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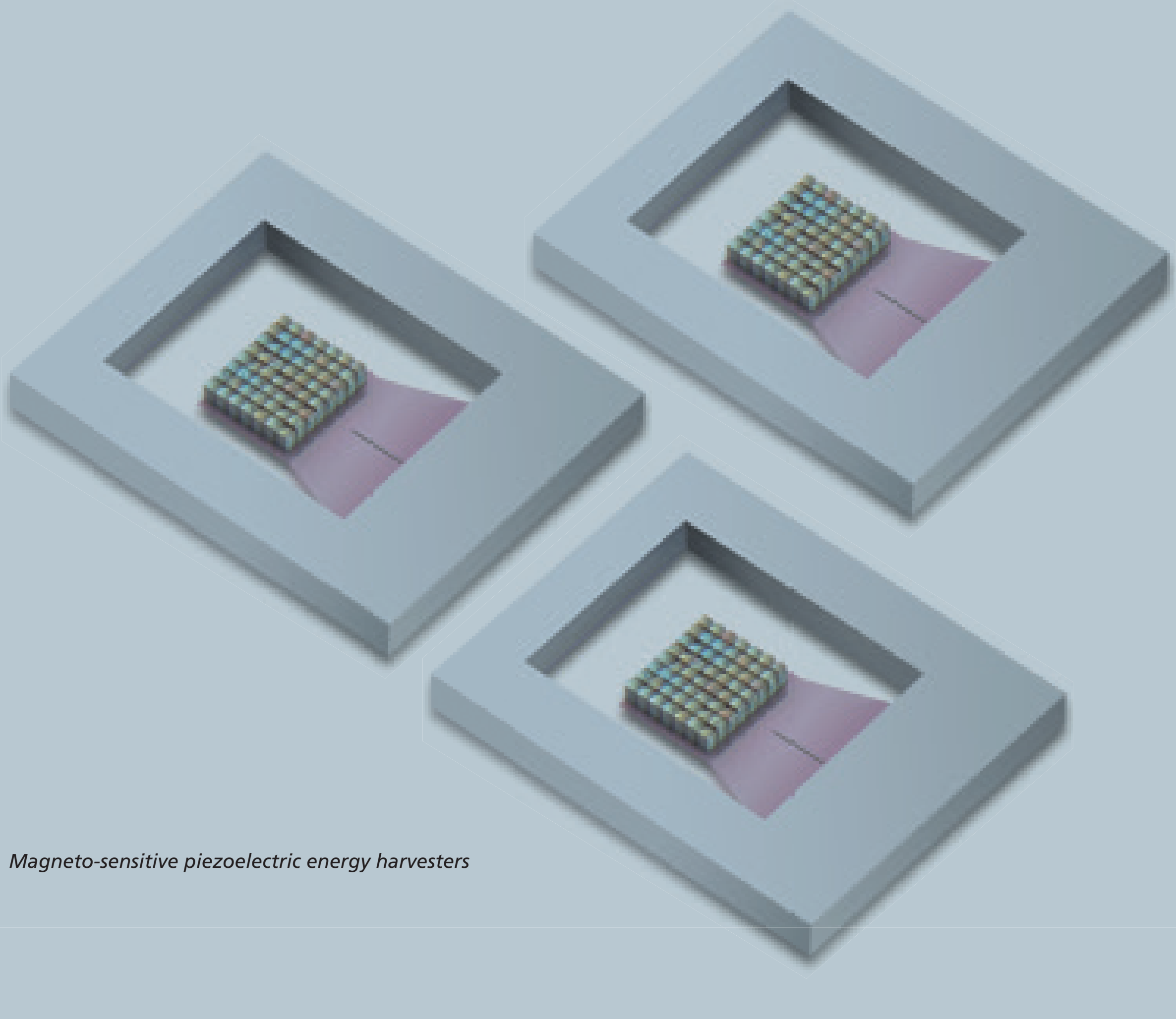
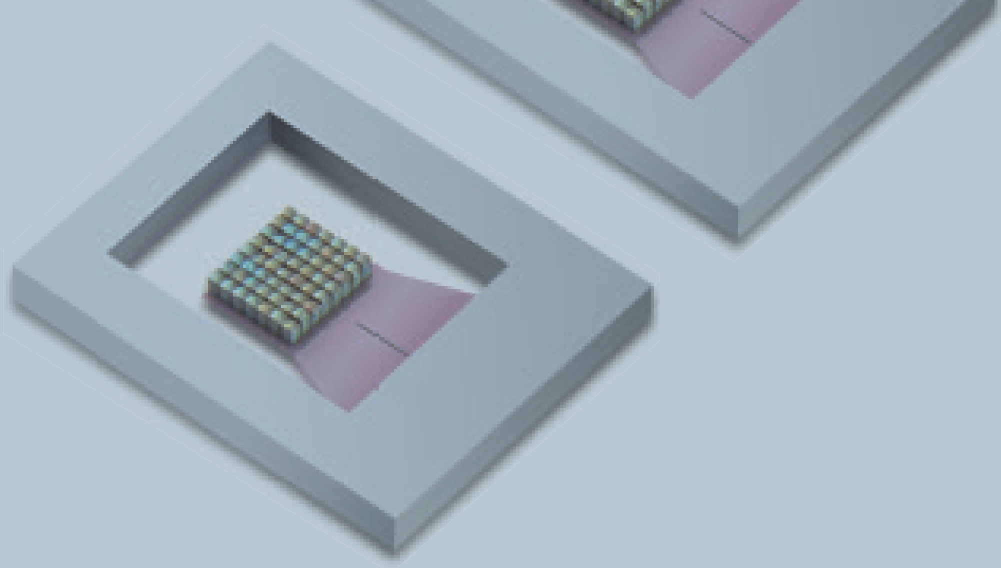
ISIT

FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE ISIT

Achievements and Results Annual Report 2017



Magneto-sensitive piezoelectric energy harvesters



Achievements and Results Annual Report 2017

ANNUAL REPORT 2017

MEMS speaker

PREFACE

Dr. Axel Müller-Groeling

NEW CLEANROOM CREATES GOOD PROSPECTS FOR FRAUNHOFER ISIT

NEUER REINRAUM SCHAFFT GUTE PERSPEKTIVEN FÜR DAS FRAUNHOFER ISIT

Dear business partners, dear friends of ISIT, dear colleagues,

The Fraunhofer Institute for Silicon Technology ISIT received important visitors early in 2017. The Schleswig-Holstein state cabinet met at our institute and the cabinet members learned about new prospects for the institute over the coming years, in particular due to the commissioning of the new clean room in 2015. Meanwhile, the clean room is running in normal operation. The strategic partnership with the X-FAB MEMS Foundry Itzehoe, which develops and manufactures microelectromechanical systems (MEMS) in the clean room jointly with Fraunhofer ISIT, has been further expanded. In the meantime X-FAB has 80 employees in Itzehoe, with a rising trend.

The strategic partnership with Vishay Siliconix in the field of power electronics was also secured for the future and intensified in 2017. Our constructive and productive collaboration has been contractually agreed for the coming years in a memorandum of understanding. Detailed provisions will be drafted and signed in 2018.

The institute has developed a stable customer base with more than 350 clients in the twenty-three years of its existence in Itzehoe, about 50 of them from Schleswig-Holstein, and continues to serve as an attractive and innovative research partner for the industry.

One of Fraunhofer ISIT's special strengths is the ability to support industry partners on site with development all the way to series production. We are hoping for ongoing federal and state support in the future in order to continue expanding this aspect.

In 2017 the institute received a considerable boost to its development from Berlin. The Federal Ministry of Education and Research (BMBF) is subsidizing microelectronics research at Fraunhofer ISIT in Itzehoe with 19.3 million euros. Fraunhofer ISIT is one of 13 institutes across Germany in the "Forschungsfabrik Mikroelektronik Deutschland" (FMD) investment program. Thus, Schleswig-Holstein

Liebe Geschäftspartner, liebe Freunde des ISIT, liebe Kollegen

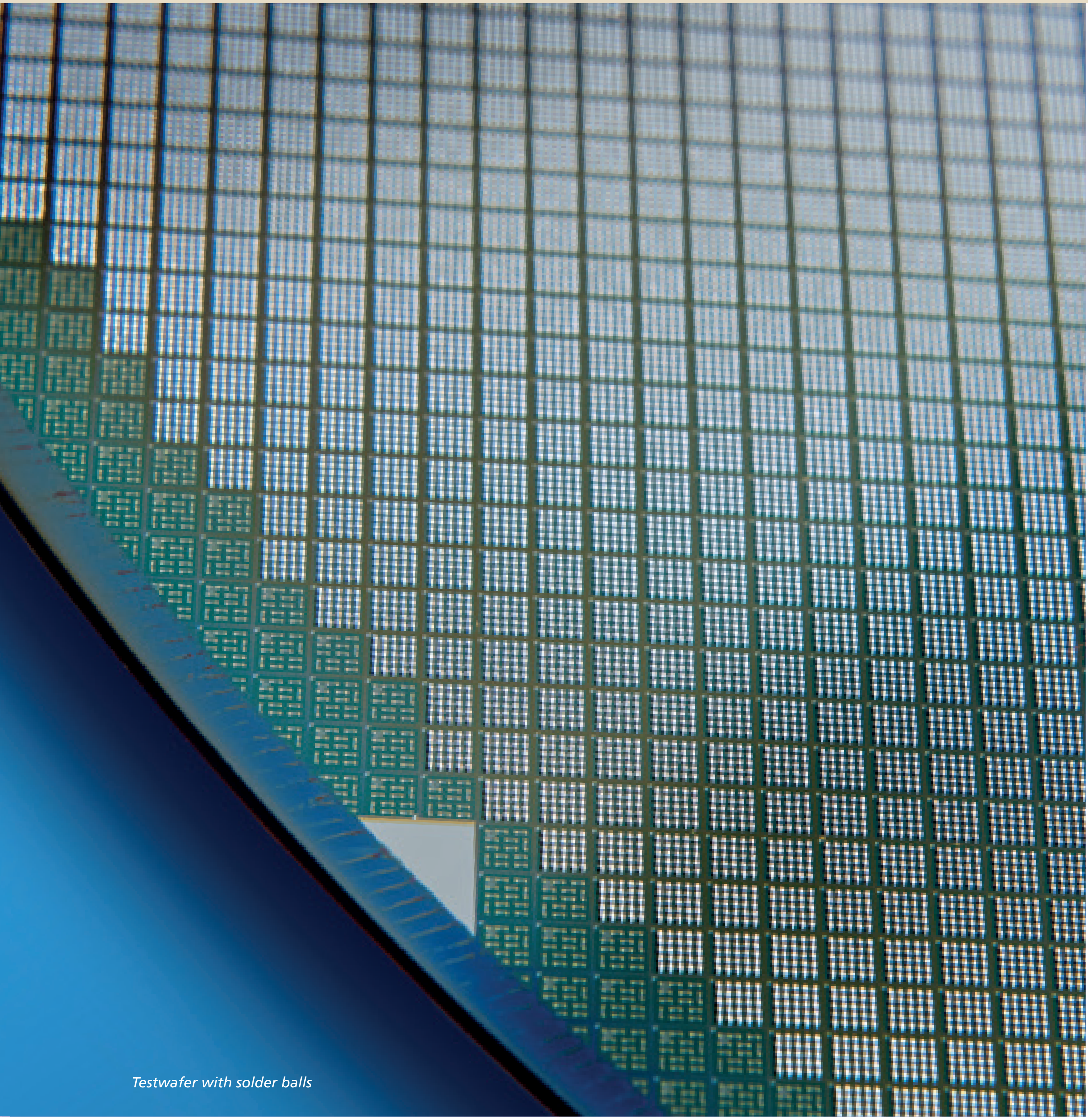
gleich zu Beginn des Jahres 2017 hatte das Fraunhofer ISIT hohen Besuch. Das Schleswig-Holsteinische Landeskabinett tagte in unserem Institut und die Kabinettsmitglieder informierten sich über neue Perspektiven für das Institut in den kommenden Jahren, die sich vor allem durch die Inbetriebnahme des neuen Reinraums 2015 eröffnet haben. Mittlerweile läuft der Reinraum im Normalbetrieb. Die strategische Partnerschaft mit der X-FAB MEMS Foundry Itzehoe, die in dem Reinraum gemeinsam mit dem Fraunhofer ISIT mikroelektromechanische Systeme (MEMS) entwickelt und fertigt, konnte weiter ausgebaut werden. X-FAB beschäftigt mittlerweile 80 Mitarbeiterinnen und Mitarbeiter in Itzehoe, Tendenz steigend.

Auch die strategische Partnerschaft mit der Firma Vishay Siliconix auf dem Gebiet der Leistungselektronik wurde in 2017 für die Zukunft gesichert und intensiviert. In einem Memorandum of Understanding haben wir die konstruktive und gute Zusammenarbeit für die kommenden Jahre vertraglich vereinbart. Die Detailregelungen sollen in 2018 formuliert und unterzeichnet werden.

In den dreiundzwanzig Jahren seines Bestehens in Itzehoe hat das Institut einen stabilen Kundenstamm mit mehr als 350 Unternehmen, davon etwa 50 aus Schleswig-Holstein, aufgebaut und bleibt ein attraktiver und innovativer Forschungspartner für die Industrie.

Eine besondere Stärke des ISIT liegt in der Fähigkeit, mit den Industriepartnern vor Ort die Entwicklung bis in die Serienproduktion hinein zu unterstützen. Um dies weiter ausbauen zu können, wünschen wir uns auch für die Zukunft die Unterstützung von Bund und Land.

Ein wesentlicher Entwicklungsschub für das Institut kam 2017 aus Berlin. Das Bundesforschungsministerium fördert die Mikroelektronik-Forschung am Fraunhofer-Institut für Siliziumtechnologie (ISIT) in Itzehoe mit 19,3 Millionen Euro. Das ISIT ist eines von bundesweit 13 Instituten im Investitions-programm „Forschungsfabrik Mikroelektronik Deutschland"


Testwafer with solder balls

is benefiting from the federal future program totaling 350 million euros.

The participating institutes have organized themselves across locations in order to strengthen the position of the European semiconductor and electronics industry in the global competitive environment. Operating as "Forschungsfabrik Mikroelektronik Deutschland" since the spring of 2017, the new organization is based in Berlin.

The investments for Fraunhofer ISIT serve to further modernize and expand the clean room equipment with a focus on power electronics, novel sensor systems, and MEMS.

In power electronics, Fraunhofer ISIT will provide systems for the development of gallium nitride as a new material basis of innovative power electronics components that previously did not exist at the institute. While silicon circuit technology is largely mature, the properties of the transistors are approaching the theoretical limit. GaN has a number of advantages over silicon, such as higher switching frequencies and lower switching losses. GaN devices will be used as central elements for power electronics modules, such as rectifiers in electric vehicles or photovoltaic and wind energy plants, helping to considerably improve the efficiency and service life of these systems. Currently however the processing of this material remains technically difficult. A lot of development work still needs to be done before GaN can establish itself for the industrial production of power components. In concrete terms, Fraunhofer ISIT is working on equipment for structuring and coating GaN substrates and devices for the measuring and electrical characterization of GaN power components.

New systems are also being acquired for the development of MEMS sensors and actuators in order to support the ongoing development of innovative technologies that can be transferred to industrial manufacturing methods. Equipment is being procured for the application of piezoelectric and magnetic materials to silicon as well as vapor phase deposition systems for

(FMD). Damit profitiert auch Schleswig-Holstein an dem 350 Mio. Euro umfassenden Zukunftsprogramm des Bundes.

Um die Position der europäischen Halbleiter- und Elektronikindustrie im globalen Wettbewerb zu stärken, haben sich die beteiligten Institute in einer standortübergreifenden Form organisiert. Die neue Organisation agiert seit Frühjahr 2017 als „Forschungsfabrik Mikroelektronik Deutschland" und hat Ihren Sitz in Berlin.

Die Investitionen für das Fraunhofer ISIT dienen der weiteren Modernisierung und dem Ausbau der Reinraumausstattung mit den Schwerpunkten Leistungselektronik sowie neuartige Sensorsysteme und MEMS.

In der Leistungselektronik wird das ISIT Anlagen für die Erschließung von Gallium-Nitrid als neue Materialbasis für innovative Leistungsbauelemente bereitstellen, die es bisher am Institut nicht gab. Silizium-Leistungsschalter sind zwar technologisch weitgehend ausgereift, jedoch nähern sich die Eigenschaften der Transistoren dem theoretischen Limit. GaN bietet gegenüber dem Silizium eine Reihe von Vorteilen, wie höhere Schaltfrequenzen und geringere Schaltverluste. GaN-Leistungsschalter werden zentrale Elemente für leistungselektronische Module, z. B. Stromrichter in elektrisch betriebenen Fahrzeugen oder in Photovoltaik- und Windenergieanlagen, und sie helfen diese Systeme deutlich leistungsfähiger und langlebiger zu machen. Zurzeit ist dieses Material technisch schwer zu bearbeiten und es besteht hoher Entwicklungsbedarf, damit sich GaN für die Herstellung von Leistungsbauelementen industriell durchsetzen kann. Konkret geht es am ISIT um Geräte zur Strukturierung und zum Beschichten von GaN-Substraten sowie um Geräte zur Vermessung und elektrischen Charakterisierung von GaN-Leistungsbauelementen.

Auch für die Entwicklung von MEMS-Sensoren und -Aktoren werden neue Anlagen angeschafft, um weiterhin innovative Technologien entwickeln zu können, die sich in industrielle Fertigungsverfahren überleiten lassen. Beschafft werden Geräte zum Aufbringen von piezoelektrischen und magnetischen Materialien auf Silizium,

ORGANIZATIONAL CHART

Head of Institute
Dr. Axel Müller-Groeling *Director*
Prof. Dr. Bernhard Wagner *Deputy Director*

Coordination of Forschungsfabrik Mikroelektronik Deutschland (FMD)
Prof. Dr. Bernhard Wagner, Dr. Klaus Reimer

Business Units

Management-Center
Karin Dusil
Rainer Finder

Business Support and Optimization

Administration

Power Electronics
Prof. Dr. Holger Kapels

Advanced Power Transistors

*PE for Renewable Power Systems**

Battery Systems for Special Applications

Micro Manufacturing Processes
Christian Beckhaus

WL Packaging and Processes

Validation and Pilot Production

Module Services

MEMS-Applications**
Dr. Fabian Lofink

Optical Systems

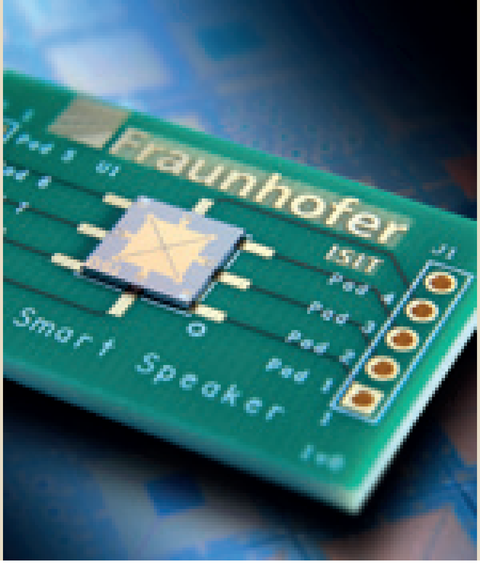
Acoustic Systems and Microactuators

Low Power Sensor Systems

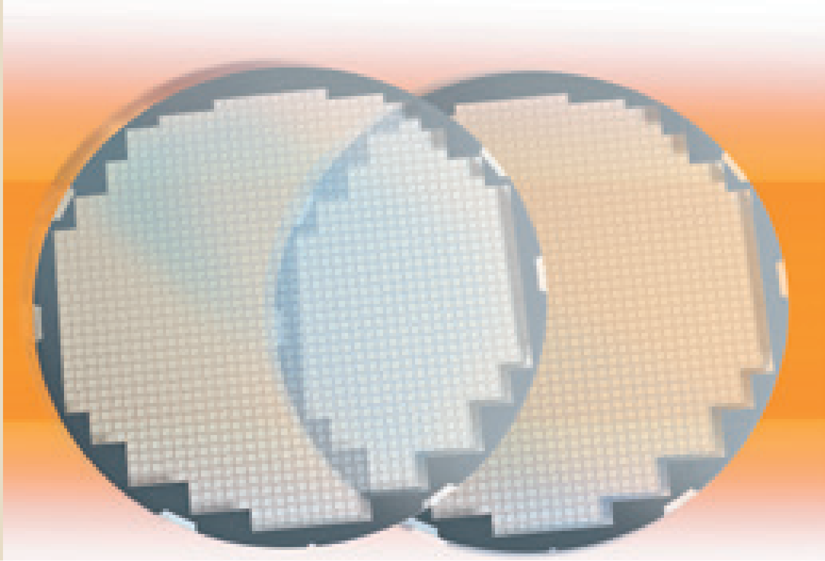
Technology-Development
Dr. Oliver Schwarzelbach

MEMS Fabrication
Dr. Klaus Reimer, Dr. Mohammad Hejjo al Rifai

* Application Center Hamburg
** with an external office at CAU Kiel and FH Westküste



MEMS speaker mounted on testboard



Glass substrate test wafer for calibration support

special optical and infrared coatings, and oven systems for the specific shaping of glass wafers.

This new equipment allows Fraunhofer ISIT to offer trendsetting manufacturing methods for the industry and enables it to develop novel components, such as magnetic field sensors, optical micro-scanners, and micro-speakers, and transfer them to production. These are important for various applications in industrial electronics (industry 4.0), automotive engineering (autonomous vehicles), and the consumer goods industry.

The social and economic relevance of Fraunhofer ISIT's research is also demonstrated by the founding of new companies by the institute. Scientists at Fraunhofer ISIT founded CAMPTON Diagnostics UG in cooperation with partners in 2017. This company is active in the medical engineering field and develops complete measurement systems for point-of-care diagnostics, i.e. is for on-site patient examinations. The founders intend to drive the market launch of their research products by founding this company.

ISIT scientists contributed to their specialists fields both nationally and internationally in 2017. Katja Reiter was presented with the 2017 metallography prize in recognition of her outstanding accomplishments in the field of preparative materialography. This prize is awarded by the German Materials Society (DGM). Katja Reiter has been active in this society for many years, giving presentations and conducting training.

Fraunhofer ISIT scientist Dr. Gerfried Zwicker was presented with the "Lifetime Achievement Award for Distinguished Contribution in the Field of Planarization" for his many years of dedication to the further development of a central process in semiconductor production, namely chemical-mechanical polishing (CMP). This award honors scientists and engineers for their contributions to the further development of this process, which has meanwhile become indispensable for the production of microelectronics components. He received the award during the International

Aufdampfanlagen für spezielle optische und Infrarot Beschichtungen und Ofensysteme, in denen Wafer aus Glas spezifisch geformt werden können.

Das ISIT kann mit diesem neuen Gerätepark der Industrie zukunftsweisende Fertigungsverfahren anbieten und ist in der Lage neuartige Bauelemente wie etwa Magnetfeld-sensoren, optische Mikroscanner oder Mikrolautsprecher zu entwickeln und in die Produktion zu überführen. Sie sind für verschiedenste Anwendungen in der Industrieelektronik (Industrie 4.0), Automobiltechnik (autonome Fahrzeuge) und der Konsumgüterindustrie bedeutsam.

Die gesellschaftliche und ökonomische Relevanz der ISIT-Forschung zeigt sich auch in den Ausgründungen aus dem Institut. In 2017 haben ISIT-Wissenschaftler zusammen mit Partnern die CAMPTON Diagnostics UG gegründet. Das Unternehmen ist in der Medizintechnik aktiv und entwickelt komplette Messsysteme für die Point-of-Care-Diagnostik, also für Vor-Ort-Untersuchungen beim Patienten. Mit ihrer Firmengründung wollen die Gründer die Markteinführung ihrer Forschungsprodukte vorantreiben.

ISIT-Wissenschaftlerinnen und Wissenschaftler konnten in 2017 national und international in Ihren Fachgebieten Akzente setzen. So erhielt Katja Reiter den Metallographie-Preis 2017 in Anerkennung ihrer herausragenden Verdienste auf dem Gebiet der präparativen Materialographie. Der Preis wird von der Deutschen Gesellschaft für Materialkunde vergeben, in der Katja Reiter seit vielen Jahren aktiv ist, sie hält dort Vorträge und gibt Schulungen.

Der ISIT-Wissenschaftler Dr. Gerfried Zwicker hat für seine langjährigen Verdienste zur Weiterentwicklung eines zentralen Prozesses in der Halbleiterfertigung, nämlich dem Chemisch-mechanischen Polierens CMP den „Lifetime Achievement Award for Distinguished Contribution in the Field of Planarization" verliehen bekommen. Die Auszeichnung ehrt Wissenschaftler und Ingenieure für ihre Beiträge zur Weiterentwicklung dieses für die Fertigung von Mikroelektronik-Bauelementen inzwischen unverzichtbaren Verfahrens. Er erhielt die Auszeichnung während der

PREFACE

ISIT scientist Katja Reiter at the DGM symposium in Aalen

Conference on Planarization/CMP Technology ICPT 2017 in Leuven. Dr. Zwicker is among Europe's CMP pioneers. He was a leader in the development of CMP systems, founded and organized European CMP user groups, and is the author of various publications and review articles for CMP textbooks.

The fundamental and ongoing contributions of Fraunhofer ISIT to the further development of MEMS technologies and components over a period of currently more than 30 years were recognized at the TRANSDUCERS 2017 conference in Kaohsiung (Taiwan). TRANSDUCERS is the world's leading and most important conference in the field, held every two years at changing locations in Europe, Asia, and America. The award was presented to Professor Wolfgang Benecke in June of 2017.

The performance of our trainees was noteworthy as well. Every year the Fraunhofer-Gesellschaft honors its best new talent across Germany for special performance in training and invites them to the head office in Munich. The trainees Laura Gersmeier and Alexander Barnbrock from Fraunhofer ISIT were among them in 2017, and were recognized for their excellent performance.

International Conference on Planarization/CMP Technology ICPT 2017 in Leuven. Dr. Zwicker zählt zu den europäischen CMP-Pionieren. Er war führend an der Entwicklung von CMP Anlagen beteiligt, hat europäische CMP Nutzergruppen gegründet und organisiert sowie verschiedenste Veröffentlichungen und Übersichtsartikel für CMP-Lehrbücher verfasst.

Die grundlegenden und stetigen Beiträge des ISIT zur Weiterentwicklung der MEMS-Technologien und -Bauelemente über einen Zeitraum von nun mehr als 30 Jahren wurden auf der Konferenz TRANSDUCERS `17 in Kaohsiung (Taiwan) gewürdigt. Die TRANSDUCERS ist die weltweit bedeutendste und wichtigste Konferenz auf dem Gebiet und findet alle zwei Jahre an wechselnden Orten in Europa, Asien und Amerika statt. Die Auszeichnung wurde an Herrn Prof. Wolfgang Benecke im Juni 2017 übergeben.

Auch die Leistungen unserer Auszubildenden können sich sehen lassen. Jedes Jahr ehrt die Fraunhofer-Gesellschaft ihre deutschlandweit besten Nachwuchskräfte für besondere Leistungen in der Ausbildung und lädt sie nach München in die Zentrale ein. In 2017 waren aus dem Fraunhofer ISIT die beiden Auszubildenden Laura Gersmeier und Alexander Barnbrock dabei und wurden für ihre sehr guten Leistungen ausgezeichnet.

Das Fraunhofer ISIT beteiligt sich regelmäßig an vielen Fachmessen, ist aber auch bei Veranstaltungen dabei, die sich an ein breiteres Publikum wenden.

In 2017 hat sich das Fraunhofer ISIT wieder einmal an der Nacht des Wissens in Hamburg beteiligt und mit einem bunten Programm in einem Ausstellungszelt am Jungfernstieg den Besuchern die Forschung am ISIT nähergebracht. Bei der Nacht des Wissens haben sich 50 Hochschulen, außeruniversitäre Forschungseinrichtungen und weitere wissenschaftliche Institutionen in Hamburg und der Metropolregion präsentiert und über 1000 Programmpunkte für interessierte Besucher vorbereitet. Die Veranstaltung fand großen Anklang; die Organisatoren haben insgesamt mehr als 32 000 Besucher gezählt.

left: Presentation of the CMP Lifetime Award to Dr. Gerfried Zwicker
right: ISIT apprentices Alexander Barnbrock and Laura Gersmeier (right) with their instructors Benjamin Karstens and Jan Lähn (left). Center: Elisabeth Ewen, Fraunhofer-Gesellschaft
bottom: Prof. Wolfgang Benecke (right) receives the award for the Fraunhofer ISIT for further development of MEMS technologies and components over a period of more than 30 years

above: Impressions from the event "Nacht des Wissens" in Hamburg
left: External meeting of the government cabinet of Schleswig-Holstein at Fraunhofer ISIT. Robert Habeck, Dr. Ingrid Nestle
bottom: Opening event of Research Fab Microelectronics Germany at Fraunhofer ISIT

Fraunhofer ISIT regularly participates in numerous trade fairs as well as events intended for a broader audience.

