsbauelementen in der Leistungselektronik durch innovative Bändchen- und Litzenverbindungen (MAXIKON)*
- *Produktionsgerechtes reaktives Nanofügen zum hermetischen Versiegeln von Mikrosensoren auf Waferebene (REMTEC)*
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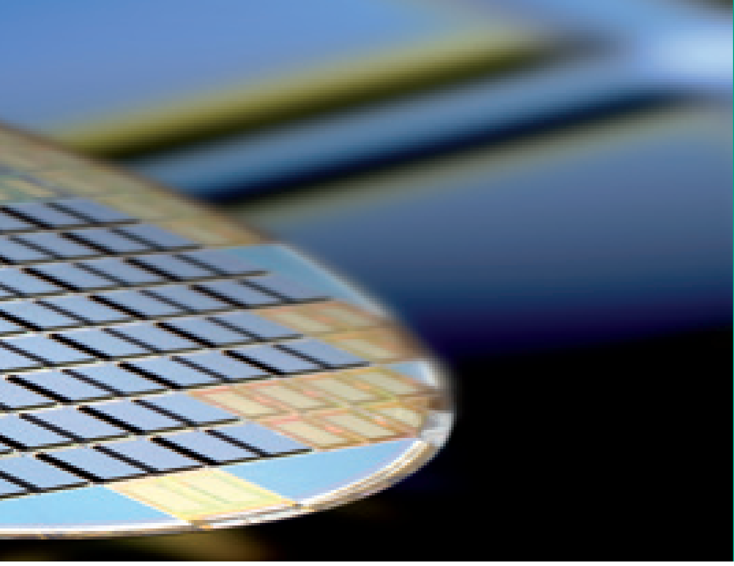
- *Glaslotbonden mit strukturierten Capwafern und Musterwafern*
- *Wafer Level Packaging*
- *Process Development for Hermetic AuSn Vacuum Sealing of IR Sensors on Wafer Level*
- *Wafer Level Balling for 100 µm up to 500 µm Spheres*
- *Neon Ultra Fine Leak Test for Resonant Micro Sensors*
- *Hochzuverlässige 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*
- *Development and manufacturing of laser profile modification apertures for human eye correction*
- *Digitaler Schreibstift für den Schulunterricht (BMBF-Projekt „DIGISTIFT“)*
- *Aufbautechnik für AlGaN-Detektoren zur Emissionsüberwachung von UV-Strahlern (WISA-Projekt „AGNES“)*
- *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-Konzept Velocity*
- *Innovatives Funktionsmaterial für Speichertechnologien „Ormocere“*
- *Entwicklung von Produktionstechnologien für Lithiumakkumulatoren (Protrak)*
- *Entwicklung und Fertigung von Elektroden für Lithium-Schwefel Batterien (Eurolis)*
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- *Temperaturoptimierte Batterietechnologien TopBat*
- *Neue Konzepte für die Elektroden und Separatorfertigung bei Lithiumakkumulatoren (S-Protrak)*

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