In 2017 Fraunhofer ISIT once again participated in the Night of Knowledge in Hamburg, presenting research at the ISIT to visitors with a colorful program in an exhibition tent on the Jungfernstieg. 50 universities, non-university research institutions, and other scientific institutions in Hamburg and the metropolitan region presented themselves during the Night of Knowledge, preparing more than 1000 program items for interested visitors. The event was very well received and more than 32,000 visitors were counted by the organizers.

Participating in the Science Match Future Energies event at the Sparkassenarena in Kiel initiated by the state government was an experiment for Fraunhofer ISIT. 100 researchers, including scientists from Fraunhofer ISIT, and representatives of science, industry, politics, and society, presented the future of energy in presentations of 3 minutes each during a single day. An event in this form has never been seen in Schleswig-Holstein before and the patron, Premier Daniel Günther, was pleased to see that the scientific conference in this innovative format was extremely well received.

The past year at Fraunhofer ISIT was defined by an ongoing, intensified dialog among managers and employees about strategic and operational topics.

This dialog not only led to an organizational realignment of Fraunhofer ISIT, the main features of which have already been outlined in the previous annual report, but in particular also to the identification of key topics in the fields of technology, application/markets, and internal processes that are going to shape the work at the ISIT for some time to come. The most important of these focal points are briefly outlined below:
Fraunhofer ISIT will focus on five microtechnology platforms in the technology segment. These include the

- epi-poly platform for the production of thicker polysilicon layers,
- the piezo-MEMS platform for the integration of piezoelectric materials into silicon substrates, 3D glass shaping for structuring micro-optics components,

Ein Experiment für das ISIT war auch die Teilnahme an der, von der Landesregierung initiierten Veranstaltung „Science Match Future Energies", in der Sparkassenarena in Kiel. Dort präsentierten 100 Forscher, darunter auch Wissenschaftler aus dem ISIT, Vertretern aus Wissenschaft, Wirtschaft, Politik und Gesellschaft, in je 3 Minuten langen Beiträgen die Zukunft der Energie – an nur einem Tag. Dieses Veranstaltungsformat hat es bisher so in Schleswig-Holstein nicht gegeben und der Schirmherr, Ministerpräsident Daniel Günther, freute sich über den regen Zuspruch für diese Wissenschaftskonferenz in innovativem Format.

Das vergangene Jahr am ISIT war geprägt durch einen weiter intensivierten Dialog unter den Führungskräften und Mitarbeitern zu strategischen und operativen Themen. Aus diesem Dialog erwuchs nicht nur eine erneuerte organisatorische Aufstellung des ISIT, wie sie in ihren Grundzügen bereits im letzten Jahresbericht vorgestellt wurde, sondern insbesondere auch die Identifikation von Schwerpunktthemen in den Bereichen Technologie, Anwendungen bzw. Märkte und interne Prozesse, die die Arbeit am ISIT noch eine geraume Zeit prägen werden. Die wichtigsten dieser Schwerpunkte sollen im Folgenden kurz skizziert werden:
Im Bereich Technologie wird sich das ISIT auf fünf mikrotechnologische Plattformen konzentrieren. Dazu zählen

- *die Epi-Poly-Plattform zur Erzeugung dicker Polysiliziumschichten,*
- *die Piezo-MEMS-Plattform zur Integration piezoelektrischer Materialien in Siliziumsubstrate,*
- *das 3D-Glas-Formen zur Strukturierung mikrooptischer Komponenten,*
- *die Powder-MEMS-Plattform zum kontrollierten Aufbau bzw. zur Integration poröser 3D-Strukturen nahezu beliebigen Materials und*
- *die GaN-Plattform zur Erschließung neuer Anwendungsbereiche in der Leistungselektronik.*

Diese fünf Plattformen haben aktuell einen noch recht unterschiedlichen Reifegrad. Hauptaufgabe in den nächsten

- the powder-MEMS platform for the controlled building and integration of porous 3D structures into just about any material, and
- the GaN platform for the development of new fields of application in power electronics.

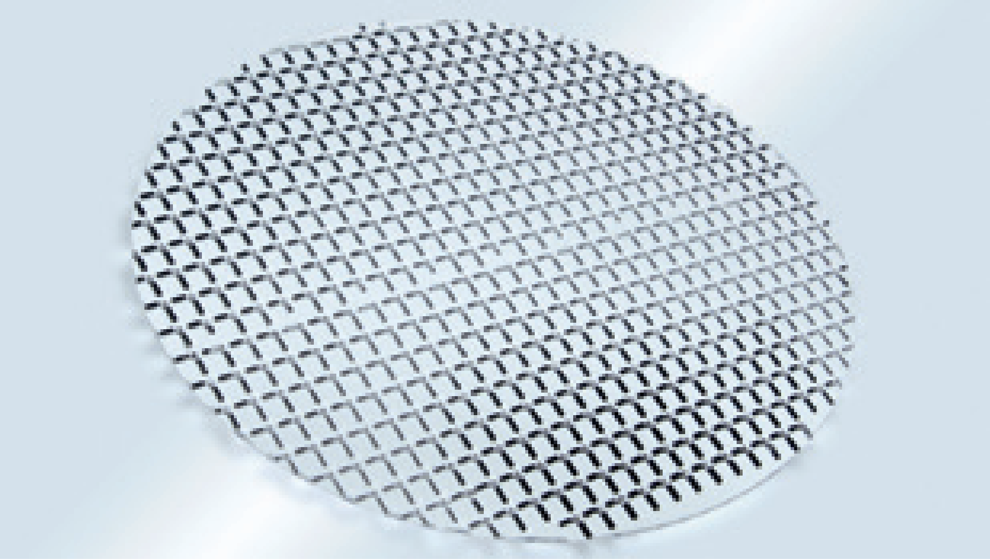
Currently the maturity of these five platforms still varies widely. Equalizing these maturity levels as far as possible will be the leading task in the coming years. This is because the most promising and interesting applications emerge precisely from the combination of these technological capabilities.

In the area of applications and markets, Fraunhofer ISIT will initially focus primarily on four market segments. First off, the micro-mirrors and micro-scanner systems currently produced at Fraunhofer ISIT are in high demand for applications in the consumer market (augmented and virtual reality goggles) and in the automobile market (LIDAR sensors for autonomous driving). Here the market interest is so promising that Fraunhofer ISIT is preparing the founding of a company for more effective marketing. Second, Fraunhofer ISIT is taking aim at the micro-speaker market. This market encompasses both the consumer segment (ear buds and free-field loudspeakers) and the medical industry (hearing aids). The corresponding systems in cooperation with the Fraunhofer Institute for Digital Media Technology IDMT and the company USound are already far advanced. Key customer benefits are unrivaled energy efficiency, extremely small installation space, and audiophile playback quality, all at costs that can be considerably below those of conventional systems. Third, Fraunhofer ISIT is addressing a specific segment in the market for MEMS contract manufacturing. Many small to midsize operations (but not only those) are unable to find offers for their MEMS production needs in the market. Either the required production process is too complex or specialized, or the quantity needed makes production unattractive for commercial suppliers (or both). The successful industrialization of MEMS and MEMS systems also requires considerable analytical and design capabilities in the fields of structural and

Jahren wird es sein, diese Reifegrade auf möglichst hohem Niveau aneinander anzugleichen. Die vielversprechendsten und interessantesten Anwendungen entstehen nämlich gerade aus der Kombination dieser technologischen Fähigkeiten.

Im Bereich Anwendungen und Märkte wird das Hauptaugenmerk des ISIT zunächst auf vier Marktsegmenten liegen. Hochaktuell sind, erstens, zurzeit die am ISIT gefertigten Mikro-Spiegel und Mikro-Scanner-Systeme für Anwendungen im Konsumentenmarkt (Brillen für Augmented und Virtual Reality) und im Automobilmarkt (sogenannte LIDAR-Sensoren für das autonome Fahren). Das Marktinteresse ist hier derart vielversprechend, dass das ISIT zum Zweck der besseren Vermarktung eine Ausgründung vorbereitet. Zweitens zielt das ISIT auf den Markt für Mikrolautsprecher. Dieser Markt umfasst sowohl den Konsumentenbereich (In-Ohr-Kopfhörer und Freifeld-Lautsprecher) als auch den medizinischen Bereich (Hörgeräte). Die entsprechenden Systeme sind in Kooperation mit dem Fraunhofer IDMT und der Firma USound bereits weit fortgeschritten. Als wesentlichen Kundennutzen bieten sie eine unerreichte Energieeffizienz, extrem kleinen Bauraum, eine audiophile Wiedergabequalität und dies zu Kosten, die deutlich unter den herkömmlichen Systemen liegen können. Drittens adressiert das ISIT ein besonderes Segment im Markt für MEMS-Auftragsfertigungen. Viele kleine und mittlere Betriebe (aber nicht nur diese) finden im Markt keine Angebote für ihren Bedarf an MEMS-Fertigung. Entweder ist der erforderliche Fertigungsprozess zu komplex bzw. speziell oder die benötigte Stückzahl macht eine Fertigung für kommerzielle Anbieter unattraktiv (oder beides). Darüber hinaus erfordert die erfolgreiche Industrialisierung von MEMS und MEMS-Systemen erhebliche analytische und konstruktive Fähigkeiten im Bereich der Aufbau- und Verbindungstechnik sowie bei der Sicherstellung von Qualität und Zuverlässigkeit, idealerweise alles aus einer Hand. Indem das ISIT in dieser „Versorgungslücke" Angebote macht, erfüllt es den satzungsgemäßen Auftrag der Fraunhofer-Gesellschaft, Brückenbauer zwischen Forschung und Vorentwicklung einerseits und kommerzieller Anwendung andererseits zu sein. Viertens zielt

Dr. Sebastian Jester, BMBF together with Dr. Axel Müller-Groeling and Prof. Holger Kapels at the opening event of Research Fab Microelectronics Germany at Fraunhofer ISIT



Glass wafer for optical packages

joining technology along with ensuring quality and reliability, ideally all from one source. With offerings to fill this supply gap, Fraunhofer ISIT is fulfilling the statutory mandate of the Fraunhofer-Gesellschaft to build bridges between research and preliminary development on the one hand and commercial applications on the other hand. Four, Fraunhofer ISIT is targeting the market for certain power electronics systems, both in e-mobility and in the renewable energy field. Here an important topic is the development of high-performance storage systems (boosters), able to make their energy available in a very short time thanks to special cell technologies and highly efficient system electronics, for instance for the climbing phase of electrically powered drones. Corresponding upscaled storage systems will also play an important role in providing system services for future strategies in power network operation.

In the area of internal processes, Fraunhofer ISIT has set the ambitious goal of developing a model together with the site partner X-FAB for the most efficient possible operation of the MEMS clean room with the realization of synergies between the two partners. This requires cooperation to be intensified considerably beyond the extent practiced to date. Fraunhofer ISIT is also working on standardizing and digitalizing key internal processes in controlling, sales, project management, and operations.

das ISIT auf den Markt bestimmter leistungselektronischer Systeme sowohl im Bereich E-Mobilität als auch bei den Erneuerbaren Energien. Ein wichtiges Thema ist hier die Entwicklung von Hochleistungsspeichersystemen („Booster“), die ihre Energie dank spezieller Zelltechnologien und hocheffizienter Systemelektronik in sehr kurzer Zeit zur Verfügung stellen können, etwa für die Steigphase elektrisch angetriebener Drohnen. Entsprechend hochskalierte Speichersysteme werden auch eine wichtige Rolle in der Bereitstellung von Systemdienstleistungen für zukünftige Strategien beim Stromnetzbetrieb spielen.

Im Bereich interne Prozesse hat sich das ISIT das ehrgeizige Ziel gesetzt, zusammen mit dem Standortpartner X-FAB zu einem Modell zu kommen, in dem der MEMS-Reinraum unter Nutzung der Synergien zwischen beiden Partnern so effizient wie möglich betrieben wird. Dies setzt eine Intensivierung der Zusammenarbeit deutlich über das bisher praktizierte Maß voraus. Darüber hinaus arbeitet das ISIT daran, wesentliche interne Prozesse in Controlling, Vertrieb, Projektmanagement und operativem Betrieb zu standardisieren und zu digitalisieren.

Insgesamt war das Jahr 2017 am ISIT ein Jahr der Weichenstellungen für die Zukunft. Der Strategieprozess, der im Jahr 2016 begonnen wurde und dessen Ergebnisse wir hier skizzenhaft vorgestellt haben, kam gegen Ende des Jahres mit

Overall 2017 was a year of establishing directions for the future at Fraunhofer ISIT. The strategy process begun in 2016, with the results that have been outlined here, reached its temporary conclusion towards the end of the year with a formal strategy audit completed with great success. "Temporary" because the strategy development and adaptation process can never truly reach its end, and remains an ongoing task for Fraunhofer ISIT albeit with reduced intensity. Last but not least, we want to mention that 2017 drew to a close with a positive financial result notwithstanding its character as a year of transition and establishing directions. This is owed to the many colleagues at Fraunhofer ISIT who are dedicated to the successful future of our institute.

We therefore want to take this opportunity to thank all employees for their commitment and outstanding performance. Our thanks also to all partners, customers, and sponsors for their trust and cooperation. We look forward to exchanging ideas with you.

We look forward to exchanging ideas with you!

einem sehr erfolgreich absolvierten formalen Strategieaudit zu seinem vorläufigen Abschluss. „Vorläufig" deshalb, weil der Prozess der Strategiefindung und -anpassung nie wirklich zu Ende sein kann und das ISIT, wenn auch mit geringerer Intensität, fortlaufend beschäftigen wird. „Last but not least" bleibt noch zu erwähnen, dass das Jahr 2017 trotz seines Charakters als Jahr des Übergangs und der Weichenstellung mit einem positiven finanziellen Ergebnis abgeschlossen wurde. Dies ist der Verdienst der vielen Kollegen am ISIT, denen eine erfolgreiche Zukunft unseres Instituts am Herzen liegt.

Auch deswegen möchten wir uns an dieser Stelle bei allen Mitarbeiterinnen und Mitarbeitern für ihr Engagement und die erhebliche Arbeitsleistung bedanken. Danken möchte wir auch allen Partnern, Auftraggebern und Förderern für die vertrauensvolle Zusammenarbeit und freuen uns auf den Gedankenaustausch mit Ihnen.

Wir freuen uns auf den Gedankenaustausch mit Ihnen!

Dr. A. Müller-Groeling

Prof. W. Benecke

FRAUNHOFER-INSTITUT FÜR SILIZIUMTECHNOLOGIE (ISIT)

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

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

Cooperation with Fraunhofer ISIT

The institute's services assist companies and users in a wide range of sectors. Components, systems, and production processes are developed, simulated, and implemented in close collaboration with customers. This process is aided by Fraunhofer ISIT's use of technology platforms – production process flows defined for whole groups of components – meaning they can be used in production unchanged or with simple modifications to the design parameters. Fraunhofer ISIT's expertise presents particularly exciting possibilities for small and medium-sized enterprises looking to realize their technological innovations.

Fraunhofer ISIT is Participant of Research Fab Microelectronics Germany

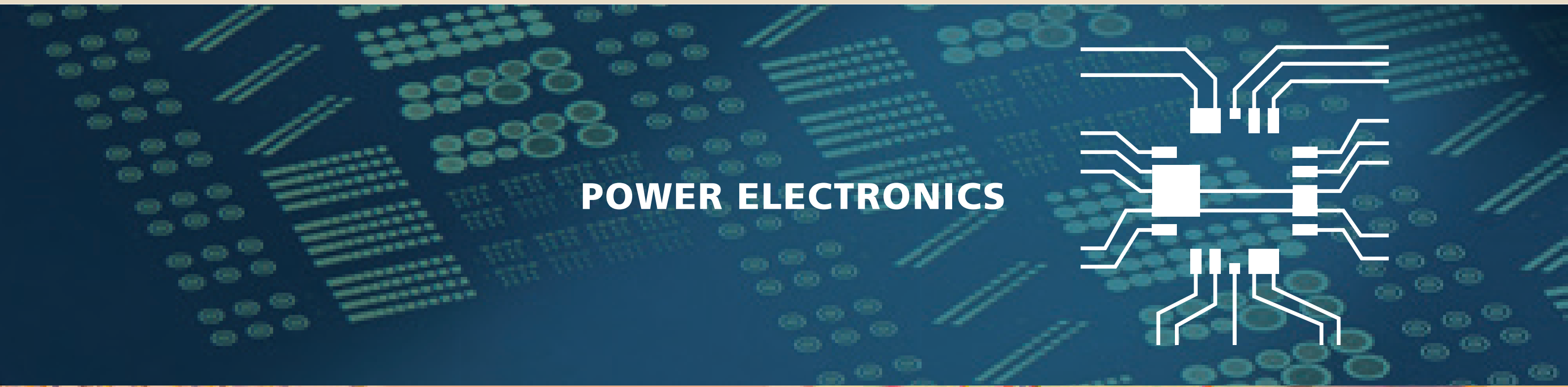
To reinforce the position of Europe's semiconductor and electronics industry within global competition, eleven institutes within the Fraunhofer Group for Microelectronics - including the Fraunhofer ISIT - have, together with the Leibniz Institute for Innovations for High Performance Microelectronics and the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik, come up with a concept for a cross-location research factory for microelectronics and nanoelectronics. In spring 2017, this new organization got off the ground.

The concept for the research fab was designed jointly by Fraunhofer and Leibniz to combine their competences in a pool for technologies. For the modernization and extension of their equipment the 13 research facilities receive around 350 million euros from the Federal Ministry of Education and Research. The investments for the Fraunhofer ISIT amounting to 19.3 million euros serve to modernize and expand the cleanroom equipment with a focus on power electronics and novel sensor systems.

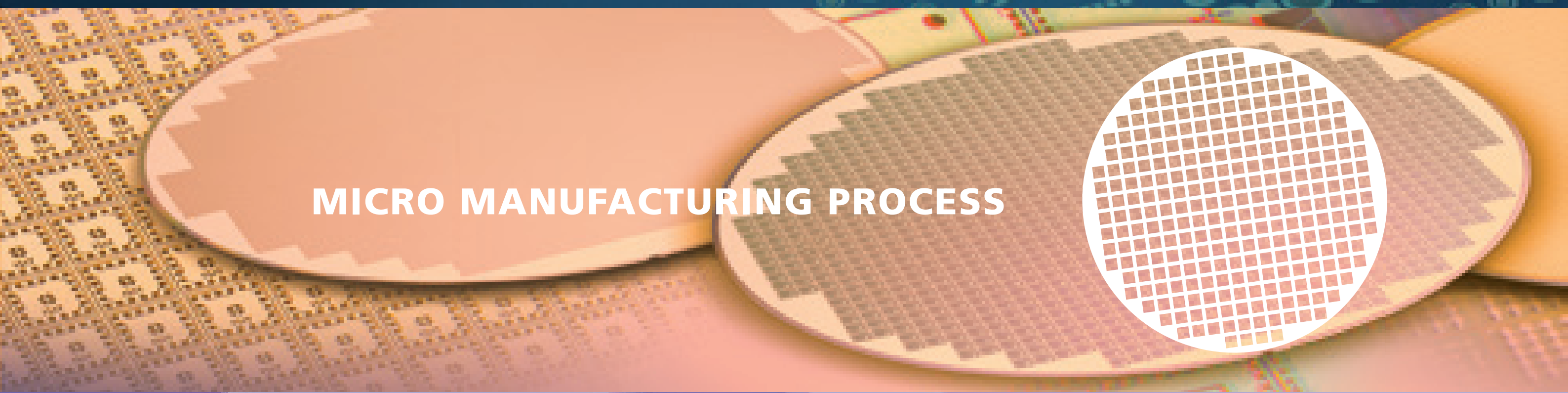
In power electronics, ISIT will provide facilities for the development of gallium nitride as a new material base for innovative power devices that did not previously exist at the institute. New systems are also being purchased for the development of sensors and actuators, for example equipment for applying piezoelectric and magnetic materials to silicon, vapor deposition systems for special optical and infra-red coatings and furnace systems in which glass wafers can be viscously shaped specifically.

With this new equipment park, ISIT can offer forward-looking manufacturing processes to the industry and is able to develop novel components and convert them into production.

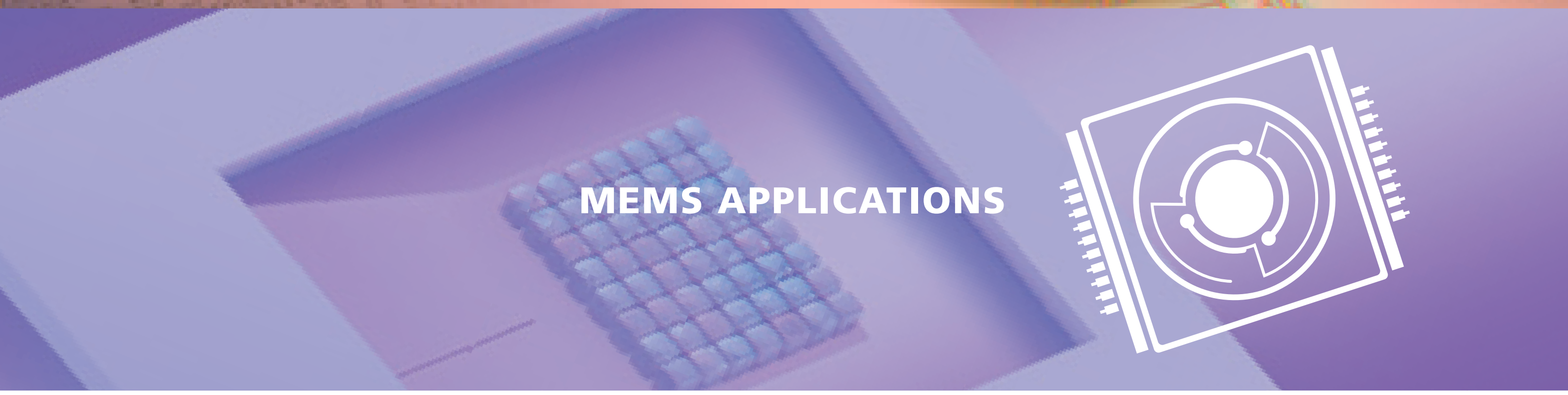
BUSINESS UNITS



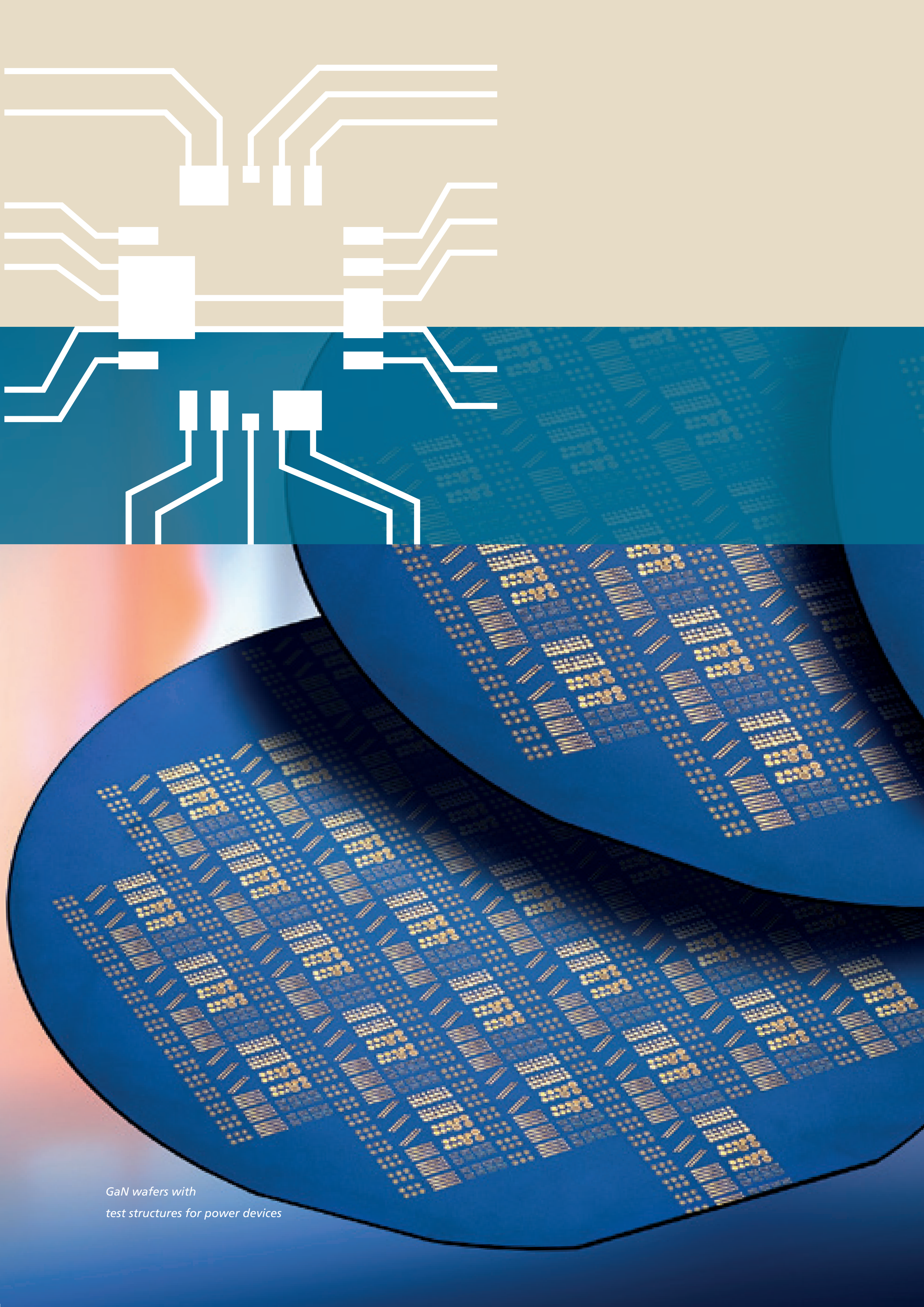
POWER ELECTRONICS



MICRO MANUFACTURING PROCESS

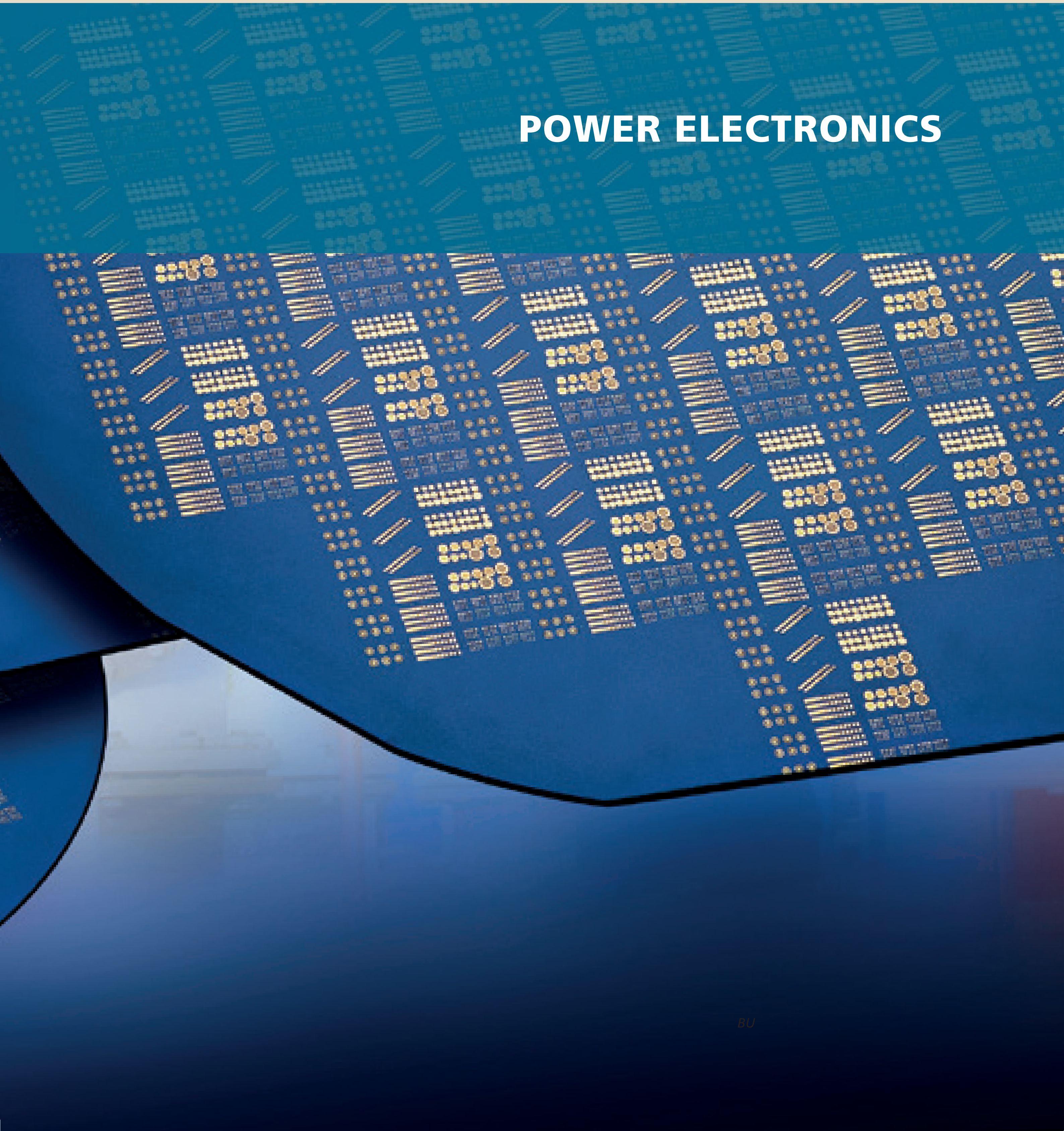


MEMS APPLICATIONS



GaN wafers with
test structures for power devices

POWER ELECTRONICS



BUSINESS UNIT POWER ELECTRONICS

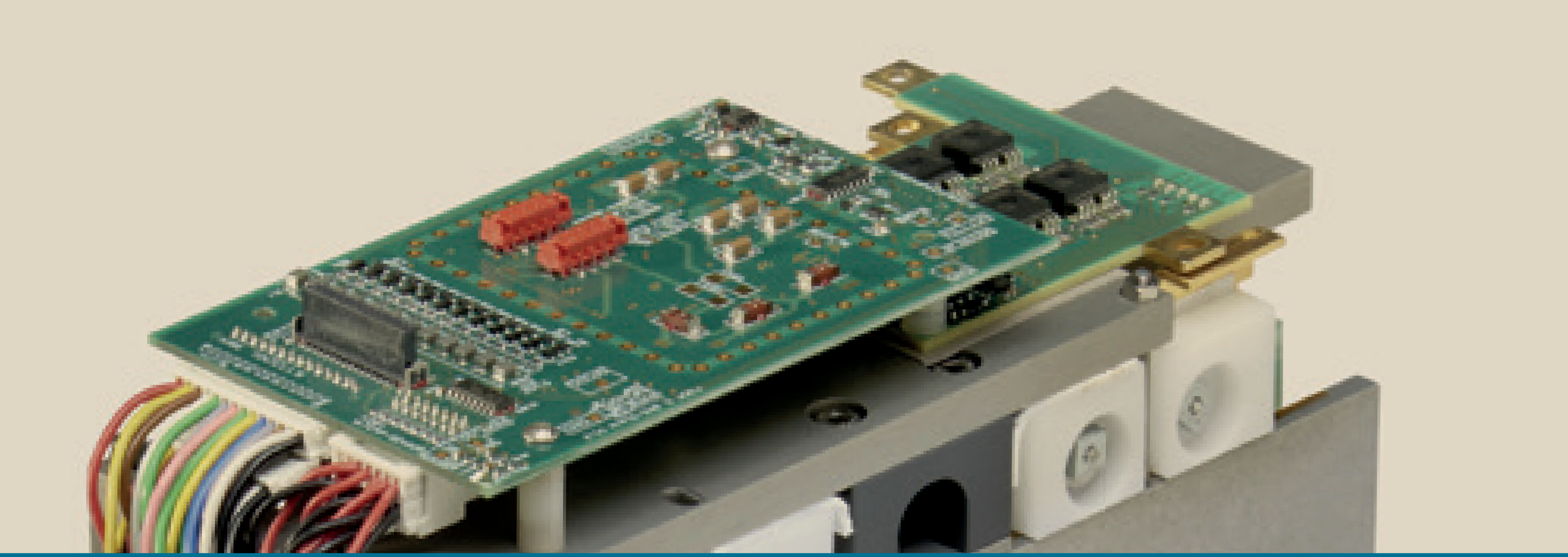
Development of technologies, components and system concepts for high-performance energy systems

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

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

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

On system level, the ISIT offers the development of novel circuit topologies and integration concepts for highly efficiency DC/DC and DC/AC power converters using application-specific power semiconductors targeting an optimized overall system performance and long-term reliability. By using resonant circuit topologies and control techniques, peak efficiencies larger than 99% are realized and a soft-switching operation is achieved over nearly the entire output power range.
For the increase usage of renewable energies, the ISIT develops solutions for increased flexibility for the overall grid



High performance battery storage system

stability by using the specific possibilities of battery systems. Furthermore, the ISIT is investigating how new control methods can be used to provide important system-stabilizing services and supports the overall system simulation. The main areas of application for these services of ISIT are in the field of regenerative energies, e-mobility and electric flying.

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

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INTEGRATED CONVERTER FOR MODULAR DISTRIBUTED ELECTRIC DRIVES OF HIGH ROTATION SPEED – INMOVE

According to the increasing activities concerning the improvement of electro- and hybrid cars, an integrated power electronic for a modular drive concept is currently under investigation within the framework of the project InMOVE (integrated converter for modular distributed electric drives of high rotation speed).

The idea behind the modular drive concept is to combine existing gearbox designs with small and medium drive motors. Depending on the vehicle class, an electric car then will be equipped with one or more modular drive units, e.g. with a maximum drive power of about 80 kW each. In order to enable the adaptation of the modular drive to various gearboxes the drive unit must be designed as a slim and fast rotating electric motor with an integrated power converter. Further details were presented in ISIT's Annual Report 2016.

A three-phase current is required by the drive motor which is generated from the direct current of a battery by use of a power inverter, as shown in figure 1.

Here, the conversion of the voltage is provided by trench field-stop Insulated Gate Bipolar Transistors (IGBTs) which are driven by a driver electronic. In order to use the IGBTs within the power inverter they must be packaged in a module to enable a proper water cooling and a secure electrical connection. To meet the space limitations a so-called mold housing is used which allows a mechanically and electrically stable chip assembly as well as a mechanical attachment of the module. To convert the battery power 1200 V IGBTs are required with a nominal current of 200 A and a maximum junction temperature of 175 °C. These are fabricated jointly with Vishay Siliconix Itzehoe within their Power-MOS production. The mold modules are then assembled and completed at Danfoss Silicon Power by use of modern DBB technology.

The IGBTs and the diodes in the mold modules contribute most to the power loss in the converter that must be dissipated by cooling water. The heat originates in normal operation of the IGBT modules, and arises from the on-state voltage and the switching energy losses $E_{TOTAL} = E_{on} + E_{off}$. Since

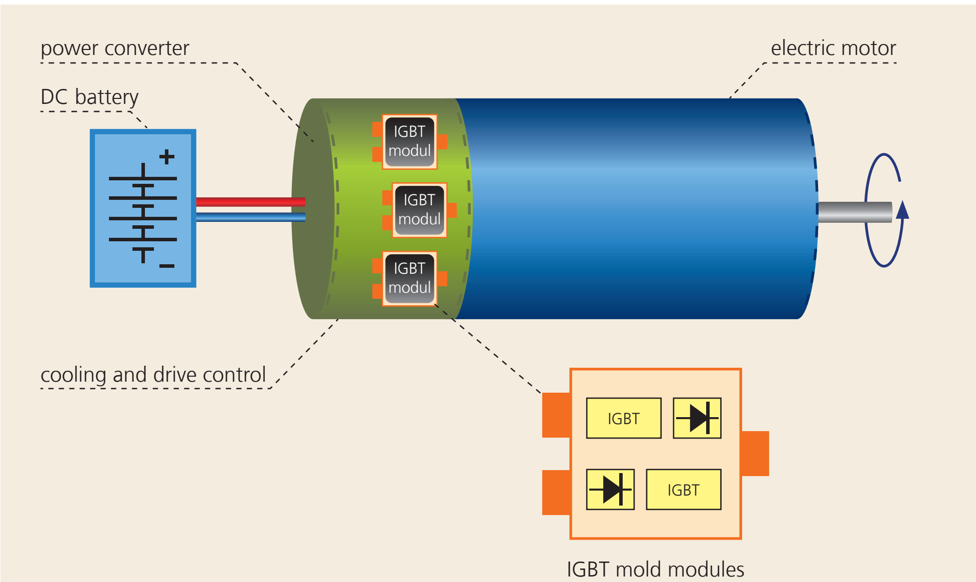


Figure 1: A power converter connected to an electric motor and a DC battery with three IGBT mold modules are integrated into the very compact converter case, together with DC link capacitors, the IGBT driver board and the cooling system. The mold modules are housing two IGBTs and two freewheeling diodes in half bridge configuration.

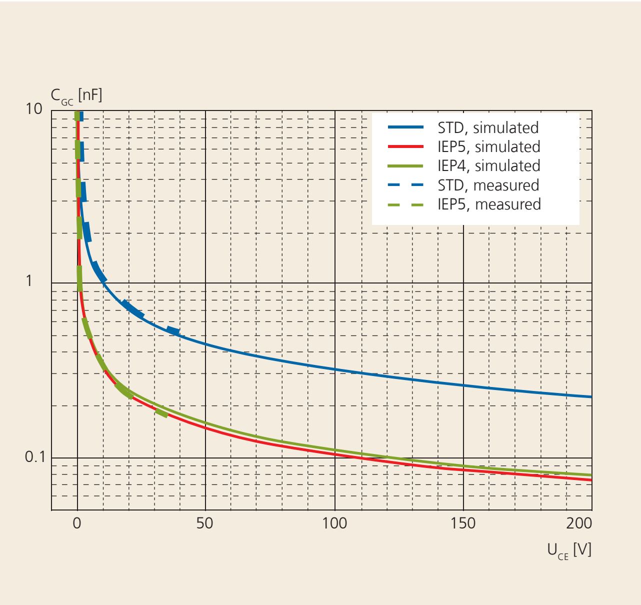


Figure 2: Simulated and measured Miller-Capacity for standard (STD) and IEP-type IGBTs. For IEP-IGBTs a C_{GC} of only 1/3 was determined compared to the initial value of an STD-IGBT

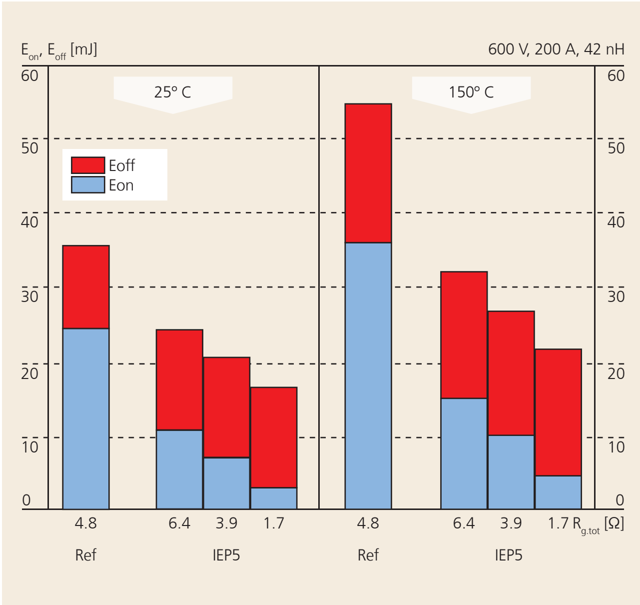


Figure 3: Bar graph diagram showing $E_{total} = E_{on} + E_{off}$ for InMOVE mold-modules and one competitor module for various gate resistances ($R_{G,tot}$), at 25 °C and 150 °C.

the customized new gate driver, developed by Reese + Thies, is operated at a frequency of 13,5 kHz, the main topic is the development of switching optimized IGBTs.

The turn-on energy (E_{on}) is strongly dependent on the Miller capacitance C_{GC} which can be decreased by a change in emitter geometry. Device simulations were carried out with respect to a new cell architecture that allows a considerable reduction of the gate-collector-capacitance. A new design with modified cell architecture, namely Injection Enhancement IGBTs with passivated gate trenches (IEP-IGBT), provides a significant reduction in gate capacity.

Figure 2 shows the measured and the simulated Miller-capacity C_{GC} for the initial standard-IGBTs and the optimized-IEP-type IGBTs in which the gate capacitance of the IEP-IGBT is about 1/3 lower than that of the initial one (STD). With the new design E_{on} was successfully reduced by 50 % compared to the STD-IGBT. E_{off} and V_{CEsat} were also optimized by modifying the implantation and laser annealing procedures on the collector side of the device.

The diagram in figure 3 compares the switching losses E_{on} and E_{off} of an IEP mold-module with a reference module of the same performance class at two temperatures of 25 °C and 150 °C. The $R_{G,ges}$ determines the charging speed of the gate capacitance. The lowest value is limited by the gate driver which contributes 1 Ω and the IGBT build in resistor of 0,7 Ω which gives a total of 1,7 Ω. The resistor of the reference module amounts to $R_{G,tot}$ is 4,8 Ω since its built-in resistor is 3,8 Ω. For both temperatures, the reference modules clearly exceed the E_{total} for the displayed IEP-IGBTs, even for

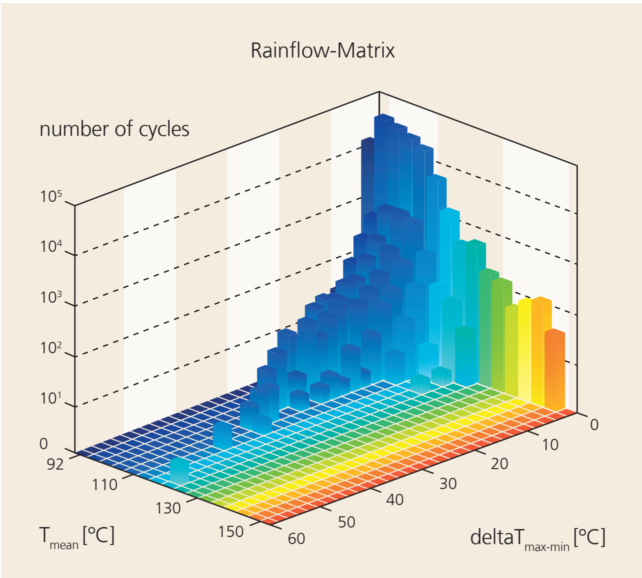


Figure 4: IGBT temperature-rainflow-matrix for a given mission profile. It shows the number of cycles versus the associated mean temperature T_{mean} and the temperature swings deltaT.

$R_{G,tot}$ = 6,4 Ω. Due to the injection enhancement approach, the energy loss of InMOVE mold modules compared with the reference module is reduced to 40 % at 25 °C and to 50 % at 150 °C. To compensate for the increase of the on-state voltage V_{CEsat} a new generation of FS Trench IGBTs with reduced cell-pitch is under way.

The quality of the mold-modules was tested in a power cycling test within the temperature range of 20 °C to 150 °C. Meanwhile the mold-modules passed this test with 200.000 cycles.

Additionally, system simulations were performed by use of a system model in Matlab/Simulink with Plecs. This was done on base of the data for the on-state and switching losses gained for the entire operating range and the mission profile. For the overall IGBT lifetime the number of well-defined temperature swings is important. The number of temperature swings was calculated by application of the Rainflow-Algorithm. The result of this classification is displayed in figure 4 as a 3D Rainflow Matrix. On base of the extrapolated mission profile a distance of 450.000 km is achieved until a defect of the module is expected. Since the mold-module IGBT-chips are built in Danfoss DBB technology, an additional lifetime increase of factor 10 in minimum is expected.

So far, the converter was successfully assembled and could be put into operation step by step.

Authors: Hans-Jürgen Schliwinski
Jörn Hinz
Malte Päsler

Projekt-Name

InMOVE

Integrierte Umrichter für modular verteilte Elektroantriebe hoher Drehzahl
Integrated converter for modular distributed electric drives of high rotation speed

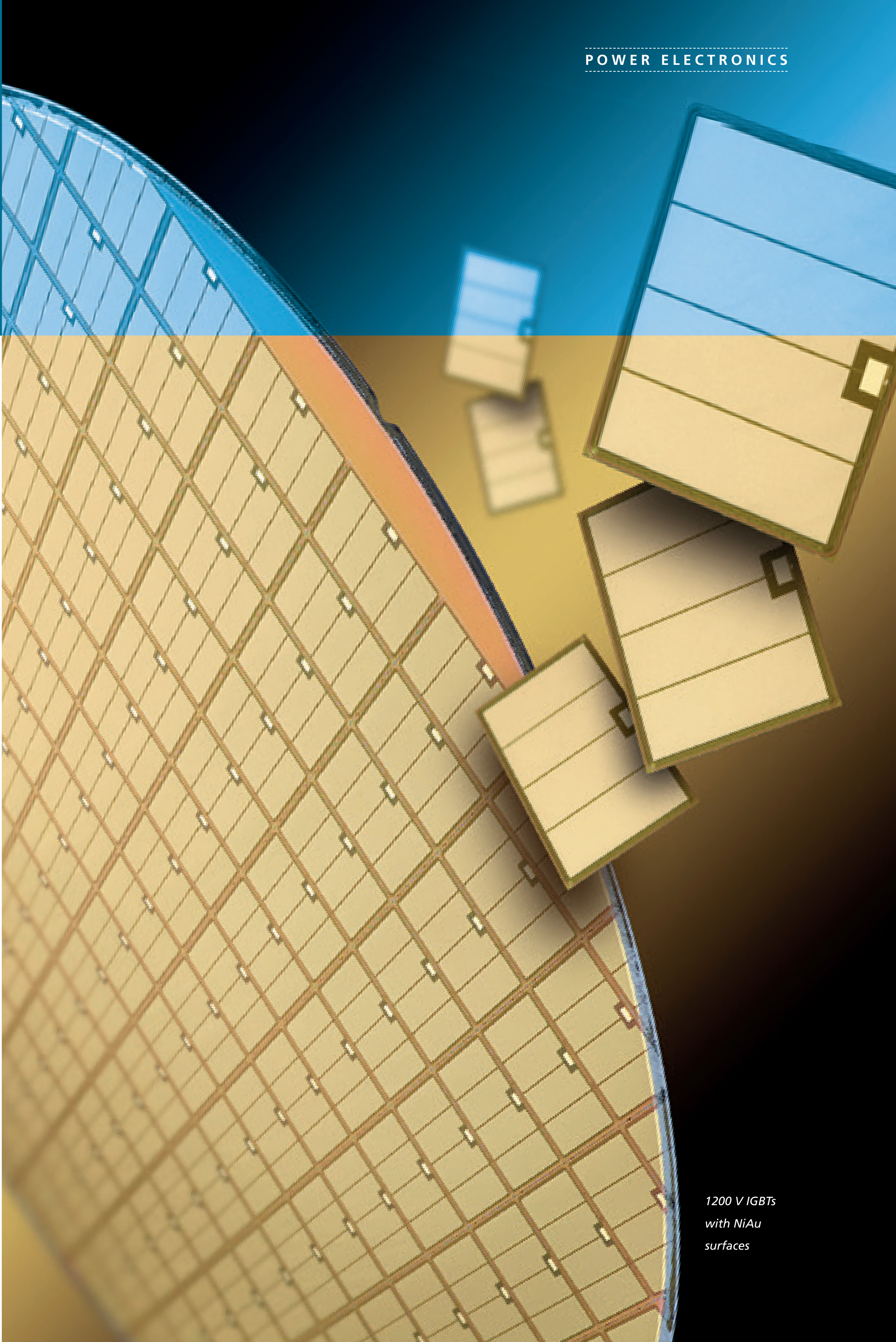
Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

aufgrund eines Beschlusses des Deutschen Bundestages

BMWi-Ausschreibung ‚ATEM3'
Koordinator: Volkswagen AG
Projektleiter ISIT: Hans-Jürgen Schliwinski
Stellvertreter ISIT: Dr. Jörn Hinz

Partner:



1200 V IGBTs with NiAu surfaces

NORTH GERMAN ENERGY TRANSITION NEW 4.0

The implementation of the energy transition agenda brings along new challenges for network infrastructure and operation. Due to the higher penetration levels of renewable energy sources connected via power electronics, power quality issues have been encountered. In a collaborative research project with about 60 partners named NEW 4.0 (North German Energy Transition 4.0), the Application Center "Power Electronics for Renewable Energy Systems" of the Fraunhofer ISIT is involved in research on new ancillary services provided by energy storage systems to ensure reliable energy supply. Work is being done in the areas of high precision measurements, simulation, virtual inertia, and ancillary service control algorithms.

High Precision Power-Grid Measurements

In response to this increasing interest in power quality along with its participation to the NEW 4.0 project, ISIT's Business Unit Power Electronics has made an investment dedicated to capture network disturbances such as voltage and frequency variations, flicker emissions and harmonics. The Application Center is now equipped with a high-end power quality measurement system, adaptable to any customer requirements, that can handle multiple site data acquisition from decentralized renewable energy sources up to transmission networks. The first application is to study harmonics propagation in distribution networks taking measurements – especially the higher order harmonics – near the battery energy storage system, built by our partner Wind-to-Gas Energy GmbH to measure the impact of our novel ancillary services.

Simulation

Market-based mechanisms for power-grid congestion management are developed to enable further integration of renewable energy sources into the power network and to enhance the system stability and efficiency. A possible solution is to synchronize energy production and energy consumption by using decentralized flexibility providers, such as battery energy storage systems, power-to-x plants or flexible loads. Therefore, a flexibility market as the ENKO platform (www.enko.energy) with a new communication approach between grid operators and flexibilities is studied in a co-simulation with the partners Fraunhofer Institute for Energy Economics and Energy System Technology IEE, University of Applied Sciences Hamburg, University of Applied Sciences Lübeck and Hamburg University of Technology to prove the mechanism's effectiveness.

Virtual Inertia

As a result of load events, the rotating masses of synchronous machines, which are directly coupled with the frequency, get accelerated or decelerated. This means their rotational speed and the energy stored in this rotation are changed, resulting in deviations of the grid frequency. The larger the sum of rotational masses in a grid, the larger is its system inertia and the less pronounced are frequency deviations. The ongoing integration of generators connected via converters leads to a successive reduction of system inertia and an increasingly instable grid. Therefore, facilities with the ability to react to load events almost instantaneously are required to ensure stable grid operation in the future. As a starting point for the project's use case "virtual inertia", a simulative study on replacing the rotating mass of a conventional power plant (synchronous machine) with a battery energy storage system was performed.

A field test of our simulative studies is planned using the energy storage system at Brunsbüttel built by our partner Wind-to-Gas Energy GmbH.

Figure 1: High precision measurement equipment (courtesy of DEVETRON GmbH)

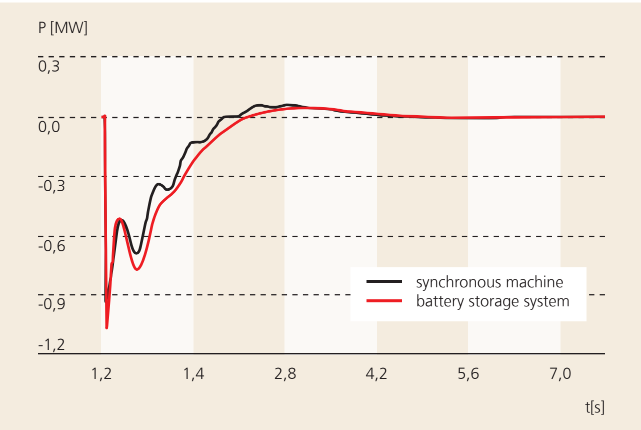


Figure 2: Comparison of virtual inertia (battery) and real inertia of a synchronous machine

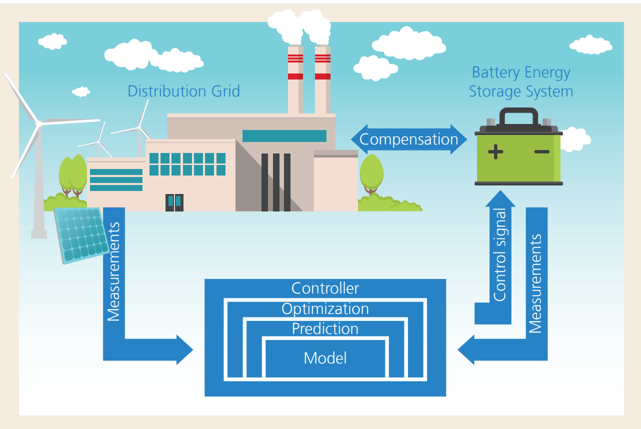


Figure 3: Linear state signal shaping by quadratic model predictive control

Ancillary Service Control Algorithm

A new control approach has been developed on the basis of model predictive control. This development aims to take advantage of the aforementioned advanced control theory features, such as a simultaneous multi-variable optimal control ahead of time, due to model-based predictions.

The latest iteration of this in-development controller has been approved as a contributed paper for the European Control Conference 2018 (ECC), to be hosted in Limassol, Cyprus. The paper is titled "An Approach to linear state Signal Shaping by quadratic Model Predictive Control". This publication defines a theoretical framework for the implementation of this new control approach and provides an application example for power quality compensation in a distribution grid. In its current state, the controller is capable to assess and compensate the harmonic distortion and frequency of power system signals. For further development, it is planned to integrate the control of the signal amplitude as well.

Over the course of the NEW 4.0 project, the Application Center will continue to develop new capabilities to evaluate the integration of renewable energy systems into the distribution grid from the modelling of renewable energy sources and power networks to the development of ancillary services supporting the energy transition.

Authors: Henri Zeller, Anna Meißner, Julian Franz, Carlos Cateriano Yáñez, Georg Pangalos

Project name:	NEW 4.0 Norddeutsche Energiewende
Sub-project:	Modellbildung und Algorithmenentwicklung, multiple Systemdienstleistungen
Funding programme:	SINTEG „Schaufenster intelligente Energie – Digitale Agenda für die Energiewende", BMWi
Partners:	About 60 Partners, direct cooperation with: Wind-to-Gas Energy GmbH, Schleswig-Holstein Netz AG, Fraunhofer Institute for Energy Economics and Energy System Technology IEE, University of Applied Sciences Hamburg, University of Applied Sciences Lübeck, Hamburg University of Technology

INNOVATIVE TECHNOLOGIES FOR HIGH-LOAD CATHODES IN LITHIUM ION BATTERIES

One of the key process steps along the manufacturing chain of Lithium ion batteries consists of manufacturing the electrodes. By structuring the electrodes in adapted shape, the energy density of Lithium ion batteries can be enhanced significantly. This is one of the key objectives in current energy storage research, e.g. in order to fulfil the driving range requirements of electric vehicles in the automotive industry.

The "HiLo" project addresses this issue by following a model-assisted development approach of proper electrode structures for an improved energy density, targeting high energy electrodes based on the Nickel-rich cathode material NCM-622. Furthermore, technologies for realizing such electrodes are investigated. Two approaches are considered in laboratory scale as well as in pilot plant scale during project progression: While Fraunhofer ISIT has developed an innovative dry coating process, a so-called foil extrusion is carried out by the project partner Fraunhofer IKTS. For the practical application of high load electrodes, TU Dresden performs simulation studies related to design parameters such as maximum useful thickness or ideal porosity (figure 1).

Figure 1: Work flow scheme of the project "HiLo"

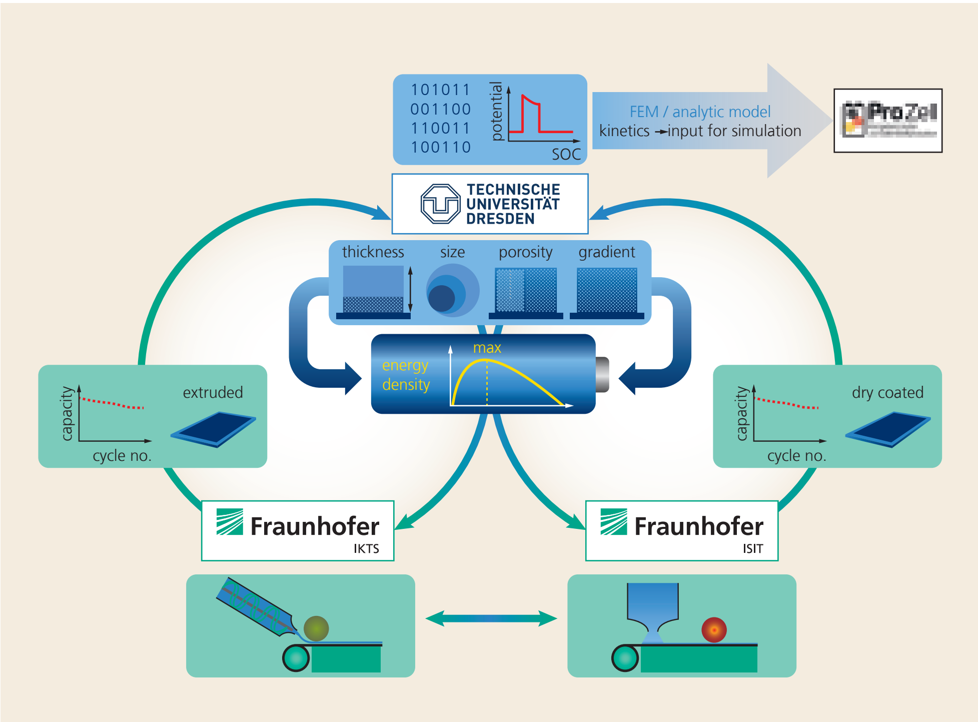


Figure 2: Picture of a dry coated electrode

Advantages of solvent-free electrode coating

Lithium ion battery electrodes normally are manufactured by coating solvent-containing slurries on a metallic current collector. The most commonly used solvents are N-Methyl-2-pyrrolidone (NMP) as well as water, which is normally used for anodes. Drying the electrode slurry after coating is generally an energy intensive process. Long drying sections are necessary for an optimal result, demanding large manufacturing space. NMP in particular requires a special recovery system for the evaporated solvent. With the dry coating process developed by Fraunhofer ISIT, the use of solvents becomes obsolete. This allows a significant cost reduction and additionally results in an enhanced environmental sustainability of the manufacturing process.

Current results

Highly optimized cathode electrodes exhibit specific loadings of about 4 mAh/cm². This is achieved by the use of high capacity active materials in combination with higher packing densities. Fraunhofer ISIT has already manufactured dry coated electrodes with loadings up to 8 mAh/cm², still offering satisfactory electrochemical results (figures 2, 3).
The developed electrodes have been evaluated with regard to processability and performance. Investigations of mechanical properties have demonstrated outstanding adhesive strength compared to conventional electrodes. Further tests are planned in close cooperation with the ProZell cluster project "High Energy". In particular, the wettability of the electrodes with electrolyte is to be considered due to its influence on the downstream electrolyte filling process. Additionally, established models for clarification of proper electrode structures and for predicting the influence of structural modifications will be validated.

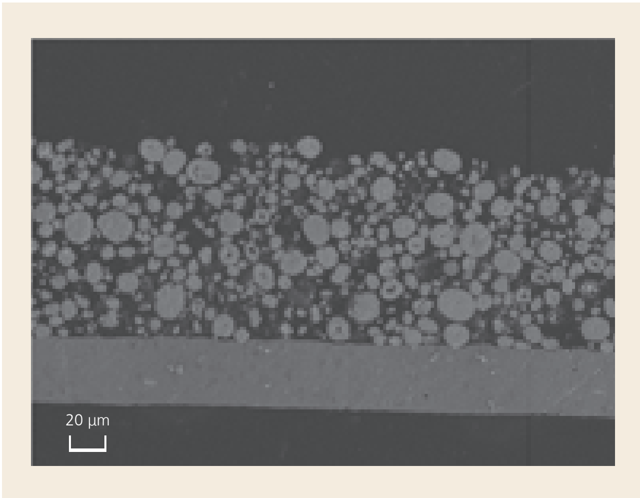


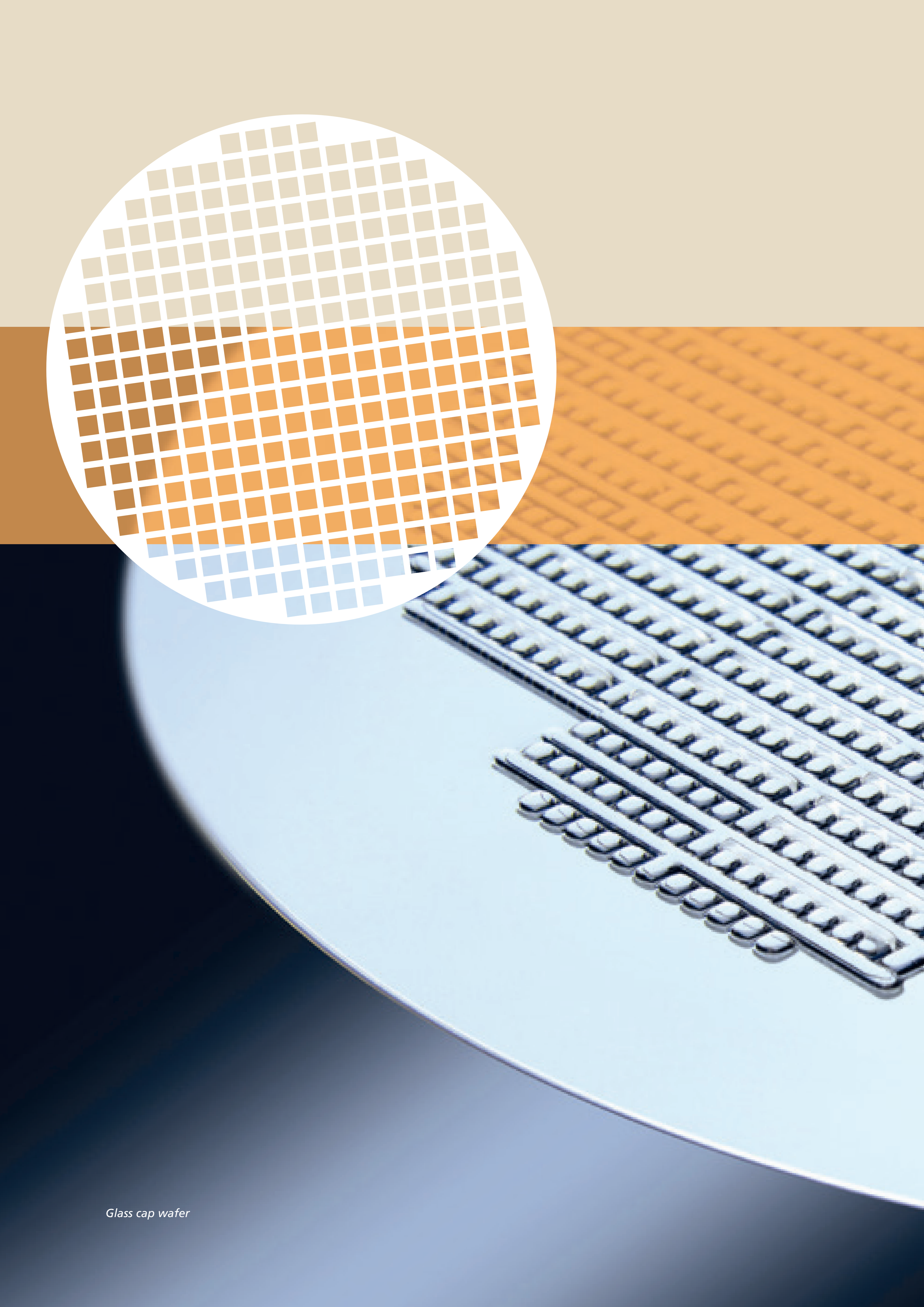
Figure 3: Cross-section SEM image of the electrode with a loading of 4,5 mAh/cm²

Conclusion

The "HiLo" project targets a profound process understanding for the realization of optimized high energy cathodes. Moreover, it contains the interaction with subsequent processes as well as their influence on cell properties (energy density, power performance). This knowledge will provide the basis for improved Lithium ion batteries and simultaneous cost reduction in manufacturing.

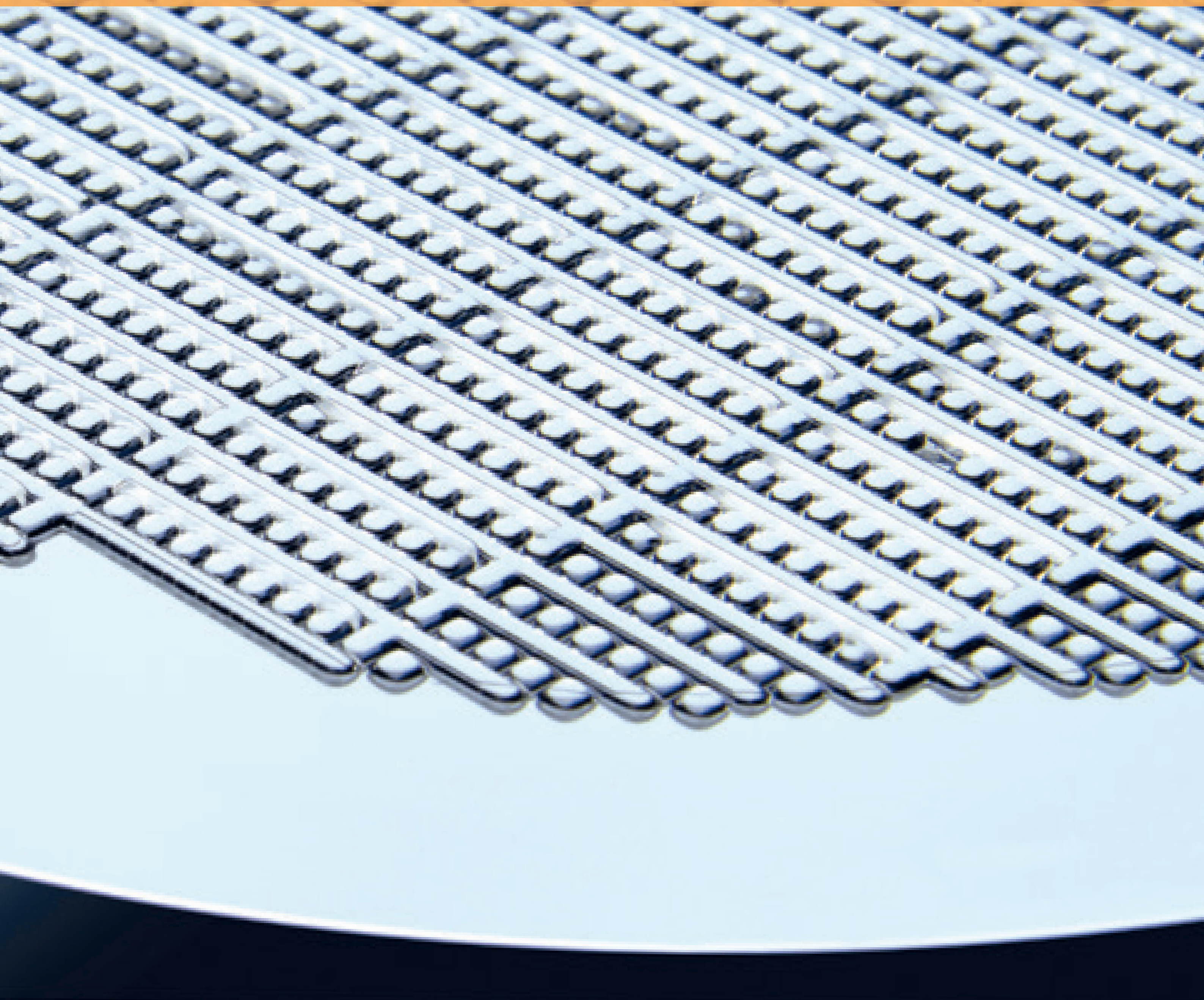
Author: Jannes Ophey

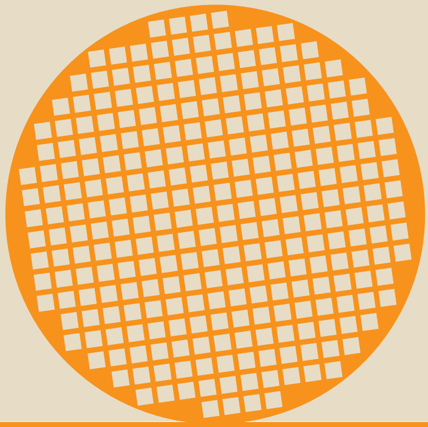
Project name:	"Umweltfreundliche Hochenergie-NCM622-Kathoden mit optimierter Speicherkapazität / High-Load-Kathoden (HiLo)" (BMBF)
Duration:	01.08.2016–31.07.2019
Partners:	Fraunhofer IKTS (Dresden), TU Dresden



Glass cap wafer

MICRO MANUFACTURING PROCESSES



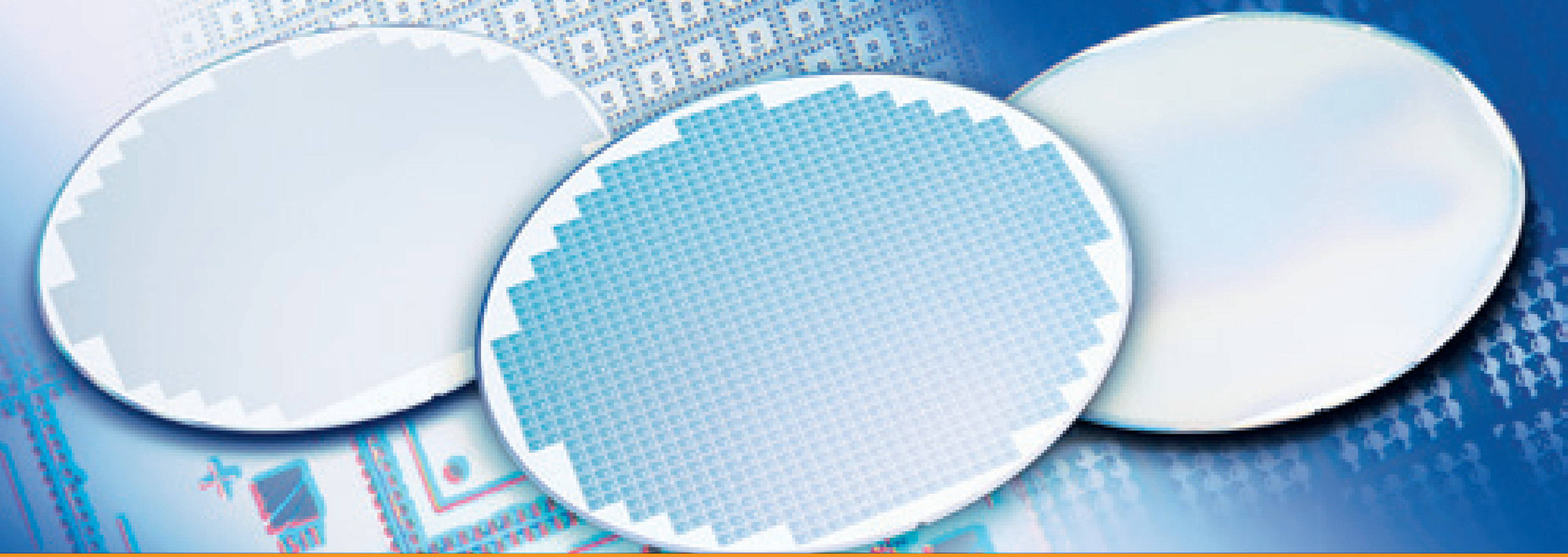


BUSINESS UNIT MICRO MANUFACTURING PROCESSES

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

Important offerings at ISIT are wafer-level packaging (WLP) and various individual processes at the wafer level.
Here the focus is on the packaging of microsystems on the wafer, but also the further processing of pre-structured wafers and the development of problem-specific technology solutions at the individual process level. The wafer technologies that are developed make it a functional part of a microsystem. Outstanding successes were achieved in the vacuum capping of MEMS sensors by means of eutectic wafer bonding. The technology basis at ISIT is excellent: Front-end processes of the and the own back-end clean room line with equipment for MEMS-specific manufacturing processes can be used. The lithographic capabilities include a wide-field stepper, backside mask aligner, spray coating and spin coating, and thick resist processing. CVD, PVD, ALD and special tools for thin films are available.

The wet processing area comprises anisotropic etching of Si, automated tools for metal etching, and electroplating. In case of dry etching, equipment for DRIE of Si and RIE of oxidic compounds is available. MEMS release etching can be performed using HF and XeF_2 gas phase etching or wet etching. A specific focus is given to hermetic wafer level packaging of MEMS using metallic, anodic, or glass frit wafer bonding technology. Wafer grinding and temporary wafer bonding are key process steps for thin wafer and 3D integrated products. In addition to the individual processes, ISIT has established a number of qualified technology platforms.
ISIT can also offer the developed components and systems to customers as prototypes or in small series from pilot production. Not only does this require proving that certain manufacturing steps and functional principles are feasible in principle, for example using demonstrators, but also taking all development steps to series readiness – an effort that must not be underestimated. High volume series production can be supported in particular through cooperation with the local company X-FAB MEMS Foundry Itzehoe GmbH, so that the industrial production of larger quantities is also possible in many cases.



Test wafer for process calibration

After all, ISIT offers a number of services at the module level to internal and external customers as module services.
In assembly and interconnection technology, ISIT specializes in the implementation of innovative processes and technologies in direct cooperation with manufacturers of assemblies, equipment, and materials. The automatic assembly of ultra-thin chips on flexible PCBs has already been tested successfully several years ago. ISIT has all basic technologies for the automated or manual handling of microchips and MEMS as well as their electrical contacting using wire bonding and flip-chip technologies. For power electronics assemblies with improved power cycle performance, ISIT has highly developed thick wire/ribbon bonding technology, both for aluminum and for copper bonding material.
ISIT has 20 years of experience with the assessment of quality, reliability, and robustness. Focal points are on the assessment of manufacturing quality, reliability testing, lifetime prediction and failure analysis, and the development of electronics as well as assembly and interconnect concepts, from the chip to the system. Beyond that, ISIT evaluates the aging behavior of assembly and interconnect techniques like chip-on-chip, chip-on-system, chip-on-board, and chip-on-polymer as well as bonding and soldering connections. The scientists create prognostics by means of model calculations, analyses under different environmental conditions, and accelerated aging tests. They also conduct extensive assessments of failure analyses in the prognostics.

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MODULAR PACKAGING PLATFORM FOR OPTO-ELECTRONIC MICRO DEVICES

With the integration of optical functionality, the packaging of components and systems on the wafer level (WLP) is facing new and exciting challenges. Packaging of MEMS is generally driven by the need to reduce the form factor and cost, as the impressing success of inertial sensors has shown in the past. Upcoming new applications like augmented and virtual reality in lightweight eyeglasses (AR/VR glasses) now require the development of small optical housings, which implies a broad diversity of design aspects from the optical, electrical and thermal domain.

Like in most WLP problems, the first concern is the hermetic sealing of sensitive elements in inert gas or vacuum. In extension to conventional encapsulation of monolithic silicon structures, optical packaging also includes assemblies of discrete components, like laser diodes and lens elements positioned on a substrate wafer. Controlling the atmosphere within an optical package greatly contributes to the reliability of such optical assemblies. Hermeticity is achieved by placing a cap wafer, for example with optical windows, on top of the substrate wafer and sealing it by a bonding process. Various metallic and glass frit bonding techniques are applied at ISIT, depending on the type of packaged optical elements.

To allow faster development of customer specific optical housings, Fraunhofer ISIT developed a modular packaging process family. A first technology toolset

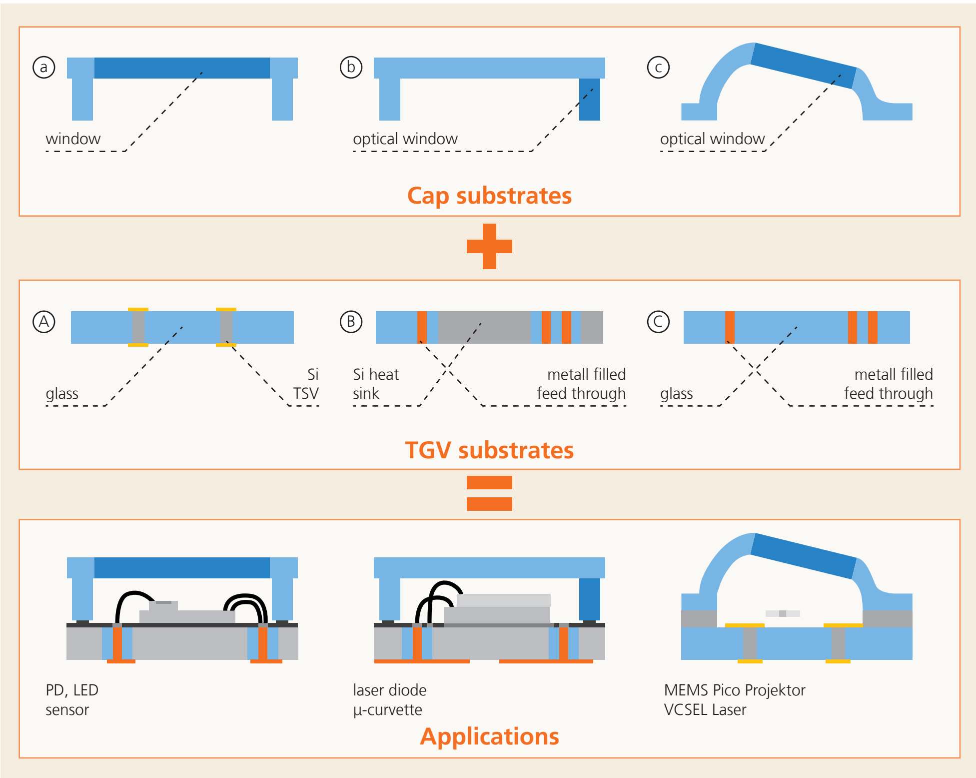

Figure 1: Schematic of different optical housing constructions supported by the modular packaging system

Figure 2: View on glass substrate wafer with silicon vias (TGV)

enables the production of differently oriented windows integrated on 200 mm glass wafers. Glass covers are formed by high temperature viscous glass micromachining, micromechanical processing and sequential bonding steps of glass and silicon wafers. Additionally, the glass flow technology can be applied to integrate electrical feedthroughs of highly conductive silicon (Through-Glass Via, TGV) or the introduction of heat sinks. Figure 1 illustrates the different possible combinations of cap wafers and TGV substrates with some example applications.

Examples for optical cap wafers and TGV integration
One of the first and most prominent examples for our optical packaging are MEMS housings for pico-projection systems. Using an inclined optical window, the problem of the so-called central reflex in a projected image was solved: As long as the scanning mirror and the window are essentially parallel to each other, an external laser source causes a bright spot in the middle of the screen. By deflecting the laser reflection from the cap, the spot can be shifted outside the image area.

For optical applications, excellent surface properties are a must and parallelism or curvature of optical surfaces have to be tightly controlled. In the inclined window glass cap, wafer production consists of sequential bonding steps combining glass wafers with structured silicon templates. The high surface quality of both glass and silicon wafers are retained throughout the process, hence no additional polishing step is needed.

A more recent development are SMD compatible glass-housings for the encapsulation of laser diodes. The key feature is a lateral emission window for the laser beam, again preserving the high-quality surface properties of the optical glass inlay. Two different process flows for the integration of a lateral emission window have been developed and evaluated: In the first approach, two glasses with different glass transition temperatures were combined, while in the second approach the shape of the optical window was protected by silicon. To keep the entire SMD component as small as possible, the electrical contacts may be realized by TGVs.

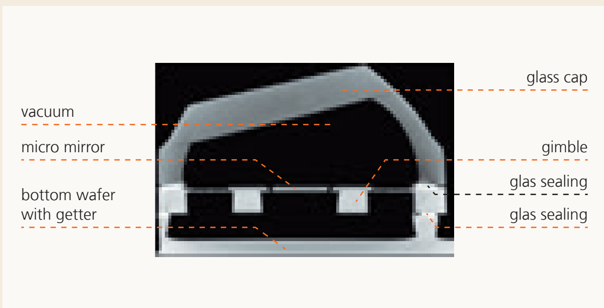

Figure 3: 3D X-Ray: cross section trough a fully-caped-mirror-device: Top: glass package, middle: micro mirror, bottom: bottom wafer with getter

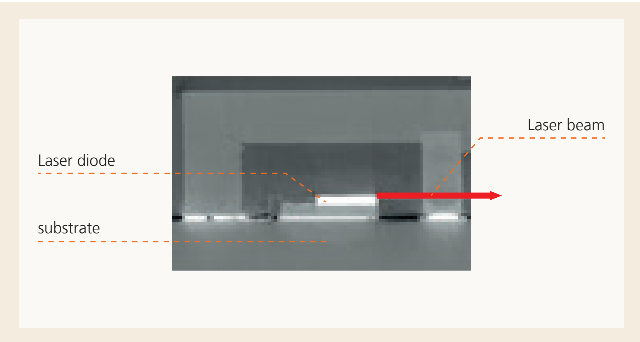

Figure 4: Laser diode housing: X-Ray cross section through a housed laser diode

Conclusion

The described two examples show the performance of the newly developed glass forming technology. Our glass wafers with inclined window surfaces for micro-mirrors achieved a good optical quality and fulfills high hermeticity requirements for resonant scanners even in automotive applications. Evaluations of the Q-factor show that pressures down to 10-3 mbar can be achieved. This technology is now available for starting the commercialization of MEMS mirrors up to a chip size of 3 mm x 4 mm with industrial partners.

Our glass cover wafers with lateral emission windows for laser diodes were already realized in a size of 2 mm x 2 mm x 1.3 mm, which is significantly smaller than conventional TO-housings. The cavity footprint can be scaled up without increasing the height of the component. The BMBF funded project PRISMA now targets to bring the technological maturity closer to industrialization and to characterize and test wafer level assemblies of laser diodes with other optical elements. Further work is planned on the integration of TGV and on glass cap wafers with more elaborated window geometries. The PRISMA project started October 1st, 2017 and has a duration of three years.

Author: Vanessa Stenchly

Project name: PRISMA

Duration: 01.10.2017–30.09.2020
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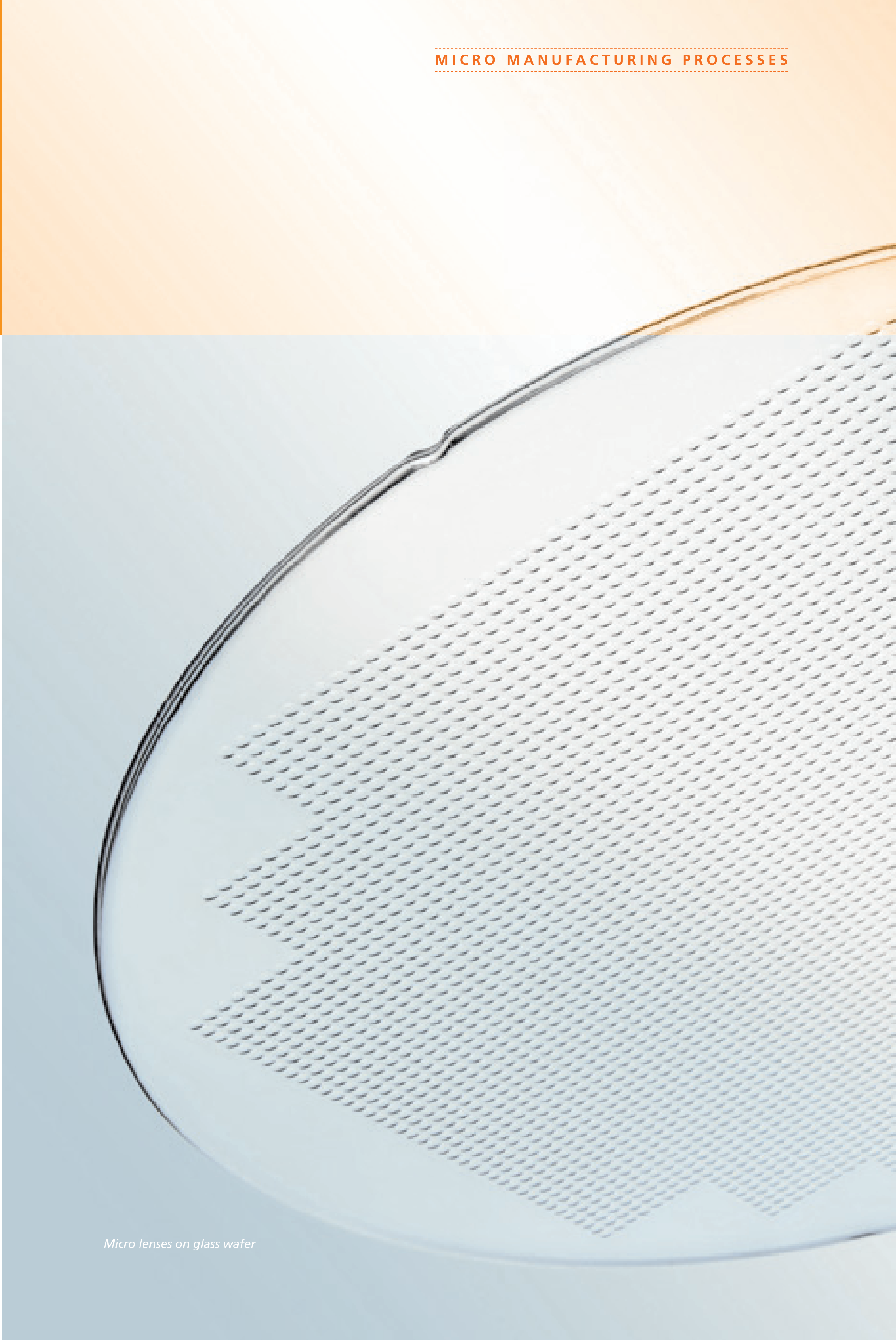
Partners: Disco, XFAB, AMICRA, Süss Micro Tec, InProces, BudaTec, Wagen-brett, Koenen



Micro lenses on glass wafer

CHIP-SIZE PACKAGING AND POST-CMOS INTEGRATION

Mobile electronic devices are based on extreme miniaturization of electronic components to thicknesses below 1 mm. Under the label "Post-CMOS processing", Fraunhofer ISIT offers a broad range of advanced hybrid assembly technologies like chip-size packaging (CSP) and wafer-level packaging (WLP) to integrate microelectronic sensors and actuators with their electronic driver circuits.

CSP technologies comprise a variety of process add-ons to the basic MEMS and CMOS flows called "back-end of line" processes. ISIT's service offer includes manufacturing MEMS in our own cleanroom as well as conditioning CMOS wafers from external fabs. Typical CSP processes on the wafer level are electrical rewiring, wafer balling, vias and electroplated structures for soldering or hermetic sealing. Discrete CSP assembly involves laminate substrates, e.g. in chip-beside-chip or chip stacking configurations. Although the motivation is generally a very compact package, electric specifications like low inductivity or reduction of parasitic capacitance may play a role as well.

With ISIT's industrial 200 mm state-of-the-art MEMS manufacturing line, it is even possible to complete the CMOS manufacturing in ISIT's cleanroom: A frequent example is the final release etch of sensor elements from an external CMOS fab prior to wafer-level packaging. Over the years, ISIT has developed a modular toolbox of post-CMOS technologies for rapid customer specific component development:

- symmetrical wafer thinning of MEMS components
- special dicing techniques, e.g. to expose wire-bond pads on MEMS devices
- electrical feedthrough in glass and silicon wafers (TSV: Through-Silicon Via)
- under-bump metallization plating (e.g. electroless Nickel-Gold)
- electroplating of metallic seal frames
- membrane release etch
- chip stacking technique with adhesive transfer foils
- spacer technology for chip mounting
- chip to wafer assembly
- 3D wire bonding
- bumping and solder balling on wafer level
- hermetic sealing technology on wafer level

Bumping and Balling

ISIT offers two technologies to deposit solder on wafers: The use of preformed solder balls allows to apply a large solder volume; the soldered devices will typically not require any additional underfill due to their large gap to a laminate substrate. Our balling process supports up to 200 mm wafer diameter (300 mm on request) and is based on a Ni-Au contact metallization. Pre-formed solder balls (≥ 150 μm) are soldered in a pitch > 300 μm with very high yield. This process is even applicable for strongly thinned TAIKO wafers down to 30 μm residual thickness. Alternatively, a precision stencil printing technique is available to form flip chip solder bumps down to 250 μm pitch in industrial quality. Pitch dimensions down to 170 μm have already been demonstrated.

Under-Bump Metallization

Fraunhofer ISIT offers deposition of electroless Nickel and immersion Gold (ENIG) on fully processed CMOS wafers, which allows to provide aluminum or copper pads with an effective barrier against solder diffusion. As a batch process without any lithography, ENIG is considerably cheaper than galvanic electroplating and available for wafers up to 200 mm. Due to our long-year experience with a large variety of customer products, this coating process runs very stable. In sequential processes with thinning, bumping or dicing, our technological approach "UBM first" strongly reduces the risk for wafer breaking. Nevertheless, excellent results have also been achieved on thinned TAIKO™ wafers with a backside that was passivated after grinding.

Electrical Feedthroughs

Two different electrical feedthrough (via) technologies for microsystem and microelectronic applications are available: Vias in glass wafers are particularly suitable for optical MEMS pa-

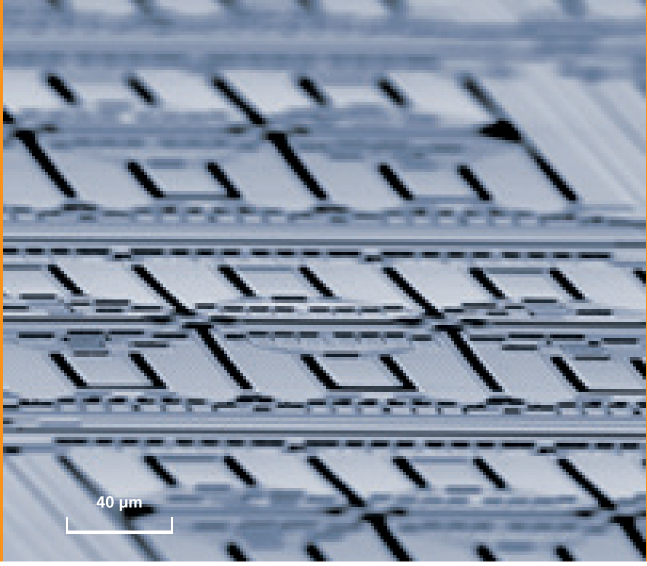


Figure 1: Ultra-thin sensor membranes after release-etch by ISIT's post-CMOS processing

ckages and high-frequency components, while dry-etching in silicon wafers achieves a larger via density. Both technologies seal hermetically and are applicable on 200 mm wafers. They can be combined with contact redistribution and balling. ISIT offers customer-specific solutions based on pre-developments with wafer thicknesses in the range of 300 µm to 600 µm.

Sealing Frame Deposition

For many types of components, like infrared imagers or inertial sensors, hermeticity is an important requirement. Placing cap elements on the active side of CMOS circuits allows monolithic integration on the wafer level, with dramatic cost reduction in high-vacuum packaging. ISIT's key technologies in metallic sealing frames and vertical interconnects include specific know-how to support elevated wafer topography and selection of adhesion promoter and barrier layers for high reliability. Getter integration and 100% leak rate screening differentiate us further. Through a tight collaboration with the customer, process and chip design are closely matched: As an example, the liquid phase formed during eutectic gold-tin bonding requires catching structures to obtain good bonding results.

Wafer Level Packaging

Wafer level packaging (WLP) is a highly parallel process for the hermetical housing of micro mechanical and micro optical components and modules. ISIT offers a continuously growing "off the shelf" WLP concept from design up to pilot production, including transfer options to high volume foundries. Various joining technologies such as glass solder or metals are available. Housings with transparent window surfaces for visible up to far-infrared radiation can be manufactured at ISIT. Verification of the inner pressure in a WLP can also be a stringent demand to estimate the expectable lifetime of a product. For resonant structures, ISIT's "Neon ultra-fine leak test" based on measuring the Q-factor of an electromechanical oscillator allows forecasting the pressure increase over a product's lifetime (Semi Guideline 4446 "Evaluating Hermeticity of MEMS Packages").

To maintain vacuum in a very small package, outgassing and desorption of gas molecules from the inner surfaces has to be controlled. So-called "getter" films allow to absorb free molecules of most frequently found gas species, like an in-situ pump that remains active through the whole lifetime of a product.

Membrane release etching

CMOS technology enables the co-integration of sensor functionalities and e.g. pre-amplification electronics on the same chip. Some sensor types are based on ultra-thin membranes formed by bulk- or surface micro-machining techniques. With numerous etching processes available at ISIT, pre-structured sensor wafers can be safely transferred from a CMOS fab to ISIT's cleanroom. The final release etch is then realized directly before packaging, using techniques like reactive ion etching, HF or XeF2 gas phase etching or a special TMAH wet etching that preserves exposed bond pads from the chemical attack. Figures 1 and 2 show an example from an etch depth capability study.

Author: Wolfgang Reinert

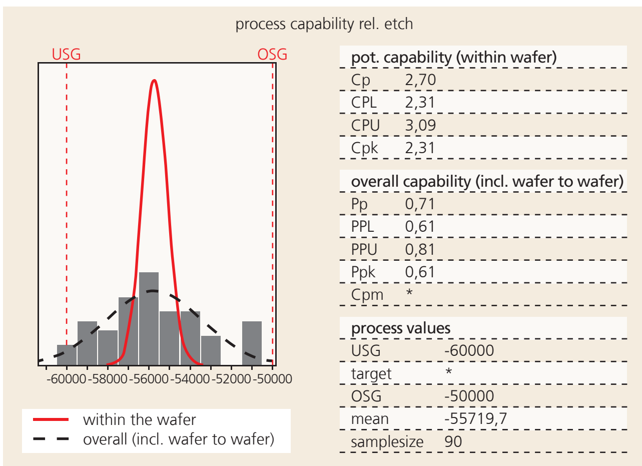


Figure 2: Statistical evaluation of the etch depth process capability study

USE OF METALLOGRAPHY IN RESEARCH, DEVELOPMENT AND QUALITY ASSESSMENT OF ELECTRONIC SYSTEMS

Electronic and microelectronic assemblies are increasingly complex material composites. The materials used are quite different in their chemical composition, their crystallographic structure and their microstructure. Metallographic investigation methods therefore have a high priority in the evaluation of the quality and reliability of electronic connections.

Important aspects for the qualification of the components are interfaces, grain boundaries and phase boundaries as well as heterogeneous precipitations. Proper imaging and analysis of the microstructure is a prerequisite to estimate the quality of a component. Further quality assessment criteria from a metallographic point of view are inclusions, contaminations, pores, cracks, holes, as well as the evaluation of contours, e.g. the wetting angle of a soft solder connection.

The growth of intermetallic phases is an important criterion for the reliability of the solder joint, as depicted in figures 1 to 3 on the example of different copper phases.

- Figure 1 shows a bonding frame in a wafer-level package. To produce a hermetic seal, a phase growth bonding mechanism is utilized where a continuous Cu_6Sn_5 phase is formed during bonding. The picture shows how the copper is dissolved.
- Thermal stress can lead to extreme growth of intermetallic phases.
- Figure 2 shows a tin soldered copper wire. During operation, the solder has completely turned into intermetallic phases. The copper wire and PCB pad had no nickel diffusion barrier. Due to temperature influence during operation, the copper wire has gone into solution. The soldering gap consists entirely of Cu_6Sn_5 phases, a thick epsilon phase can be seen close to the copper.

Nickel corrosion on the printed circuit board (figure 3, 4) is still a problem, especially for BGA soldering. Nickel corrosion can be detected by means of scanning electron microscopy (SEM) on the PCB solder pad after component shear-off. The nickel corrosion is also recognizable in the cross section. Because the entire board is not affected consistently, the BGA may need to be grinded in several layers to identify the problem. The picture shows a nickel corrosion on a PCB pad. The arrow points to typical corrosion spikes in the nickel layer. Here, the solder cannot wet the surface.

For high-resolution investigations at interfaces, a focused ion beam (FIB) preparation is used. Figure 5 shows a FIB-preparation of a silver layer on an Al_2O_3 ceramic. There is poor adhesion due to fine porosity in the boundary layer. This is the cause of low shear strength.

ISIT supports industrial customers in process development and quality monitoring. To illustrate this service we portrait a

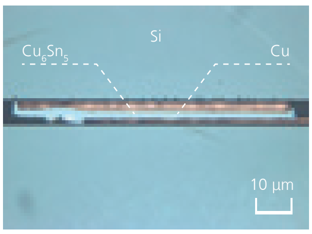


Figure 1: Bonding frame of CuSn phases

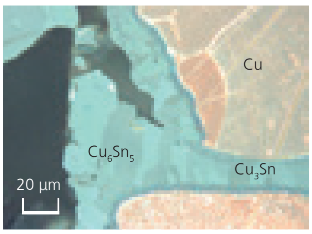


Figure 2: CuSn phase growth after thermal stress

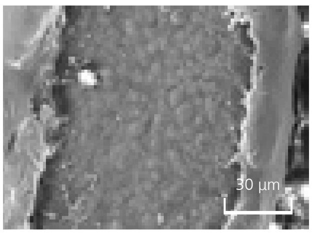


Figure 3: Area of Ni-corrosion on NiAu surface of a BGA PCB layer

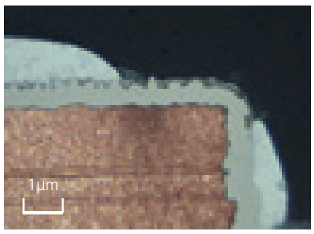


Figure 4: Cross-section through the pad shown in figure 4

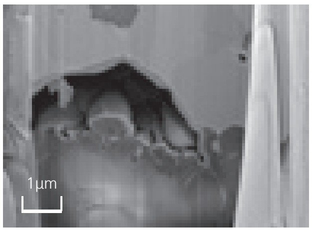


Figure 5: Pore between silver layer and Al_2O_3 ceramic

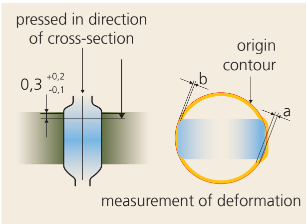


Figure 6: Analysis of press-fit contact according to DIN EN 60352-5: 2008-11 (Section 5.2.2.5.2)

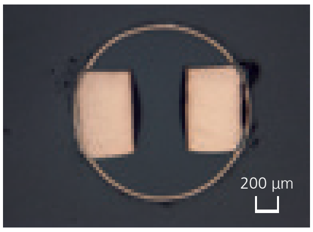


Figure 7: Overview of cross section with cracked metallization

Figure 8: Detail of cross section with cracked metallization showing a type b failure

typical case on the example of press-fit contacts: Press-fit contacts are used for both control connections and load connections because the current carrying capacity of printed circuit boards is growing rapidly today. The cross section is used to investigate the deformation of the plated through-hole and the damage to the printed circuit board material caused by the press-fit connection. For cross sections, the deformation "a" of the hole contour for the plated hole may not exceed 70 µm. The smallest residual thickness "b" of the metallization must be at least 8 µm. The metallization of the hole must not be cracked. Examples are shown in figures 6 to 8.

For the purpose of analyzing the press-fit contact, according to DIN EN 60352-5: 2008-11 (figure 6), longitudinal and transverse cuts are made from the press fit connections. For longitudinal cuts the deformation "c" of the pattern of the plated through hole may not exceed 50 µm. Neither the metallization of the hole nor the conductor may have cracks (figures 10 to 11). Defects are caused when pins are too big for a via or when the via metallization is too thin.

Author: Katja Reiter

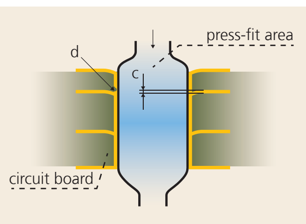


Figure 9: Placement of longitudinal cut according to DIN EN 60352-5:2008-11 (Section 5.2.2.5.3)

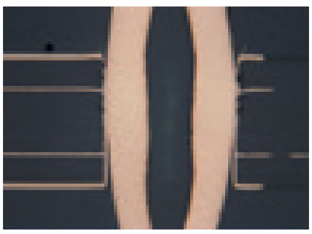


Figure 10: Overview of longitudinal cut of the pin

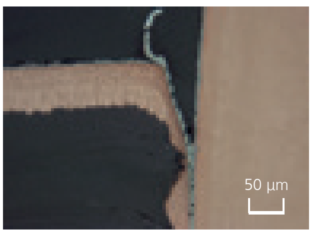
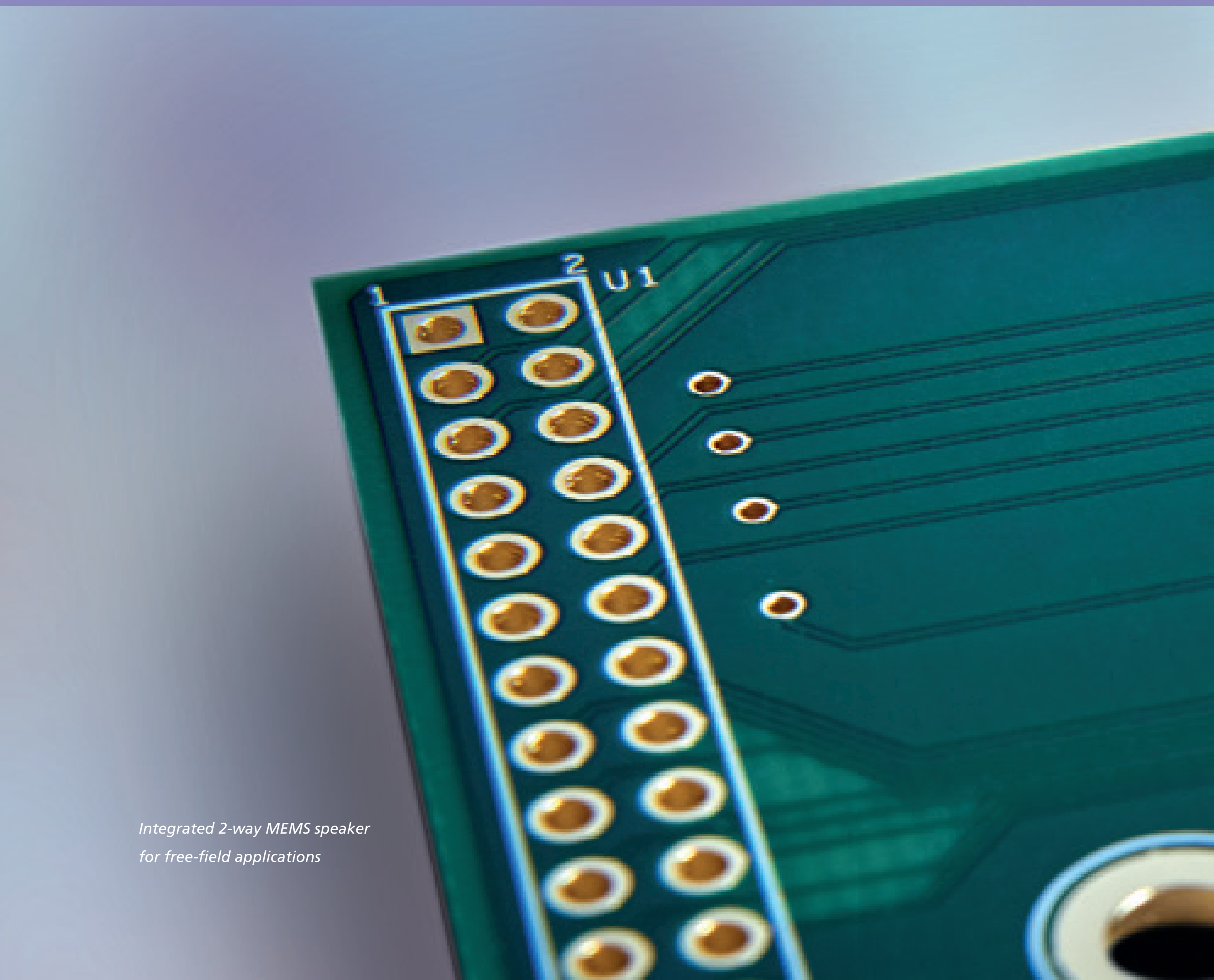
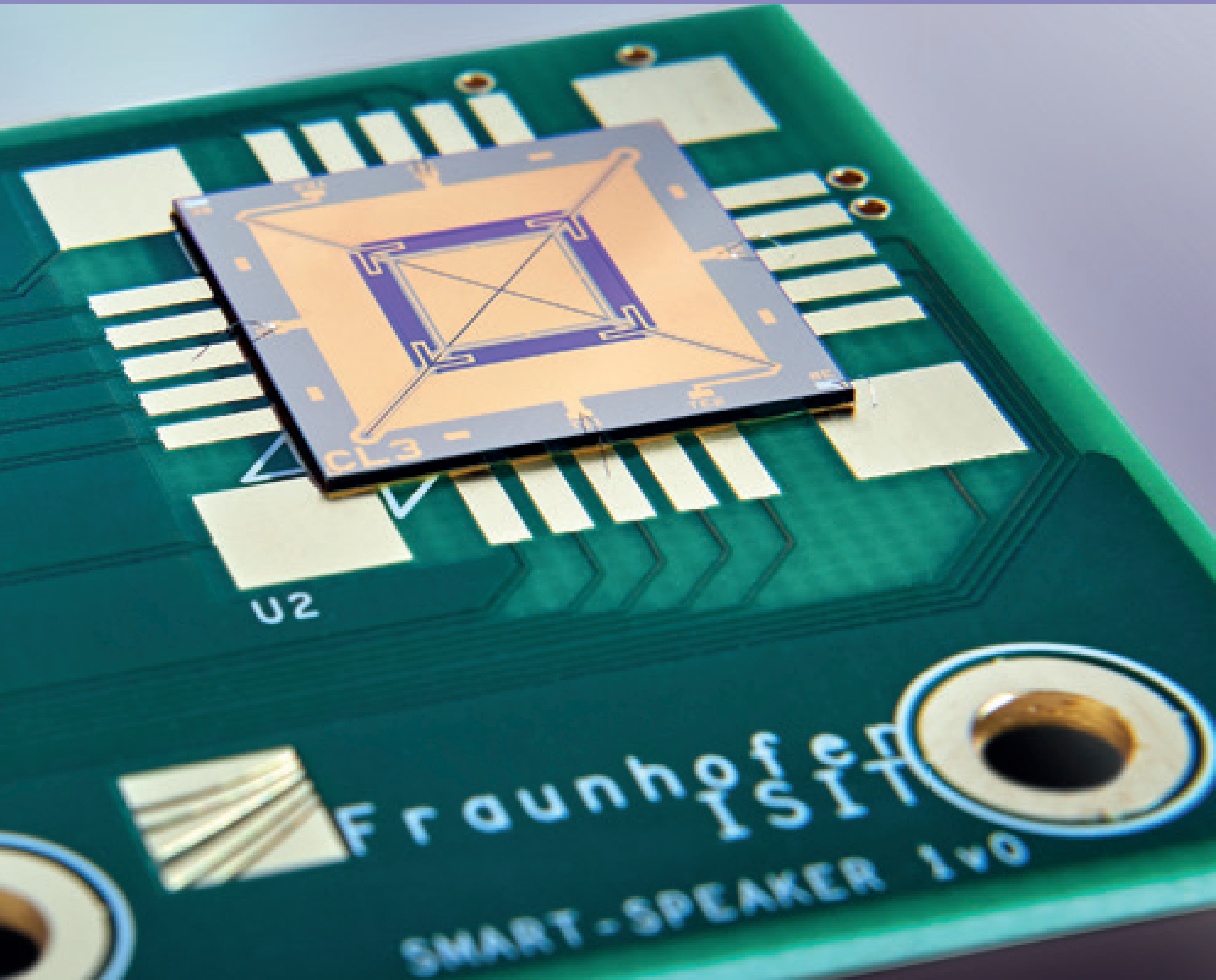


Figure 11: Longitudinal cut of the pin with deformation



Integrated 2-way MEMS speaker for free-field applications

MEMS APPLICATIONS



BUSINESS UNIT MEMS APPLICATIONS

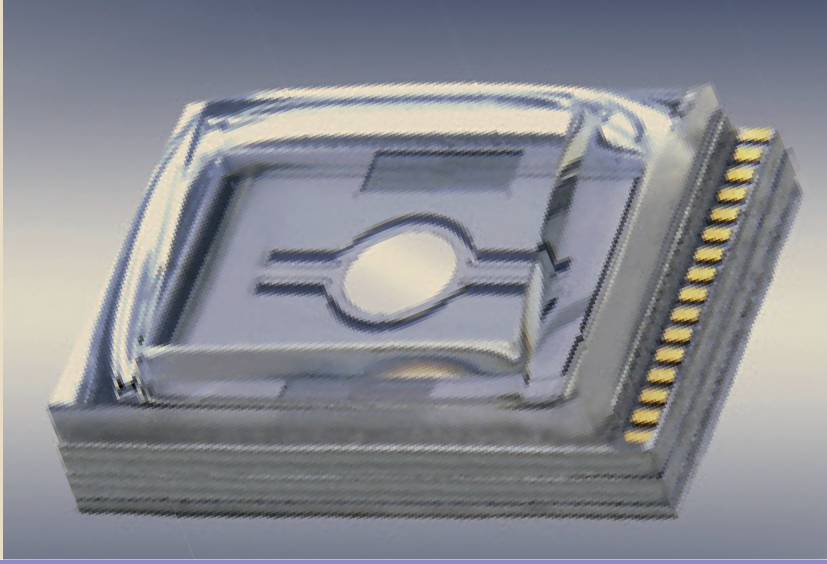
ISIT scientists have been working on the development of micro electro mechanical systems (MEMS) for more than 30 years. In the Business Unit MEMS Applications, ISIT focuses on the design, development, and production of MEMS components and MEMS systems.

Optical microsystems are a key focal point in this business unit. Here ISIT develops MEMS scanners, that is to say scanning micromirrors including control and read electronics for different kinds of laser projection displays, for optical measuring and detection systems (such as LIDAR), and power applications in the fields of laser material processing and generative manufacturing. Based on a patented fabrication process, ISIT is currently the world's only manufacturer of wafer-level vacuum packaged dual-axis MEMS scanners. Operating these scanning micromirrors in a vacuum environment offers significant advantages.

Damping by the gas molecules is reduced to a minimum, enabling high-frequency scanning with unrivaled scan angles even at low electrostatic driving voltages. Hermetic encapsulation at the wafer level also results in the cost-effective and permanent protection of the scanning micromirrors against all kinds of contamination. This for example makes the steam sterilization of these MEMS scanners in an autoclave for endoscopy applications possible without causing damage.

ISIT has also realized a 3D camera with a depth resolution of just a few millimeters and a detectable object distance of 2 meters on the basis of 2D MEMS scanners. Novel scanning micromirrors with apertures of up to 2 centimeters and highly reflective coatings even permit highly dynamic dual-axis laser beam deflection for CW laser outputs of up to 500 watts. In addition to capacitively driven scanning micromirrors, piezoelectrically driven scanning micromirrors are currently a research focal point at ISIT. This drive concept is particularly attractive due to its high force with simultaneous low energy consumption. Deflections of up to 1600 µm have already been realized on individual scanning micromirrors of this type for resonant, translatory lifting movements.

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



Vacuum packaged micro mirror for laser projection

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

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

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ADAPTIVE HEADLIGHTS FOR IMPROVED TRAFFIC COMMUNICATION

For many years, safety- and assistance systems in cars contributed to a significant reduction of mortality in road traffic. However, global trends like increasing traffic density, the aging society and autonomous vehicles create new risks: As it becomes more and more difficult for traffic participants to understand and anticipate the "behavior" of vehicles, better communication can help to resolve upcoming critical situations or to avoid them.

The design of modern cars tends to isolate drivers from their surroundings rather than improving vision and visibility that would allow making contact with other road users. But the car as a technology carrier can create new communication means between different road users: "Car-to-x communication" is now a major trend in automotive development and traffic management, where "x" stands for other cars, traffic infrastructure and human beings.

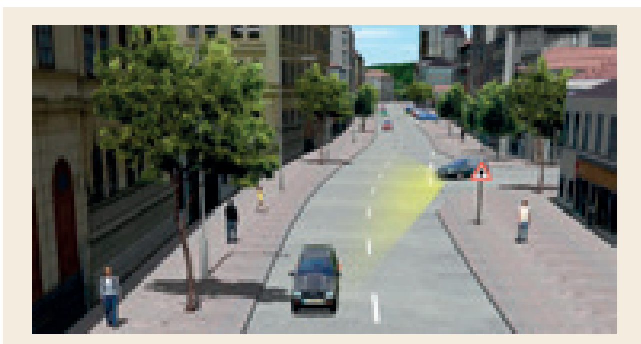
More than 90% of the required driving information is perceived visually. Projection of additional contents onto the road and thus directly into the field of view of road users therefore seems to be an appropriate communication channel. The project "KOLA – Kooperativer Laserscheinwerfer" (co-operative laser headlight) targets to improve the cooperation in traffic through the development of assistance systems that promote the communication possibilities between individual road users, in particular car drivers (figure 1). The BMBF-funded project was started in November 2016 and has a duration of three years.

Visual communication in traffic situations

KOLA stands for an intelligent laser module for dynamic headlight applications in cars. Fraunhofer ISIT contributes a long-year experience in developing 2D-MEMS scanners, with applications ranging from fast "pico-projection" scanning mirrors to robust and high performing automotive LIDAR systems, or even high-power laser machining systems. Depending on the application, the integrated light sources vary from low power laser diodes with only some mW output up to high power lasers with several Watt.

Within the KOLA consortium, Volkswagen AG and Fraunhofer ISIT carry out the technology-oriented conceptual design and implementation. The creation and illustration of traffic situations, visual communication and sociologic and psychologic aspects are covered by the Technical University of Braunschweig (Department of Engineering and Transportation Psychology) and the University of Siegen (Department of Experience Design) with the aim to create novel projection-based assistance concepts.

Figure 1: A virtual street scenario



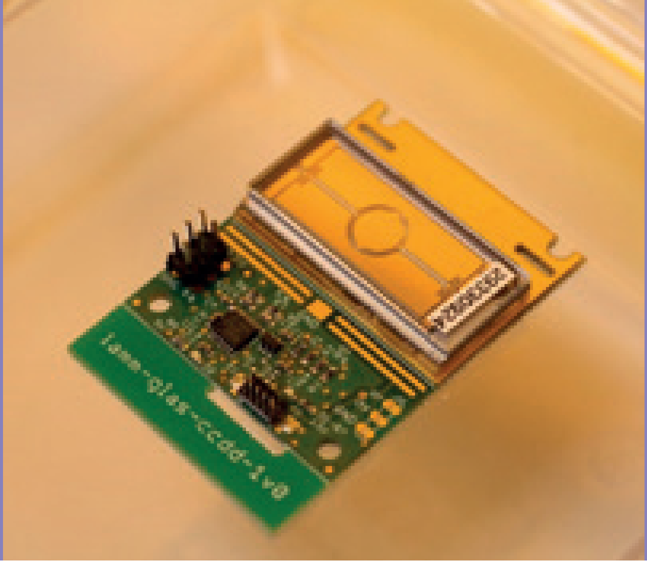


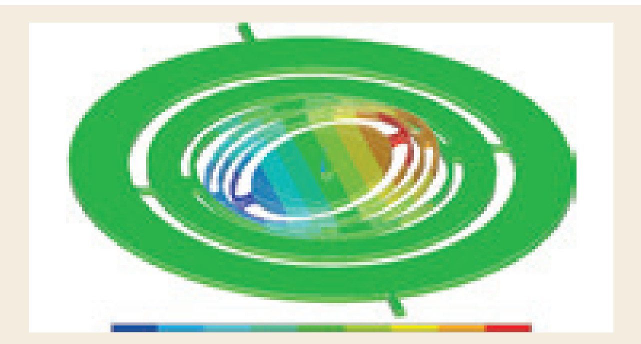
Figure 2: Circuit board with a large-aperture scanning system

Technologies behind KOLA

ISIT`s role in the project is to develop a 2D-MEMS scanner device for high power RGB-laser headlight projection in cars. The development comprises the whole projection system including design and simulation studies, the implementation of the driving and reading electronics as well as the data processing (e.g. video signals) synchronized with the light source modulation. A unique feature of ISIT's MEMS scanner technology is the vacuum glass encapsulation, which allows large mirror apertures and enables longevity and robustness of the components.

The KOLA requirements are challenging: To obtain a bright color projection at daylight, the scanning mirror has to withstand up to 5 W laser beam power, which requires an appropriate broad band high reflective coating. For good projection resolution, the mirror plate is relatively large (~ 5 mm in diameter) and oscillates with high amplitudes and frequencies around 10-15 kHz. For illuminating a wide area on the road, scanning angles up to 30 degrees are needed. The MEMS scanners have to be exceptionally robust against shock and thermal cycles. Here, ISITs unique vacuum encapsulation technology with custom 3D-shaped glass cap wafers is essential.

Figure 3: Simulation of scanning micromirror displacement in operation

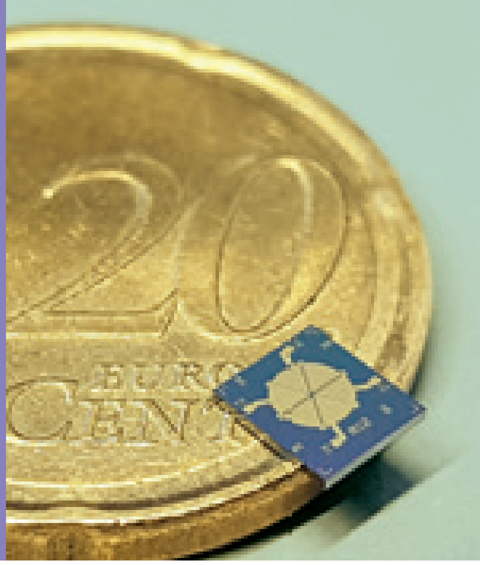


Modular project organization

Because the realization of an integrated system is time consuming, VW and ISIT develop the complete headlight system on a modular base. In order to get preliminary impressions of the performance, the project is organized in parallel activities: On the application side, ISIT's already available 1D scanner (figure 2) is provided to VW for system-level integration of the headlights. At the same time, ISIT designs two variations of a 2D-MEMS scanner and performs simulation studies (figure 3).
Then, the layouts are generated and photo masks are ordered for the fabrication in ISIT's MEMS cleanroom.

Author: Gundula Piechotta

Project name:	KOLA – Kooperativer Laserscheinwerfer (BMBF)
Duration:	01.11.2016 – 31.10.2019
Partners:	Volkswagen AG, Fraunhofer ISIT, Universität Braunschweig, Universität Siegen



INTEGRATED MEMS LOUDSPEAKERS FOR MOBILE APPLICATIONS

MEMS chip of an in-ear speaker

"Acoustic MEMS" are primarily associated with microphones, which have been successfully established in mobile applications. A tremendous interest is now directed towards MEMS loudspeakers, which promise lower size, higher energy efficiency and better performance than conventional solenoid-based devices. Beside free-field sound emission in smartphones and tablets, highly miniaturized and energy-efficient speakers will contribute to the evolution of wireless headphones and hearing aids, and even enable new products in the "hearables" domain. With outstanding miniaturization and volume-production capabilities, MEMS technology seems to be the perfect solution. Yet, first attempts to manufacture MEMS speakers suffered from insufficient acoustic performance as well as expensive additional fabrication steps like hybrid integration of magnets or membranes.

Driven by an enormous market potential, the Fraunhofer-funded project "Smart Speaker" wants to overcome these issues with innovative MEMS speakers for both in-ear and free-field applications. Besides achieving excellent acoustic performance at smallest size and power consumption, the project aims for enhanced "smartness" on the system level with features like sound directivity. In this sense, the partner Fraunhofer IDMT focuses on signal processing and intelligent drive control, while Fraunhofer ISIT is responsible for development and fabrication of the actual MEMS speaker.

The novel integrated MEMS speakers utilize ISIT's piezo technology platform to build multiple bending actuators, each of them comprising a passive poly-Si layer with 2 µm thick piezoelectric PZT embedded between two driving electrodes (figure 1).

Clamped on a silicon frame, all actuator elements form an acoustically active surface, whereas the individual actuators are mechanically separated by narrow gaps. When operated, the actuators perform an out-of-plane movement to displace the adjacent air. Since all actuators are mechanically decoupled

Figure 1: Schematic cross-sectional illustration of the speaker concept. The actuators perform an out-of-plane bending to displace the adjacent air

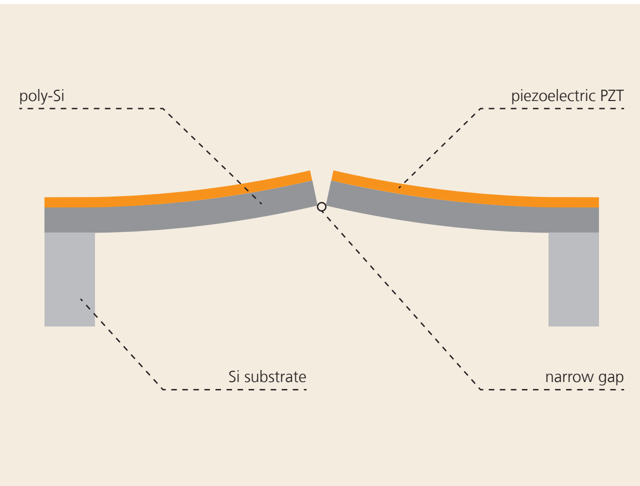
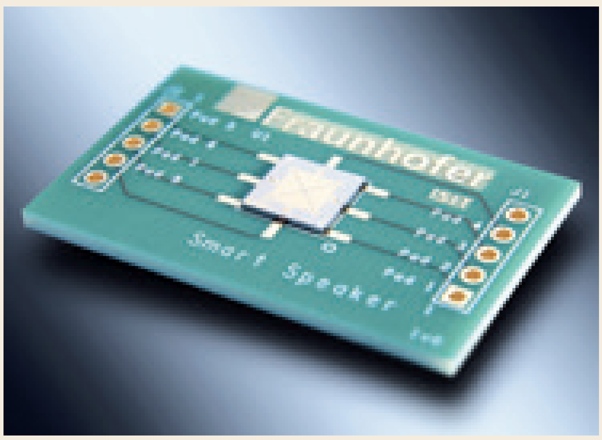
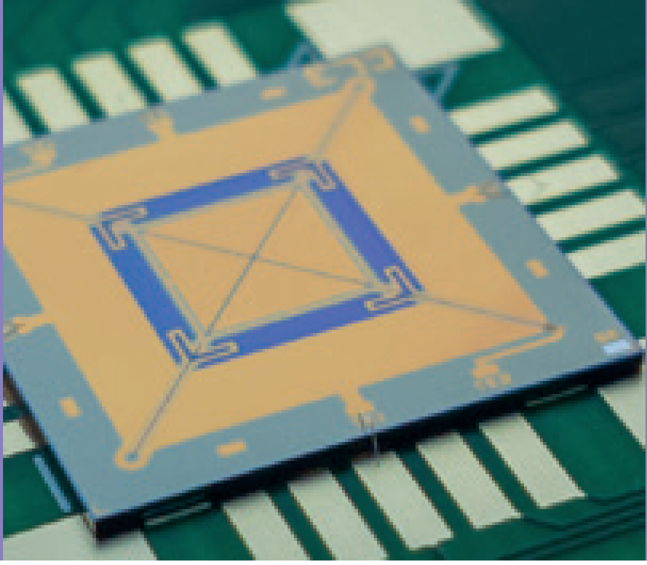


Figure 2: In-ear speaker assembled on test board for acoustic characterization





Integrated two-way MEMS speaker for free-field applications assembled on PCB

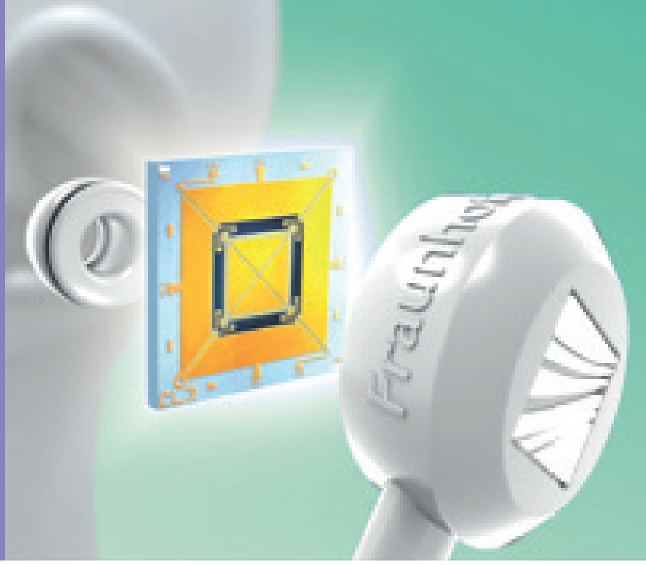
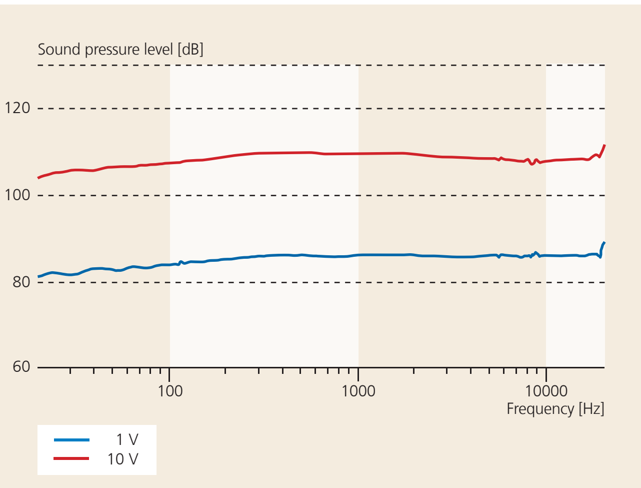


Illustration of an in-ear headphone (MEMS chip magnified)

from each other, high deflections and forces can be realized. Parasitic air leakage through the gaps is however inhibited by high viscous losses that emerge along the sidewalls of the narrow gaps. Consequently, the segmented surface acoustically behaves like a closed membrane, but maintains the mechanical performance of the decoupled structure. This enables higher electromechanical efficiency and better linearity than a closed membrane, as well as very good manufacturability, since no additional flexible membrane has to be integrated.

Measurements and hearing tests have proven remarkable performance and energy efficiency: In case of the 4 x 4 mm² in-ear speaker shown in figure 2, a flat frequency response with up to 110 dB sound pressure level (SPL) is achieved (figure 3), significantly exceeding the demands of most applications. In contrast to conventional in-ear speakers, the SPL is retained over the full audio spectrum (20 Hz to 20 kHz) and even beyond, which is highly attractive for high quality audio (e.g. high-resolution audio). Combined with the

Figure 3: Generated SPL of an in-ear speaker measured in an artificial ear simulator at two different driving voltages



characteristic low harmonic distortion, the speakers yield a sound that has been described by multiple independent listeners as "very powerful with outstanding brilliance at high frequencies". In case of free-field speakers, a two-way approach, comprising a MEMS woofer and tweeter, has been pursued. Implemented in a smartphone housing, more than 80 dB SPL in 10 cm distance have been demonstrated, again featuring an exceptional bandwidth of 500 Hz to 20 kHz.

Albeit the developed speakers are already capable of outperforming conventional speakers in terms of form factor, bandwidth and efficiency, ongoing developments are indicating a further substantial development potential. Among others, the addressed advancements comprise an improved MEMS concept allowing significantly smaller device sizes. Additionally, lead-free Aluminum-Scandium-Nitride (AlScN) is about to be integrated as piezoelectric material, offering even higher energy efficiency, linearity as well as full CMOS compatibility. Apart from that, dedicated driving electronics featuring adaptive signal processing are currently being developed, allowing even higher performance. Altogether, the developed speaker technology shows great potential for bringing forth completely new generations of ultra-small sized audio components for a wide range of applications, both in low-cost and high-quality product segments.

Author: Fabian Stoppel

Project name:	Smart Speaker (Fraunhofer WISA programme)
Duration:	03.2015–10.2018
Partners:	Fraunhofer ISIT, Fraunhofer Institute for Media Technology IDMT, Ilmenau

GENERATING DISINFECTANTS AT THE POINT OF USE

In many areas of our daily life, in particular food processing and sanitary environments, rigorous hygiene precautions necessitate chemical means to clean and disinfect surfaces. Even more exigent demands arise due to a startling increase in antimicrobial resistance, sometimes bringing the use of chemical disinfectants to practical handling limits.

Nowadays, chlorine-containing agents are among the most frequent products to keep surfaces or waters clean.
In addition to an increasing resistance of pathogens and germs, toxic chlorinated compounds accumulated in nature are usually stable for long terms. Another problem is the risky transport of chemicals to the place of use and their disposal.

Water decomposition by electrolysis

A cheaper and safer alternative is the production of disinfecting agents at the point of use: Through an electrolytic process, water and mineral salts contained in it can be decomposed into their constituents, which temporarily releases disinfecting agents like chlorine ions or ozone. This technology is already well established in industrial environments and swimming pools.

In consumer and other distributed applications, the elimination of chemicals would equally lead to an enormous relief of the environment and greatly reduced handling risk. Scaling down the existing technology to small systems is therefore becoming an attractive market. The economic and technical challenge is high: For home appliances, there is a need to miniaturize not only the ozone generators (volume less than 10 cm3), but also the sensor technology and the process control. Current and voltage measurement as well as the monitoring of water flow velocity, temperature and conductivity must be integrated into the generator housing. A smart process control has to be developed that efficiently conducts the electrolysis process for any water quality and temperature without user intervention.

The project partner CONDIAS is already a specialist for manufacturing boron-doped diamond electrodes used in large-scale ozone generators. Due to their high oxidation potential, these special electrodes allow the decomposing of water molecules into ozone and hydrogen. Only a tiny amount of water is converted, which makes the process safe and effective. The open-loop process control, however, requires measuring the water quality and quantity at the inlet in order to achieve the desired disinfecting power. Within the permitted composition of the generally closely monitored water quality in Germany, the formation of unwanted by-products can be avoided to a much greater extent than with chlorine-based agents.

A regional research cooperation

The project is funded by the region of Schleswig-Holstein and by the European fund for regional development (EFRE), with partners based in Itzehoe and Kiel. They jointly develop the ozone generator system, including miniaturized electrodes, sensors and a special power supply for a well-controlled electrolysis. The aim is to make micro-ozone generators available for a wide range of domestic and professional applications.

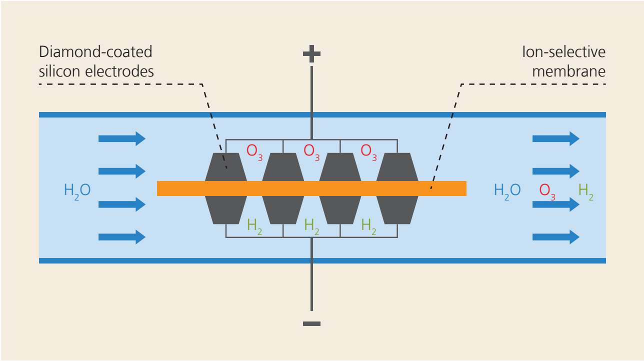


Figure 1: Concept of the electrolysis cell with two diamond-coated electrodes separated by a membrane

The Fraunhofer ISIT is involved in the electrode substrate process development as well as in the multi-sensor design for monitoring mass flow, water conductivity and temperature. The disposable cartridge targets 1-2 years operation time between exchange. To achieve a low price, the sensor shall be built on a simple glass substrate.

Figure 1 schematically shows the electrolysis cell that is integrated into the micro-ozone generator. Basically, it consists of two grid-like electrodes separated by a thin, ion-conducting membrane. The electric potential between the electrodes leads to formation of ozone on one side and hydrogen on the other. The gases remain dissolved in the water for a limited, but highly temperature-dependent time.

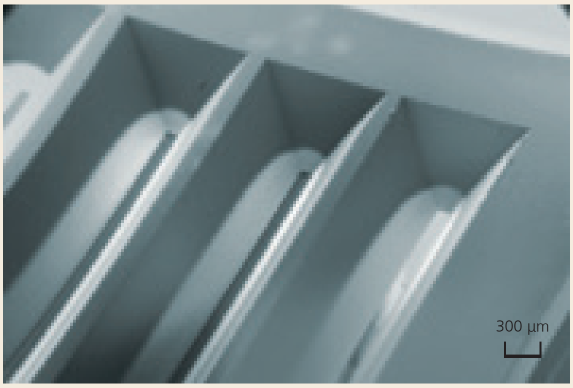


Figure 2: SEM picture of Silicon electrodes after diamond coating at Condias

According to the measured water flow and temperature, a variable amount of ozone is generated in order to achieve the desired disinfecting effect.

An electrode sample is shown in Figure 2 (SEM = Scanning Electron Microscope), illustrating the precisely etched grooves

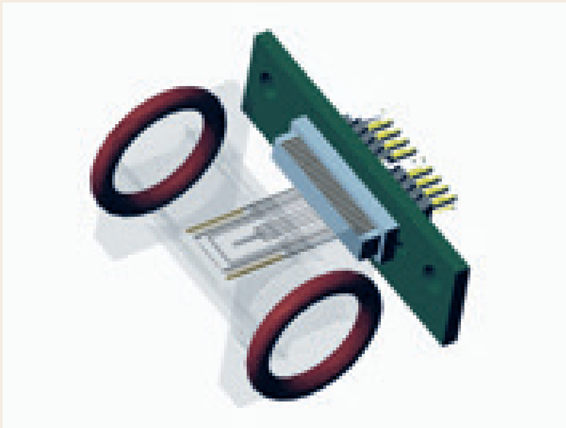


Figure 3: Flow-cell concept with multi-sensor structures deposited on a glass substrate

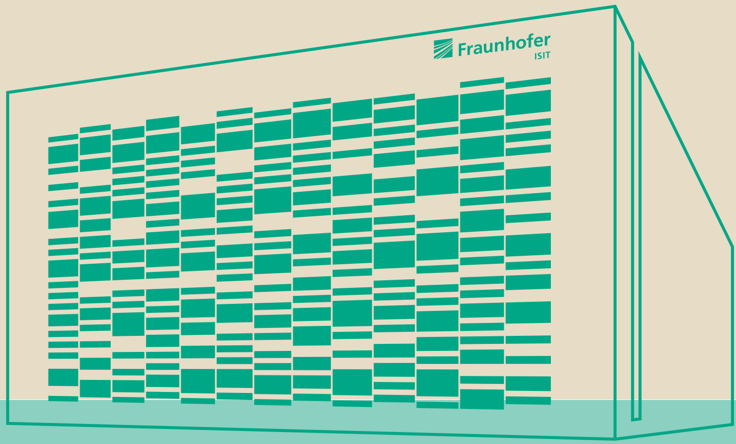
in a Silicon substrate. A thin diamond layer was deposited on the surface. The generator cell contains two of these coated electrodes in a back-to-back configuration on a separator membrane.

The sensor arrangement is illustrated in Figure 3, combining various structured metal layers on a single glass chip that is mounted in a flow channel of approx. 5 mm diameter.

Authors
Thomas Knieling, Norman Laske

Project name:	MIROOZON (WTSH, Land SH, EFRE)
Duration:	01.04.2017–31.03.2020
Partners:	Condias GmbH (Itzehoe), Fraunhofer ISIT (Itzehoe), GO Systemelektronik GmbH (Kiel)

TECHNOLOGY DEVELOPMENT



TECHNOLOGY DEVELOPMENT

Fraunhofer ISIT is running a 200 mm Silicon technology line ($2500\ m^2$) for front-end processes (MOS and PowerMOS). Specific processes for MEMS and NEMS as well as for packaging are implemented in a special and newly built cleanroom ($1000\ m^2$). This includes wet etching, dry etching, DRIE, deposition of non-IC-compatible materials, lithography with thick-resist layers, electroplating, microshaping, and wafer bonding. Further cleanroom laboratories are set up for chemical-mechanical polishing (CMP) and post-CMP processing.

Extra laboratories covering an area of $1500\ m^2$ 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.

Technology-Platforms

ISIT has a wide portfolio of qualified single process technologies available, which were combined to five specific technology process platforms. They form a kind of tool box to realize various applications. In addition, Fraunhofer ISIT has further technology offers, e.g. for the development of lithium batteries.

Poly Silicon MEMS Technology Platform (PSM-X2)

The technology platform PSM-X2 features a low stress 10–30 µm thick poly silicon layer for the realisation of mechanical active and passive MEMS structures. The use of high resolution lithography allows minimal structure dimension down to 0.5µm. An additional electrode layer beneath the active polysilicon layer is implemented. This gives the opportunity for out-of-plane signal detection or sensor stimulation. Additive functional layers enhance reliability and robustness of the MEMS devices (anti stiction, high-g shock). For the wafer scale bonding of the sensor device and the protective encapsulation a dedicated multi pressure wafer level packaging process is applied using e.g. a gold silicon eutectic process at about 400°C. The metallic bond frame induces a hermetic encapsulation of the cavity and the pressure applied during the bond process will persist. Integrated getter films allow cavity pressure levels down to 10–6 bar and a pressure ratio within adjacent cavities of up to 1:400. The application range of PSM-X2 platform includes e.g. inertial sensors, micro mirrors or electro-optic deflection devices.

Recently, Fraunhofer ISIT has developed an innovative process technology for the manufacturing of sophisticated MEMS scanners ($^2\varepsilon$ Process), called "Dual-Layer Epi Poly Silicon Process". Following the success of the well established surface micromachining technology PSM-X2 for inertial sensors, the $^2\varepsilon$ process is based on structuring two 30 microns thick epitactically grown polysilicon layers. This allows the realisation of staggered finger combdrives for mirror actuation and detection and the design of suspension

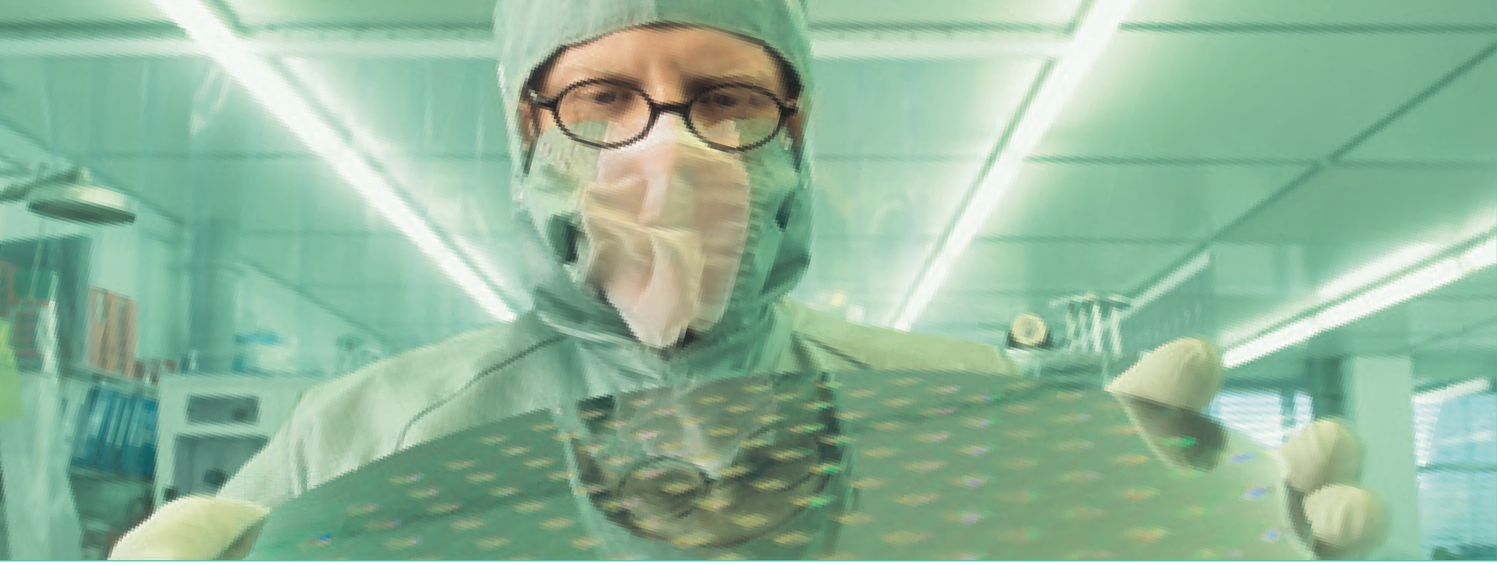
Sputter tool at ISIT cleanroom

Glass Micromachining

The Fraunhofer ISIT developed a process based on hot temperature viscous glass micromachining. It is mainly used for the production of micro-lenses and glass packages with inclined window surfaces. Using this process, it is possible to structure glass wafers with high aspect ratios on wafer level. A structured silicon wafer is chosen as so-called primitive form, so glasses must be used whose softening temperature is well below that of silicon. This has the advantage that the standardized methods to structured silicon wafers of a clean room can be used. The etched structures or cavities correspond later the molded areas in the glass. The structured silicon wafer is then anodically bonded to a glass wafer. In this case, a defined pressure within the cavities is enclosed. When a relative vacuum is enclosed the cavities and the heat treatment takes place under atmospheric pressure, the glass is pressed into the cavities. If an atmospheric pressure is enclosed and the heat treatment takes place under vacuum then the glass is forced out of the cavities. Depending on the application, the glass may now be further processed by grinding and polishing.

Pizeo MEMS Technology Platform

The Fraunhofer ISiT has been working for more than 10 years on the deposition of thin films of the piezoelectric materials aluminum nitride (AlN) and lead zirconium titanate (PZT). Currently, sputtering processes with film thicknesses of up to 4 µm for AlN and up to 3 µm for PZT are available. The integration into MEMS structures is typically realised via unimorphs consisting of a piezoelectric layer embedded between two metal electrodes on top of a passive support layer made from mono- or polycrystalline silicon. PZT is mainly used for actuator applications, as its high piezoelectric coefficients enable particularly large deflections and high forces with only low drive voltages. The PZT actuators are integrated for their utilization in MEMS scanners and loudspeakers. For sensory applications, AlN is preferred due to its considerably better signal-to-noise ratio. At ISIT it is currently used in ultrasonic transducers, MEMS microphones and vibrational energy harvesters. In addition to these established materials scandium-doped AlN (AlScN) is being developed in cooperation with the Christian-Albrecht University of Kiel. Despite the higher piezoelectric coefficients compared to pure AlN, this material retains the advantageous properties (high dielectric strength, IC-compatible, low dielectric losses) of the AlN and is therefore suitable for both sensor and actuator MEMS components. In the long term, it is intended to completely replace the lead-containing PZT. Among other things, a highly sensitive magnetoelectric sensor and MEMS scanners based on AlScN films of higher piezoelectric performance are currently being developed.



CMP polished wafer

Powder MEMS Technology Platform

At Fraunhofer ISIT a novel technology has been developed which allows the integration of nearly any material onto planar substrates. It is based on the agglomeration of micro-n-sized powder (particles) by atomic layer deposition (ALD). Like for the fabrication of ceramics, firstly a mold, in this particular case a silicon substrate with dry etched micromold pattern, is filled with loose powder. However instead of sintering the particles together with high pressure at 800°C to 1400°C, the silicon substrate is subjected to an ALD process at much lower temperatures. Thanks to the outstanding coating capability of ALD the loose particles in the micromolds are fixated to porous 3D structures over the whole mold depth (up to 700 µm) by a layer with a thickness of only 75 nm. These porous 3D structures are shrinkage-free and stable mechanically as well as thermally. Lateral dimensions between 50 µm and several mm can be realized with high precision. The nearly perfect envelopment of each particle by the ALD layer ensures an excellent protection against environmental influences. Substrates with embedded porous 3D structures can be post-processed in a cleanroom using standard processes of IC and MEMS fabrication at up to 400 °C. That opens up a unique range of applications. One of the evaluated ones is the fabrication of integrated permanent micromagnets from NdFeB powder. Strong magnetic fields on small scale are of interest for many MEMS sensors and actuators. The focus at ISIT is currently on magnetically driven vibrational energy harvesters and microscanners. Other promising applications of the novel technology are miniaturized organic-free phosphor converters for solid state lighting (SSL) or the thermal isolation of calorimetric MEMS, like mass flow and gas sensors, from the substrate by evacuated porous 3D structures, which is comparable to conventional super vacuum insulation.

GaN Technology

In addition to the research of new high voltage silicon devices the ISiT is developing high voltage devices with gallium nitride (GaN) substrates. This material is used to replace silicon because of higher electric strength, higher switching speed and higher possible working temperature. These benefits lead to a higher efficiency. While lateral HEMT devices can be purchased today, the research objectives of the ISiT are vertical transistors on 8” wafer. The substrates of these wafers are made of silicon, only the top layers where the power device is placed in are epitaxial grown GaN. To achieve the goal, the equipment and know-how of the newly built MEMS cleanroom will be used. Technology is and has been adapted to meet the requirements of the new material. Supplemental equipment to avoid silicon contamination of GaN material (Si is a dopant for GaN) is going to be ordered in the project “Forschungsfabrik Mikroelektronik Deutschland” (FMD). That includes tools for e.g. dry etching, wafer cleaning and annealing.

Wet cleaning bench

Further Technology Offers

Metal Surface Micromachining

Metal surface micromachining is an alternative way to build up complete MEMS systems or a part of them. By using mainly electroplating and lithography in combination with PVD, PECVD and etching processes it is possible to fit the requirements for a variety of applications. The low CMOS/ASIC compatible temperature budget makes this process suitable for the monolithical integration of a complete MEMS system. Additional a high flexibility in design and thickness is given. Additional fields of application are electrodes for electrostatic actuation/deflection, bondframes for waferlevel packaging, metal wiring, bondpads, bumps and high-Q inductors

Pouch Cell Technology

Based on the lithium ion battery technology, Fraunhofer ISIT provides a flexible manufacturing platform enabling technical realisation of accumulator development. The production of cells can be divided in two main steps:

- Manufacturing of electrodes and separators
- Assembling of cells

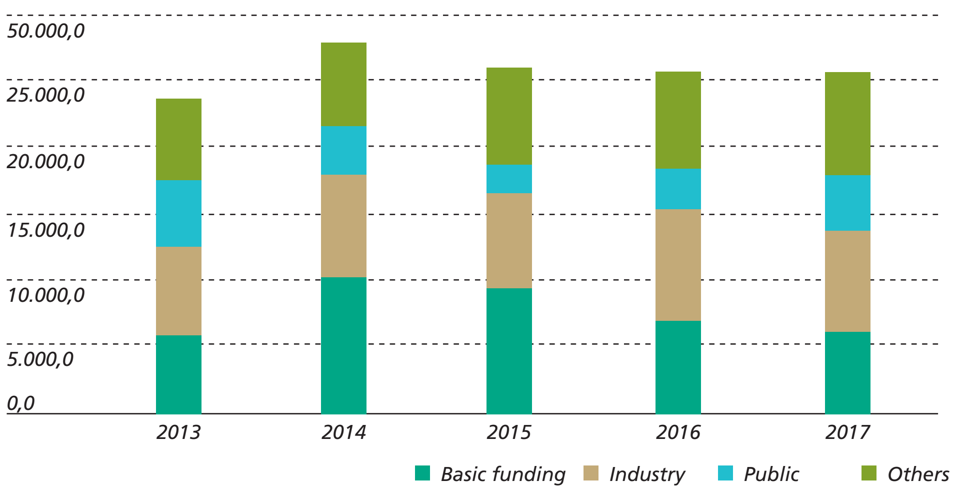
The electrodes can be produced with laboratory equipment up to pilot line level with a maximum speed of 2 m/min. In this context the proprietary separator concept developed by Fraunhofer ISIT is an integral part of the cell technology. It is exactly matched to the assembling process (lamination) for the production of cells. By variation of materials in the lithium accumulator its performance can be controlled within a wide range. In addition, the pouch casing enables an adaption of the cell design in a wide format range to predetermined dimensions. By continuous introduction of new materials a considerable „electrochemical system module" was generated over the years. It is adjusted continuously to increasing requirements.

REPRESENTATIVE FIGURES

BUDGET

Budget of Fraunhofer ISIT from 2013 up to 2017
The budget 2017 was financed by proceeds of projects of industry/industrial federations/small and medium sized companies amounting to 7.642,6 T€, of government/project sponsors/federal states amounting to 4.266,4 T€ and of others amounting to 7.672,0 T€. Furthermore there were Franhofer-projects and basic funding with 5.951,8 T€.

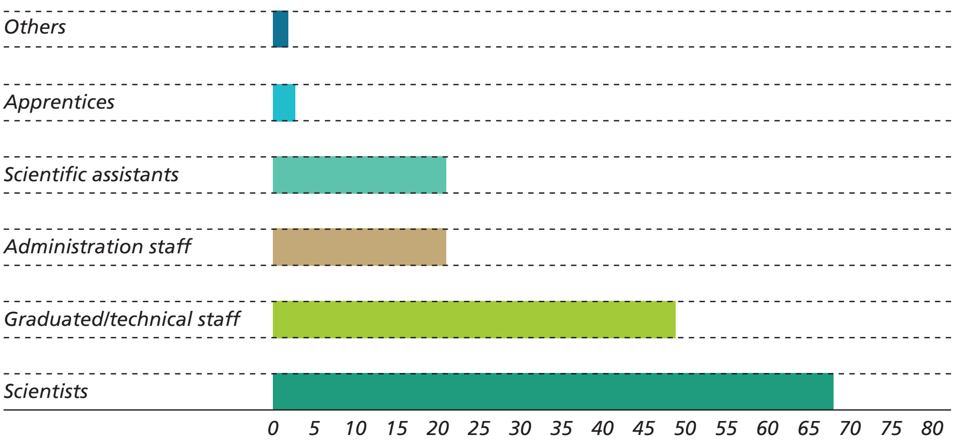
Budget [T€]



Staff Development

At the end of 2017 the staff consisted of 138 employees. 68 were employed as scientific personnel, 49 as graduated/ technical personnel and 21 worked within organisation and administration. The employees were assisted through 21 scientific assistants, 3 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 69 institutes and research units. The majority of the 24,500 staff are qualified scientists and engineers, who work with an annual research budget of 2.1 billion euros. Of this sum, 1.9 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 state 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.

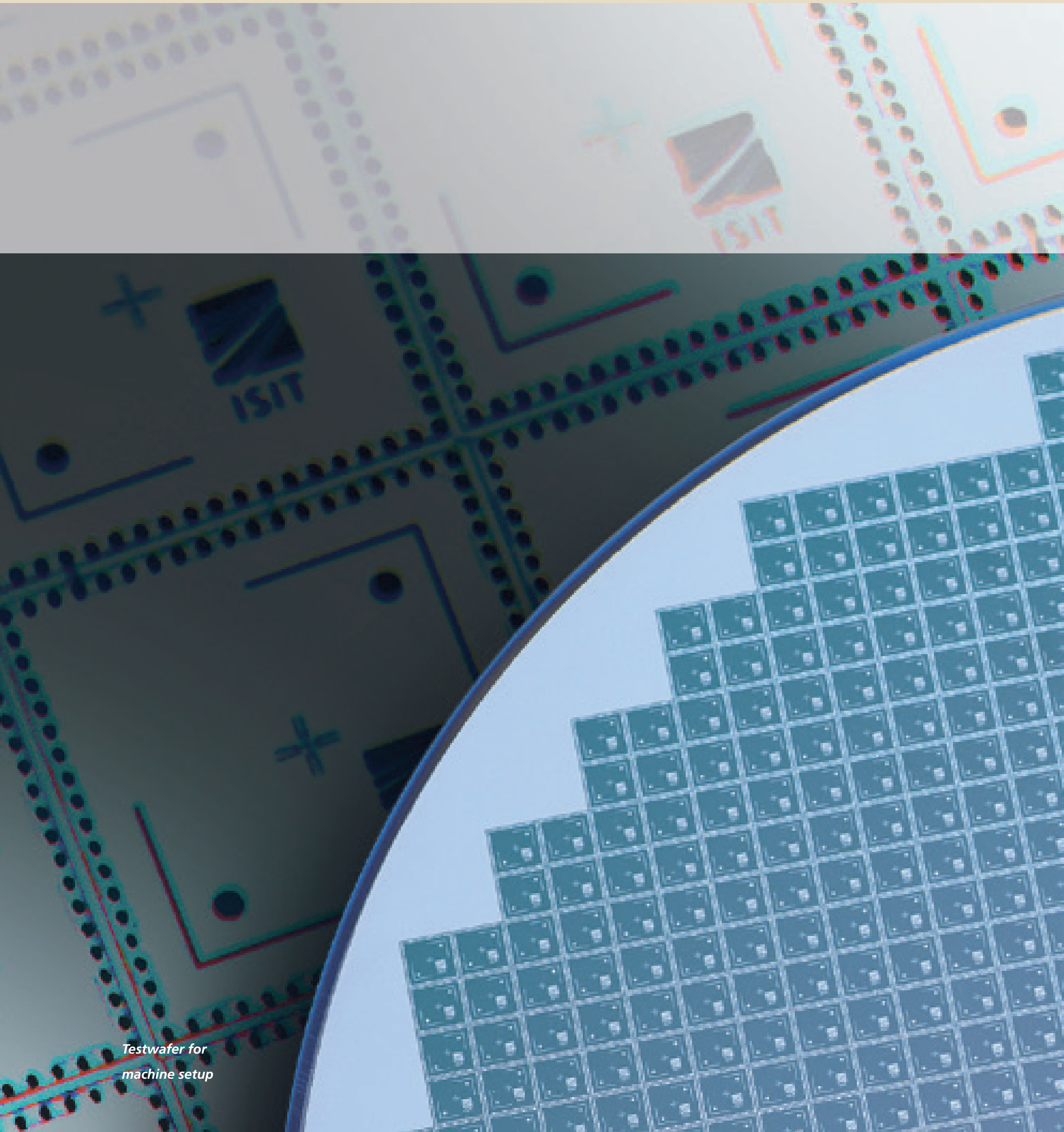
International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

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.

LOCATIONS OF THE RESEARCH FACILITIES



Testwafer for machine setup

IMPORTANT NAMES, DATA, EVENTS

CUSTOMERS

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

Advaplan Inc.,
Espoo, Finland

Airbus-Systeme,
Buxtehude

aixACCT Systems GmbH,
Aachen

Asteelflash Hersfeld GmbH,
Bad Hersfeld

Basler AG,
Ahrensburg

Besi APac Sdn. Bhd.,
Shah Alam, Malaysia

Besi Austria GmbH,
Radfeld, Austria

B. Braun Melsungen AG,
Melsungen

Brose Fahrzeugteile GmbH & Co. KG,
Hallstadt

CAMPTON Diagnostics UG,
Itzehoe

CAPRES A/S,
Kongens Lyngby, Denmark

CCI GmbH,
Itzehoe

Christian Koenen GmbH,
Ottobrunn-Riemerling

Condias GmbH,
Itzehoe

congatec AG,
Deggendorf

Conti Temic microelectronic GmbH, Nürnberg

Daimler AG,
Stuttgart

Danfoss Drives A/S,
Graasten, Denmark

Danfoss Silicon Power GmbH,
Flensburg

DELO Industrie Klebstoffe GmbH & Co. KGaA,
Windach/ München

Dräger Safety AG & Co. KG,
Lübeck

Endress + Hauser GmbH Co. KG,
Maulburg

Engineering Center for Power Electronics GmbH,
Nürnberg

Eppendorf Instrumente GmbH,
Hamburg

ERSA GmbH,
Wertheim

ESCD GmbH,
Brunsbüttel

Evonik Litarion GmbH,
Kamenz

FMP TECHNOLOGY GmbH,
Erlangen

Freudenberg Gruppe,
Weinheim

Garz & Fricke,
Hamburg

Hako GmbH,
Bad Oldesloe

Hanking Group,
China

Hannusch Industrieelektronik e.K.,
Laichingen

Harman Becker Automotive Systems GmbH,
Karlsbad

Hella KG, Lippstadt

HENSOLDT Sensors GmbH,
Ulm

Heraeus Materials Technology GmbH Co. KG, Hanau

Ifm electronic GmbH,
Kressbronn

Ifm ecomatic GmbH, Essen

IMS Nanofabrication AG,
Wien, Austria

JAQUET Technology Group AG, Basel, Switzerland

Jenoptik ESW GmbH, Wedel

Johnson Matthey Battery Materials GmbH,
Moosburg

Jonas & Redmann Group GmbH,
Berlin

Jungheinrich AG,
Norderstedt

Kendrion Kuhnke Automation GmbH,
Malente

Kristronics GmbH,
Harrislee-Flensburg

Kulicke & Soffa Germany GmbH,
Nürnberg

Laser Display Technology GmbH,
Jena

Liacon Batteries GmbH,
Itzehoe

Liebherr Elektronik GmbH,
Lindau

Melexis Ieper N.V.,
Belgium

Miele & Cie KG,
Lippstadt

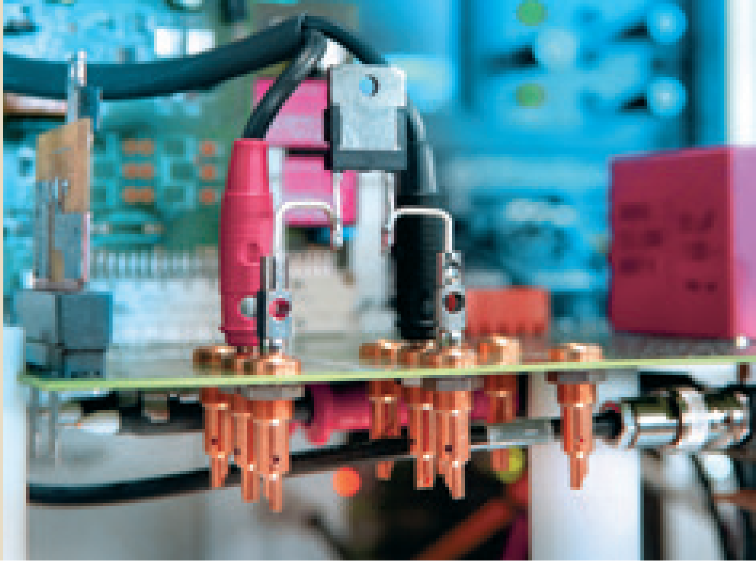
ml&s GmbH,
Greifswald

m-u-t GmbH,
Wedel

Nexperia Germany GmbH,
Hamburg

OSRAM GmbH,
München

PAC Tech, Packaging Technologies GmbH,
Nauen



Peter Wolters GmbH,
Rendsburg

Philips Medical Systems DMC GmbH,
Hamburg

Plath EFT GmbH,
Norderstedt

PRETTL Elektronik Lübeck GmbH, Lübeck

RAWE Electronic GmbH,
Weiler - Simmerberg

Reese + Thies Industrieelektronik GmbH,
Itzehoe

Renault SA,
Boulogne, Billancourt, France

Rheinmetall Landsysteme GmbH,
Kiel

Robert Bosch GmbH,
Bühl

Robert Bosch GmbH,
Renningen

Robert Bosch GmbH,
Reutlingen

Robert Bosch GmbH,
Salzgitter

SAFT SA,
Bagnolet, France

Sensitec GmbH,
Lahnau

SGL Carbon GmbH,
Meitingen

Sicoya GmbH,
Berlin

Siebtronic GmbH,
Salzburg, Austria

SMA Regelsysteme GmbH,
Niestetal

Solvionic Site SNPE,
Toulouse, France

Still GmbH,
Hamburg

Technolas Perfect Vision GmbH,
München

Technosert Electronic GmbH,
Wartberg ob der Aist

TESAT SPACECOM GmbH,
Backnang

Thyssen Krupp Marine Systems GmbH,
Kiel

Trainalytics GmbH,
Lippstadt

Trinamic Motion Control GmbH & Co. KG,
Hamburg

Umicore NV,
Olen, Belgium

USound GmbH,
Graz, Austria

Venneos GmbH,
Stuttgart

Vishay BCcomponents BEYSCHLAG GmbH,
Heide

Vishay Siliconix Itzehoe GmbH,
Itzehoe

Vishay Siliconix,
Santa Clara, USA

Volkswagen AG,
Wolfsburg

WABCO GmbH,
Hannover

WAGO Kontakttechnik GmbH & Co. KG,
Minden

Würth Elektronik GmbH,
Schopfheim

X-FAB MEMS Foundry Itzehoe GmbH,
Itzehoe

X-FAB Semiconductor Foundries AG,
Erfurt

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
Lehrstuhl Halbleiterbauelemente,
Technische Fakultät, Christian-Albrechts-Universität zu Kiel

O. Schwarzelbach
Mikrosystementwurf, 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)

L. Bertels
Member of Netzwerk „Qualitätsmanagement“ of the Fraunhofer-Gesellschaft

L. Bertels
Member of DGQ kooperative Firmenmitgliedschaft

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

P. Gulde
Member of Bundesverband Energiespeicher (BVES)

J. Hagge
Member of GfKORR Arbeitskreis „Korrosionsschutz in der Elektronik und Mikrosystemtechnik“

U. Hofmann
Member of Programm Committee „MOEMS and Miniaturized Systems Conference“, OPTO, Photonics West, San Francisco, 2017

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

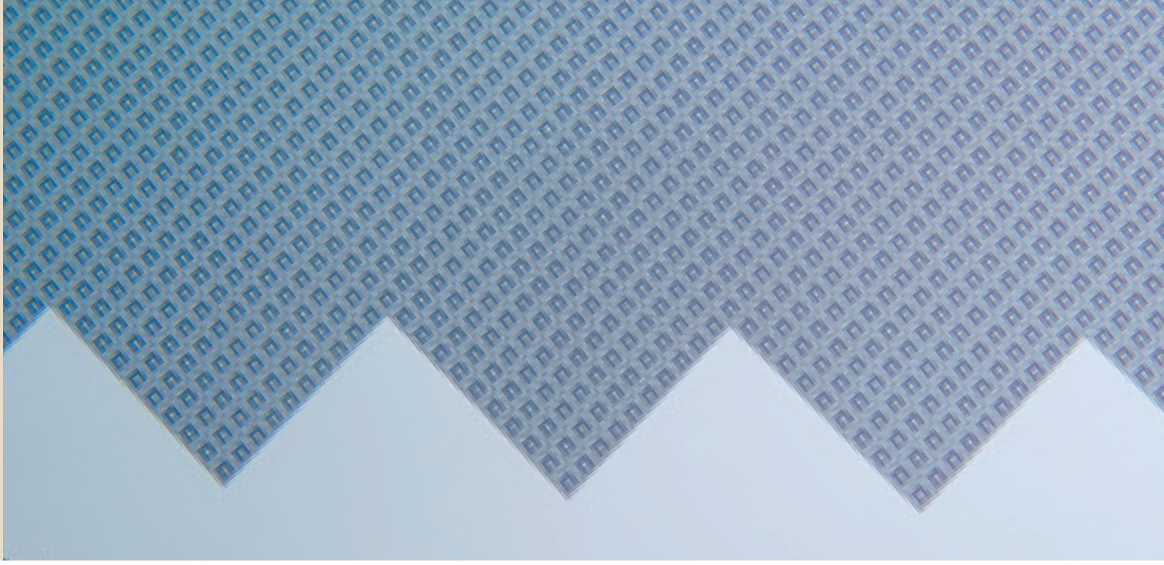
T. Knieling
Technologienetzwerk Körpernahe Systemtechnik (Body Tec)

M. Kontek
Member of AG 2.4 Drahtbonden

M. Kontek
Member of AG 2.7 Kleben in der Elektronik und Feinwerktechnik

J. Lähn
Member of Hamburger Lötzirkel

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



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

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

W. Reinert
Member of DVS-Fachausschuss FA10 “Mikroverbindungstechnik“

W. Reinert
Member of IMAPS Deutschland

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 GMM Workshop Packaging von Mikrosystemen

W. Reinert
Member of Wafer Bond Technologie Konferenz

K. Reiter
Member of DGM, Arbeitskreis Probenpräparation

K. Reiter
Member of Metallographie Nord

K. Reiter
Member of „Preparation-Board“ Praktische Metallographie

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

H. Schimanski
Member of 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
Member of FED Arbeitskreis „Baugruppe“

H. Schimanski
Member of FED Regionalgruppe Hamburg

H. Schimanski
Member of DVS Fachausschuss FA10 „Mikroverbindungstechnik“

H. Schimanski
Member of GfKORR Arbeitskreis „Korrosionsschutz in der Elektronik und Mikrosystemtechnik“

V. Stenchly
Senior Advisor GMM VDE/VDI- Gesellschaft für Mikroelektronik, Mikro- und Feinwerktechnik

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 Allianz Energie of the Fraunhofer-Gesellschaft

A. Würsig
Member of Bundesverband Energiespeicher (BVES)

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

A. Würsig
Member of Subsea of the Fraunhofer-Gesellschaft

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

Technische Universität
Dresden

Universität Duisburg-Essen

Universität Freiburg

Hochschule für Angewandte Wissenschaften,
Hamburg

Fachhochschule Westküste,
Heide

Fachhochschule Kaiserslautern

Christian-Albrechts-Universität, Technische Fakultät,
Kiel

Fachhochschule Kiel

Fachhochschule Lübeck

Technical University of Denmark,
Lyngby, Denmark

Westfälische Wilhelms-Universität,
Münster

Sydansk Universitet,
Sonderburg, Denmark

Fachhochschule Wedel

Distinctions

Alexander Barnbrock
Distinction of being best Apprentice as "Mikrotechnologe" at IHK Kiel for which he was awarded by the Fraunhofer-Gesellschaft, München, 2017

Laura Gersmeier
Distinction of being best Apprentice as "Mikrotechnologin" at IHK Kiel for which she was awarded by the Fraunhofer-Gesellschaft, München, 2017

Katja Reiter
Metallographie-Preis 2017
Deutsche Gesellschaft für Materialkunde (DGM)
Aalen, September 2017

Gerfried Zwicker
Lifetime Achievement Award for the Advancement of CMP awarded by the Executive Committee of the International Conference on Planarization/CMP Technology ICPT
Leuven, Belgium,
October 13, 2017

Trade Fairs and Exhibitions

SPIE 2017
Photonics West Exhibition,
January 28 –February 02, 2017,
San Francisco, USA

Energy Storage 2017
March 14 –16, 2017,
Düsseldorf

SMT/Hybrid/Packaging 2017
Hybrid Packaging System
Integration in Micro Electronics,
May 16 –18, 2017, Nürnberg

PCIM Europe 2017
International Exhibition &
Conference, Power Conversion
Intelligent Motion,
May 16–18, 2017, Nürnberg

Laser 2017
Micro-Actuators for
Optical Applications,
June 26 –29, 2017, Munich

Tranducers 2017
June 18 –22, 2017,
Kaohsiung, Taiwan

Nordjob Unterelbe Westküste 2017
Trade Fair for
Education and Study,
July 11–22, 2017, Brokdorf

The Battery Show 2017
September 12.–14, 2017,
Novi, Michigan, USA

Mikrosystemtechnik Kongress 2017
MEMS, Mikroelektronik,
Systeme,
September 23–26, 2017,
München

Battery+Storage 2017
October 09–11, 2017,
Stuttgart

microtec nord 2017
September 07, 2017, Hamburg

WindEnergy 2017
International Trade Fair for
Wind Industry,
September 12–15, 2017,
Husum

AzubIZ 2017
Regional Training Fair,
September 29, 2017, Itzehoe

Nacht des Wissens 2017
November 04, 2017, Hamburg

Compamed 2017
High Tech Solutions for
Medical Technology
International Trade Fair,
November 13 – 16, 2017,
Düsseldorf

Productronica 2017
Development and Manufacture
of Electronic
November 14–17, 2017,
München

Miscellaneous Events

External meeting of the Government Cabinet of Schleswig-Holstein at Fraunhofer ISIT
January 24, 2017,
Fraunhofer ISIT, Itzehoe

Pilotfertigung von Elektronik-Modulen am ISIT
Seminar: February 01, 2017,
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 20, 2017,
Fraunhofer ISIT, Itzehoe

Industrie 4.0
Erste Erfahrungen in der Region – Chancen an der Unterelbe
Business event organized by
IHK Kiel, branch office
Elmshorn and Fraunhofer ISIT
March 23, 2017, Fraunhofer
ISIT, Itzehoe

8. Wet Users Meeting
April 06, 2017, Dublin, Ireland

37. CMP Users Meeting
April 07, 2017, Dublin, Ireland

Materialwissenschaftliche Aspekte der Leistungselektronik
Event organized by NINA,
WTSH, PE: Region and
Fraunhofer ISIT
May 8, 2017, Fraunhofer ISIT,
Itzehoe

Innovationstag Mittelstand des BMWi
May 15, 2017, Berlin

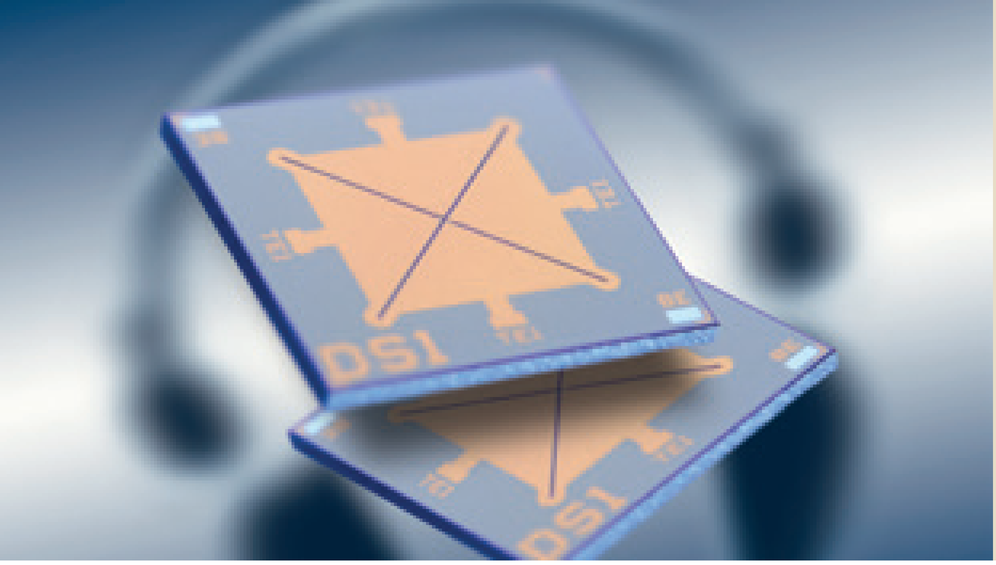
Transducers 2017
The 19th International
Conference on Solid-State
Sensors, Actuators and
Microsystems
June 18–22, 2017,
Kaohsiung, Taiwan

Opening event of Research Fab Microelectronics Germany in Schleswig-Holstein
Press Conference, Speakers:
Dr. Axel Müller-Groeling,
Prof. Holger Kapels, Fraunhofer
ISIT, Martin Schneider, Vishay,
Volker Herbig, X-FAB,
Mark Helfrich, MdB, CDU,
Dr. Karin Thissen MdB, SPD,
Dr. Sebastian Jester, BMBF
July 06, 2017, Fraunhofer ISIT,
Itzehoe

Eurosensors 2017
Conference:
September 3–6, 2017,
Paris, France

ICPT 2017
International Conference on
Planarization/CMP Technology
2017
Conference Chair:
Gerfried Zwicker
October 11–13, 2017,
Leuven, Belgium

On-Site Lithium-Ion Cell Production Technology Seminar
October 23–24, 2017, Itzehoe



Patents

W. Reinert, J. Quenzer, K. Gruber, S. Warnat
Method for Forming a Micro-Surface Structure and for Producing a Micro-Electro-mechanical Component
US 9,637,377 B2

W. Reinert
Selbstaktivierender Dünnschichtgetter in reaktiven Mehrschichtsystemen
DE 102012110542 B4

S. Gu-Stoppel, H.-J. Quenzer, U. Hofmann
Device Comprising a Spring and an Element Suspended Thereon, and Method for Manufaturing Same
CN ZL201410260339.5

S. Gu-Stoppel, H.-J. Quenzer, U. Hofmann
MEMS-Struktur und Verfahren zum Herstellen derselben
DE 102013209238 B4

T. Lisec, M. Knez
Verfahren zum Erzeugen einer dreidimensionalen Struktur sowie dreidimensionale Struktur
JP 6141197

S. Gu-Stoppel, H.-J. Quenzer, J. Janes
Device Comprising a Vibratably Suspended Optical Element
CN ZL2014102115762
US 9,733,470 B2

T. Thoennessen, G. Neuman
Method for Filling Electrochemical Cells
CN ZL2013800497588

O. Schwarzelbach, M. Weiss, V. Kempe
Sensor zur Erfassung von Beschleunigungen
EP 2076783 B1

U. Hofmann, H.-J. Quenzer, T. Lisec, T. v. Wantoch
Konverter zur Erzeugung eines Sekundärlichts aus einem Primärlicht, Leuchtmittel, die solche Konverter enthalten, sowie Verfahren zur Herstellung der Konverter und Leuchtmittel
DE 102016106841 B3

L. Blohm, E. Nebling, J. Albers, G. Piechotta
Integriertes Einweg-Chip-kartuschensystem für mobile Multiparameteranalysen chemischer und/oder biologischer Substanzen
CN ZL201380018149.6

U. Hofmann, F. Senger, T. v. Wantoch, C. Mallas, J. Janes, M. Weiss
Method for Activating a Deflection Device for a Projection Device, a Deflection Device for a Projection Device and a Projection Device
US 9,832,434 B2

E. Nebling, J. Albers
Verfahren zum Detektieren von chemischen oder biologischen Species sowie Vorrichtung zum Durchführen des Verfahrens
EP 2286227 B1

U. Hofmann, H.-J. Quenzer, J. Janes, B. Jensen
Micromirror System and Method of Manufacturing a Micromirror System
CN ZL201380015580.5

U. Hofmann, M. Weiss
Deflection device for a scanner with Lissajous scanning
JP 6012276

U. Hofmann, G. Fakas, J. Janes, P. Blicharski, B. Wagner
Verfahren und Projektor zur Bildprojektion
DE 102004060576 B4

N. Marenco
Verfahren zur Herstellung einer Vielzahl von mikroopto-elektronischen Bauelementen und mikrooptoelektronisches Bauelement
EP 2406825 B1

F. Stoppel, B. Wagner
Micro-Electromechanical System and Related System, Utilization, Micro-Electro-mechanical System Loudspeaker and Regulating Unit
TW 1595738

C. Wijayawardhana, G. Neumann, P. Gulde
Electrochemical Cell Based on Lithium Technology with Internal Reference Electrode, Process for its Production and Methods for Simultaneous Monitoring of the Voltage or Impedance of the Anode and the Cathode Thereof
KR 10-1804512

Doctoral Theses

V. Stenchly
Herstellung und Untersuchung neuer Optopackages auf Waferebene
Christian-Albrecht-Universität zu Kiel,
November 2017

Diploma, Master's and Bachelor's Theses

Swarna Balasubramanian
Development of an Automated Control System Based on Integrated Biochip Cartridges for Point of Care Diagnostics
Master's thesis, HAW Hamburg,
January 2017

Migen Bebeti
Entwicklung, numerische Simulation und Konstruktion einer Mikrofluidikpumpe für ein Speichelsensorsystem
Bachelor's thesis, FH Kiel,
February 2017

Alexander Boldt
Elektrische Charakterisierung von Kompensations-Power-MOSFETs und Bestimmung dynamischer Kenngrößen
Bachelor's thesis, FH Kiel,
July 2017

Mirco Drews
Analyse, Entwicklung und Nachweis von Anforderungen zum Einsatz von Speichertechnologien im Bereich der Systemdienstleistungen
Bachelor's thesis,
August 2017

Matthias Eggert
Development of a Platform-Independent Control Software for a Medical Point-of-Care-System
Master's thesis, HAW Hamburg,
May 2017

Kay Haake
Entwicklung eines automatisierten Biosensorsystems für die sequentielle Vor-Ort-Analyse mehrerer Meerwasserproben
Master's thesis, FH Westküste,
January 2017

Victor Rasmus Johannsen Tolstrup
Micro-Scale Magnetically Actuated Piezoelectric Energy Harvesters
Bachelor's thesis,
SDU Sonderborg,
January 2017

Yash Kalapi
Development and Assessment of Miniaturized Saliva Lactate Monitoring System with Integrated Wireless Electronics
Master's thesis, HAW Hamburg,
November 2017

Alexander Koch
Erstellung einer grafischen Oberfläche zur Parameterbestimmung für die Simulation eines Kalman-Filters
Bachelor's thesis, FH Kiel,
February 2017

Savani Kulkarni
Development of Electrochemical Biosensors for Lactate Measurement in Saliva
Master's thesis, HAW Hamburg,
March 2017

Pauline Malaurie
New Way to Produce Macro Glass Lenses by Hot-Viscous Glass Micromachining,
LMIS1 Laboratory of MEMS devices and systems
Master's thesis,
École polytechnique fédérale de Lausanne,
March 2017

Lena Miebrodt
Bestimmung des Ladezustandes von Lithium-Ionen-Zellen auf Basis eines Kalman-Filters mit erweitertem Batteriemodell unter Einbeziehung von Belastungseinflüssen
Master's thesis,
Fachhochschule Westküste,
February 2017

Teresa Obregon
Herstellung und Charakterisierung eines Glasgehäuses auf Waferebene für die hermetische Verkappung eines Mikrospiegels
Bachelor's Thesis,
FH Westküste,
June 2017

Andrej Oster
Analyse von Schaltvorgängen eines IGBT-Halbbrückemoduls und Automatisierung eines Doppelpulsmessplatzes
Bachelor's thesis,
September 2017

Karnjit Singh
Entwurf und Implementierung von Regelungskonzepten für einen hocheffizienten DC/AC-Wechselrichter
Master's thesis,
July 2017

Finn-Hendrik Zöllkau
Entwicklung eines Batterie-Managment-Systems mit aktivem Balance-Verfahren
Bachelor's thesis, FH Kiel,
April 2017

Journal Papers, Publications and Contributions to Conferences

L. Blohm, J. Albers, G. Piechotta, E. Nebling
Silicon Based Electrical Biosensor Technology for Mobile Diagnostics.
AMA Conferences 2017 – SENSOR 2017 and IRS2 2017, *May 30 – June 01, 2017, Nürnberg*

S. Chemnitz, T. Reimer, T. Lisec
Herstellung neuartiger Mikrostrukturen für MEMS-Anwendungen durch Pulververfestigung mittels ALD.
MikroSystemTechnik Kongress, *October 23-25, 2017, München*

S. Fichtner, N. Wolff, G. Krishnamurthy, A. Petraru, S. Bohse, F. Lofink, S. Chemnitz, H. Kohlstedt, L. Kienle, B. Wagner
Identifying and Overcoming the Interface Originating C-Axis Instability in Highly Scenhanced AlN for Piezoelectric Micro-Electromechanical Systems.
Journal of Applied Physics 122, 035301, 2017

R. de Oliveira Hansen, M. Matefi-Tempfli, R. Safonovs, J. Adam, S. Chemnitz, T. Reimer, B. Wagner, W. Benecke, S. Matefi-Tempfli
Magnetic Films for Electromagnetic Actuation in MEMS Switches.
Microsystem Technologies, DOI 10.1007/s00542-017-3595-2, *October 24, 2017*

T. Knieling, B. Greenwalt, J. Kjelstrup-Hansen
Integration of Organic LED and Optical Sensing to Create a Wearable Health Monitoring Device.
LOPEC Conference, *March 28-30, 2017, München*

T. Lisec, S. Chemnitz, F. Lofink, T. Reimer, A. Kulkarni, G. Piechotta, B. Wagner
A Novel Technology for MEMS Based on the Agglomeration of Powder by Atomic Layer Deposition.
19th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers, *June 18-22, 2017, Taiwan*

T. Lisec, T. Reimer, M. Knez, S. Chemnitz, A. V. Schulz-Walsemann, A. Kulkarni
A Novel Fabrication Technique for MEMS Based on Agglomeration of Powder by ALD
Journal of Microelectromechanical Systems. Vol. 26, *October 10, 2017*, 1093–1098

T. Lisec, F. Stoppel, D. Kaden, F. Heinrich, A. Neumann, B. Wagner
MEMS Switch with Prolonged Lifetime under Hot Switching Conditions Based on Gold as Contact Material.
19th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers, *June 18-22, 2017, Taiwan*

F. Lofink, V. Tolstrup, T. Lisec, S. Bohse, T. Reimer, A. Piorra, D. Meyners, E. Quandt, B. Wagner
Magnetically Driven Energy-Harvester with Monolithically Integrated High-Energy-Density Magnets.
Proceedings: Solid-State Sensors, Actuators and Microsystems
19th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers, *June 18-22, 2017, Taiwan*

F. Lofink, A. Philippi-Kobs, M. R. Rahbar Azad, S. Hankemeier, G. Hoffmann, R. Frömter, H. P. Oepen
Domain Walls in Bent Nanowires.
Phys. Rev. Applied 8, 024008, *2017*

A. Männchen, D. Beer, F. Niekiel, J. Nowak, F. Stoppel, B. Wagner
Analysis of the Mechanical Vibration and Acoustic Behavior of a Piezoelectric MEMS Microspeaker.
Audio Engineering Society, Convention Paper, Presented at the 143rd Convention *October 18–21, 2017, New York*

J. Paul, Mainz, H. Knoll, C. Sailer, C. Glenske, S. Felix-Henningsen, M. Lang, K. Zoschke, H. Oppermann, M. Theis, C. Vetter, M. Saumer, F. Lofink, J. Eichholz, D. Meyners
High Resolution Magnetic Position Sensors for Precise Control of Production Tools
MikroSystemTechnik Kongress, *October 23-25, 2017, München*

V. Postica, T. Reimer, E. Lazari, N. Ababii, S. Shishiyanu, S. Railean, V. Kaidas, S. Kaps, O. Lupan, W. Benecke, R. Adelung
Sensing Properties of Ultra-Thin TiO_2 Nanostructured Films Based Sensors.
3rd International Conference on Nanotechnologies and Biomedical Engineering 2016, FMBE Proceedings, Vol. 55, pp. 149-152 Springer, *2016, Singapore*

R. K. Raja Mahendra Varman, T. Knieling, T. Grunemann, G. Domann
MoniShirt – Large Area Printed Piezoelectric Sensors For Body Motion Tracking.
Smart Systems Integration Conference, *March 7-9, 2017*

S. Gu-Stoppel, T. Giese, H.-J. Quenzer, U. Hofmann, W. Benecke
Piezoelectrically Driven and Sensed Micromirrors with Extremely Large Scan Angles and Precise Closed-Loop Control.
Proc. Eurosensors 2017, Vol. 1, No. 4, S. 561, *August 2017*

S. Gu-Stoppel, T. Giese, H.-J. Quenzer, U. Hofmann, W. Benecke
Piezoelectrically Driven and Sensed Micromirrors with Large Scan Angles and Precise Closed-Loop Control.
MikroSystemTechnik Kongress, *October 23-25, 2017, München*

S. Gu-Stoppel, T. Giese, H.-J. Quenzer, U. Hofmann, W. Benecke
PZT-Actuated and -Sensed Resonant Micromirrors with Large Scan Angles Applying Mechanical Leverage Amplification for Biaxial Scanning.
Micromachines, Vol. 8, No. 7, p. 215, *Jul. 2017*

V. Stenchly, W. Reinert, H.-J. Quenzer
Innovative Hermetic Packaging Concept for Laser Diodes on Wafer Level. MikroSystem-Technik Kongress,
October 23-25, 2017, München

V. Stenchly, W. Reinert, H.-J. Quenzer
Modular Packaging Concept for MEMS and MOEMS, Micromechanics and Microsystems. Europe workshop,
August 23-25, 2017, Uppsala, Sweden

F. Stoppel, C. Eisermann, S. Gu-Stoppel, D. Kaden, T. Giese, B. Wagner
Novel Membrane-Less Two-Way Mems Loudspeaker Based on Piezoelectric Dual-Concentric Actuators.
19th International Conference on Solid-State Sensors, Actuators and Microsystems, Transducers,
June 18-22, 2017, Taiwan

F. Stoppel, F. Niekiel, T. Giese, S. Gu-Stoppel, A. Männchen, J. Nowak, D. Beer, B. Wagner
Novel Type of MEMS Loudspeaker Featuring Membrane-Less Two-Way Sound Generation.
Audio Engineering Society, Convention Paper, Presented at the 143rd Convention
October 18–21, 2017, New York

F. Stoppel, F. Niekiel, T. Giese, S. Gu-Stoppel, C. Eisermann, B. Wagner
Novel Piezoelectric Two-Way MEMS Loudspeaker.
MikroSystemTechnik Kongress,
October 23-25, 2017, München

F. Stoppel, A. Männchen, F. Niekiel, D. Beer, T. Giese, B. Wagner
New Integrated Full-Range MEMS Speaker for In-Ear Applications.
Proc. MEMS 2018 -The 31st IEEE International Conference on Micro Electro Mechanical Systems,
January 21-25, Belfast, Northern Ireland, UK

Y. Wang, C. Costa, E. Sobolewska, J. Fiutowski, R. Brehm, J. Albers, E. Nebling, F. Lofink, B. Wagner, W. Benecke, H.-G. Rubahn, R. de Oliveira Hansen
Micro-Cantilevers for Optical Sensing of Biogenic Amines.
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A. Würsig
High Pressure Energy Storage Systems for Maritime Applications.
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E. Yarar, A. Piorra, S. Fichtner, V. Tolstrup, T. Lisec, T. Reimer, F. Lofink, D. Meyners, B. Wagner, E. Quandt
Piezoelektrika für Energy-Harvester – Ein Vergleich.
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Talks and Poster Presentations

L. Blohm
Mobile Diagnostic System for the Point-of-Care-Detection of Infectious Diseases by Integrated Electrical Biochip Cartridges. SelectBioscience Konferenz Point-of-Care, *May 10–11, 2017, München*

L. Blohm
Silicon Based Electrical Biosensor Technology for Mobile Diagnostics. AMA Conference, *May 30 –June 01, 2017, Nürnberg*

L. Blohm
Entwicklung mobiler Analysesysteme für die Point-of-Care-Diagnostik.MedConf Nord, *June 12–14, 2017, Hamburg*

S. Chemnitz, T. Reimer, T. Lisec
Herstellung neuartiger Mikrostrukturen für MEMS-Anwendungen durch Pulververfestigung mittels ALD.7. MikroSystemTechnik Kongress "MEMS, Mikroelektronik, Systeme" *October 23–25, 2017*

T. Giese
MEMS basiertes LIDAR System für die Gesten- und Objekterkennung.MicroTec Nord Mensch – Elektronik – Maschine, *September 07, 2017, Hamburg*

S. Gu-Stoppel, T. Giese, H.-J. Quenzer, U. Hofmann, W. Benecke
Piezoelectrically Driven and Sensed Micromirrors with Extremely Large Scan Angles and Precise Closed-Loop Control. 7. MikroSystemTechnik Kongress "MEMS, Mikroelektronik, Systeme" *October 23–25, 2017, München*

S. Gu-Stoppel, T. Giese, H.-J. Quenzer, U. Hofmann, W. Benecke
Piezoelectrically Driven and Sensed Micromirrors with Extremely Large Scan Angles and Precise Closed-Loop Control. Eurosensors 2017, *September 3–6, 2017, Paris, France*

S. R. Jeyakumar, T. Knieling
Printed Stretchable Sensors for Garments and Automotive Applications. LOPEC 2017, *Munich, Germany*

M. Kalkhorst
Vergleich von 2D- und 3D-Röntgen und dessen Mehrwert. DGQ-Regionalkreis „3D-Druck - Revolution in der industriellen Fertigung". *July 06, 2017, Itzehoe*

H. Kapels
Neue Materialien der Leistungshalbleiterentwicklung: GaN – SiC vs. Si. Materialwissenschaftliche Aspekte der Leistungselektronik *May 05, 2017, Itzehoe*

T. Knieling, C. Beale, L. Blohm, M. Fahland, E. Nebling
Printed and Flexible Electrochemical Lactate Sensors for Wearable Applications. I3S, 5th International Symposium on Sensor Science *September 28, 2017, Barcelona, Spain*

T. Knieling, L. Blohm, E. Nebling
Sensors for People – What to know about Body and Environment. COMPAMED HIGH-TECH FORUM, *November 15, 2017, Düsseldorf*

T. Knieling, B. Greenwalt, J. Kjelstrup-Hansen
Integration of Organic LED and Optical Sensing to Create a Wearable Health Monitoring Device. LOPEC 2017, *Munich*

N. Laske
Digitale Wirtschaft – Leistungsangebote bei Fraunhofer. *March 23, 2017, Itzehoe*

T. Lisec
Integrierte 3D-Spulen mit Pulvermaterialkernen für miniaturisierte DC-DC-Wandler. Materialwissenschaftliche Aspekte der Leistungselektronik *May 05, 2017, Itzehoe*

T. Lisec, F. Stoppel, D. Kaden, F. Heinrich, A. Neumann, B. Wagner
MEMS Switch with Prolonged Lifetime under Hot Switching Conditions Based on Gold as Contact Material. Transducers 2017 – The 19th International Conference on Solid-State Sensors, Actuators and Microsystems, *June 18-22, 2017, Kaohsiung, Taiwan*

F. Lofink, V. Tolstrup, T. Lisec, S. Bohse, T. Reimer, B. Wagner, A. Piorra, D. Meyners, E. Quandt
Magnetisch angetriebener Energy-Harvester mit monolithisch integrierten Mikromagnet. 7. MikroSystemTechnik Kongress „MEMS, Mikroelektronik, Systeme" *October 23–25, 2017*

F. Niekiel, F. Stoppel, A. Männchen, J. Nowak, D. Beer, T. Giese, B. Wagner
MEMS Microspeaker Made from Piezoelectric Bending Actuators. PiezoMEMS Workshop *January 15–16, 2018, Orlando, Florida*

J. Ophey
Basics of Battery Technology and Materials / Methods for Lithium Ion Battery Cell Production Current Research Status & Prospects for the Future. German-Danish Seminar, *Itzehoe*

K. Reiter
Schadensanalyse von Brandschäden in der Metallographie. DGQ-Regionalkreis „3D-Druck - Revolution in der industriellen Fertigung". *July 06, 2017, Itzehoe*

H. Schimanski
Influence on Electrochemical Migration Due to Combination of Soldering Processes Climatic Reliability of Electronics. *January 19–20, 2017, Lyngby*

H. Schimanski
Sichere Prozessierung von mikro- und niedrig-silber legierten Loten. BFE Fachkreistreffen, *February 08–09, 2017, Weitenburg*

H. Schimanski
Elektrochemische Migration (ECM) auf elektronischen Baugruppen durch kombinierte Lötprozesse. Arbeitskreis „Systemzuverlässigkeit von AVT", *February 15, 2017, Berlin*

H. Schimanski
Fertigungsoptimiertes Leiterplattendesign – neue Herausforderungen durch miniaturisierte Bauelemente. Eltroplan Technologietag, April 06 – 07, Endingen

H. Schimanski
Rework elektronischer Baugruppen – qualifiziert, prozesssicher, dokumentiert, Technologie, wir gehen in die Tiefe. Seminar für aktuelle Trends in der Aufbau- und Verbindungstechnologie
June 21–22, 2017, Dresden

H. Schimanski
Einfluss der Nutzentrennung auf die Baugruppenqualität. 25. FED-Konferenz,
September 21–22, 2017, Berlin

H. Schimanski
Inhouse – Workshop Temperaturmesstechnik und Reflowprofiloptimierung.
June 07, 2017, Itzehoe

H. Schimanski
Inhouse – Workshop Temperaturmesstechnik und Reflowprofiloptimierung.
June 07, 2017, Itzehoe

H. Schimanski
Inhouse – Workshop Wellen- und Selektivlöten.
June 08, 2017, Itzehoe

H. Schimanski
Löten von elektronischen Baugruppen, Technologieworkshop für LP-Anschlusstechnik. Wago Kontakttechnik,
September 14, 2017, Minden

H. Schimanski
Fertigungsgerechtes Leiterplattendesign für die SMD-Verarbeitung aus Sicht der Elektronik Fertigung – Seminar Fehlermanagement in der Elektronikfertigung.
September 27–28, 2017, Rehm, Blaubeuren

H. Schimanski
Leiterplattendesign – Design for Reliability – Auswirkungen auf die Zuverlässigkeit, Seminar Fehlermanagement in der Elektronikfertigung.
September 27–28, 2017, Rehm, Blaubeuren

H. Schimanski
Leiterplattentechnologie – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

H. Schimanski
Lotpastenapplikation – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

H. Schimanski
Bauelementetrends – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

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Lötqualität und Reflowlötverfahren – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

H. Schimanski
Wellen- und Selektivlöten – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

H. Schimanski
Einfluss der Nutzentrennung auf die Baugruppenqualität – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

H. Schimanski
Baugruppen- und Fehlerbewertung – Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

H. Schimanski
Zuverlässigkeit von Lötstellen keramischer SMD-Komponenten in Abhängigkeit von Padlayout und Lotvolumen, Seminar Fertigung elektronischer Baugruppen.
November 30, 2017, Itzehoe

V. Stenchly, W. Reinert, H.-J. Quenzer
Innovatives hermetisches Packaging-Konzept für Laserdioden auf Waferebene. 7. MikroSystemTechnik Kongress „MEMS, Mikroelektronik, Systeme“,
October 23–25, 2017

F. Stoppel, F. Niekiel, T. Giese, S. Gu-Stoppel, C. Eisermann, B. Wagner
Neuartiger piezoelektrischer Zwei-Wege-MEMS-Lautsprecher. 7. MikroSystemTechnik Kongress "MEMS, Mikroelektronik, Systeme",
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F. Stoppel, F. Niekiel, T. Giese, S. Gu-Stoppel, A. Männchen, J. Nowak, D. Beer, B. Wagner
Novel Type of MEMS Loudspeaker Featuring Membrane-Less Two-Way Sound Generation. 143rd Audio Engineering Society Convention,
October 18–21, 2017, New York City, USA

F. Stoppel, C. Eisermann, S. Gu-Stoppel, D. Kaden, T. Giese, B. Wagner
Novel Membrane-Less Two-Way Mems Loudspeaker Based on Piezoelectric Dual-Concentric Actuators. Transducers 2017 – The 19th International Conference on Solid-State Sensors, Actuators and Microsystems
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New Integrated Full-Range MEMS Speaker for In-Ear Applications. MEMS 2018 -The 31st IEEE International Conference on Micro Electro Mechanical Systems
January 21-25, Belfast, Northern Ireland, UK

R. Varman, T. Knieling, T. Grunemann, G. Domann
MoniShirt – Large Area Printed Piezoelectric Sensors for Body Motion Tracking.
SSI Cork

B. Wagner
High-Performance Piezoelectric and Magnetic Materials for MEMS and Energy Harvesters.
International Workshop for Piezoelectric Materials and Applications & Annual Energy Harvesting Workshop
September 12, 2017, Falls Church, Virginia, USA

E. Yarar, A. Piorra, S. Fichtner, V. Tolstrup, T. Lisec, T. Reimer, F. Lofink , D. Meyners, B. Wagner, E. Quandt
Piezoelektrika für Energy-Harvester. Ein Vergleich.
7. MikroSystemTechnik Kongress "MEMS, Mikroelektronik, Systeme",
October 23– 25, 2017

G. Zwicker
Application of CMP to More-than-Moore Devices.
Keynote at CMP Forum
September 12, 2017, Taipeh, Taiwan

GENERAL VIEW ON PROJECTS

Power Electronics

- Cell for High Temperature/ Shock, AIF-CHiTS
- Entwicklung und Herstellung von wiederaufladbaren Magnesium-Schwefel-Batterien, MagS
- EU-Antrag Otimized energy management and use, OPTEMUS
- Forschung zur Einführung neuer Materialien, Materialeinführung
- High energy lithium sulphur cells and batteries, HELIS
- Hochstromfähiges Lithium-Batteriemodul, Entwicklung einer Hochleistungs-Lithiumbatterie, AIF-Hochleistungsbatterie
- Research Report on Advanced Battery for Wearable Device, Battery Study
- Schnellladefähige Lithium-Energiespeicher mit verbesserter Energiedichte für den Einsatz in modularen Unterstützungs- und Antriebskonzepten, HiPoLit
- Umweltfreundliche Hoch-Energie-NCM 622-Kathoden mit optimierter Speicherkapazität, HiLo
- Development and production of trench based field stop IGBT´S, IGBT´s
- Diodencharge, Diodencharge
- Herstellung von Kupfermetallisierungen auf Leistungsbauelementen mittels kaltaktiven Atmosphärenplasmas, AIF-Herkules
- Integrierte Umrichter für modularverteilte Elektroantriebe hoher Drehzahl; Teilvorhaben: Simulation, Technologische Sonderprozesse und Zuverlässigkeitsuntersuchungen für integrierte Umrichter, InMOVE
- Netzwerk Leistungselektronik Schleswig-Holstein, Netzwerk LE · SH
- PowerMOS-Bauelemente II – Weiterentwicklung
- Prozessierung von Si-Substraten, TESAT-Diodencharge
- SEM- und FIB-Analysen sowie elektrische Messungen an PEV-Wafern, SEM/FIB-Analysen
- Vertikale GaN MOSFETs für effiziente Leistungselektronik im Niederspannungsbereich (VERTIGO)
- Wafer mit MEMS-Elektroden für Mikro-Ozon-Generatoren, Condias-Wafer
- Zukünftige, effiziente Energiewandlung mit GaN-basierter Leistungselektronik der nächsten Generation, ZuGaNG
- Fraunhofer Anwendungszentrum Leistungelektronik für regenerative Energiesysteme, ALR, Standort Hamburg, ALR
- Norddeutsche Energiewende 4.0, NEW 4.0
- Schaufenster intelligente Energie, TV 3.7/4.1/8.1

Micro Manufacturing Processes

- Investigation of new discrete components, R&D Service new discretes
- Qualifikation von zwei Starr-Flex-Leiterplattenaufbauten, Starr-Flex-LP
- Chipkartenbestückung von Grautonblenden, Technolas AVT ab 2016
- Study on acceleration sensors for TPMS applications SWINDON
- Technologische Prozessanbahnungen der Pads im UBM Kapitel für die Realisierung eines geeigneten Interfaces für die ATE-Tests elektrischer Zwischenmessungen an laufenden TROM2 Waferlosen, TROM2B/ TROM2PILOT
- TROM2Y – Transfer of fabrication process for switchable e-beam mask, TROM2Y
- AuIn WLP, Project Plato, Plato
- Entwicklung einer Plattform für funktionelle Glasgehäuse für die Integration mikrooptischer und -mechanischer Systeme auf Waferebene, PRISMA
- Glass Silicon Cap Wafer, Lantern

- MIRS – Miniaturisierte IR-basierte Sensorsysteme – Teilvorhaben: Optische Waferlevel-Integration von FIR-Sensoren und innovativen pyroelektrischen Sensormaterialien, MIRS-PENTA – MEMS
- Multifunktionale Sensorintegration auf anwenderspezifischen ICs, MUSIC

MEMS Applications

- Development of piezoelectric microspeakers Gen2, Gen2
- Generative Herstellung effizienter Piezo-MEMS für die MikroaktorikTVB Auslegung und Herstellung gedruckter Mehrlagen-Piezzoaktuatoren, Generator
- Process module development and sample fabrication of piezoelectric MEMS microphones on CMOS, MEMS microphones WP1
- Elektrische Array-Chips 8 Zoll, Elektrische Array-Chips
- Entwicklung eines kombinierten Sensors zur Messung und telemetrischer Übermittlung zweier orthogonaler Kräfte und zweier orthogonaler Beschleunigungen, AIF-MECHASENS
- Entwicklung und Herstellung eines sensorgesteuerten Ozongenerators, MIKROOZON
- FH Kooperation (HMI) Mikrosysteme für neue Mensch-Maschine-Schnittstellen, FH Kooperation
- FlexFunds Biomarkers, Rapid-Mal
- Mobiles In-Situ Belastungs-Monitoring von mechanischen Bauteilen aus Faserverbundwerkstoffen, MobiMo
- Pilot Line for Micro-Transfer-Printing of functional components on wafer lavel, MICROPRINCE
- Service processing annealing wafers, Energy Harvester Processing
- SFB 1261-A3, Resonant magnetoelectric sensors, SFB 1261-A3
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- Towards Zero Power Electronics, ZePowEl
- Verbundvorhaben (AQUILA); Teilprojekt ISIT: Multi-Energy-Harvester für den autarken Betrieb einer hochauflösenden und hochkompakten MR Positionssensorik, AQUILA
- Entwicklung eines hochintegrierten digitalen Hochleistungsbelichters für die Belichtung von Lötstopplacken, DAHLIA
- Industrietaugliche UKP-Laserquellen und systemweite Produktivitätssteigerungen für hochdynamische Bohr- und Schneidanwendungen, InBus
- MEMS-basiertes Laserstrahl-Ablenksystem für einen Laser-Projektions-Scheinwerfer, KOLA

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