Dear friends and partners of the Fraunhofer Research Institution for Modular Solid State Technologies EMFT, dear reader,

The second year of independence has seen lots of new developments and accomplishments in the world of the Fraunhofer EMFT and it gives us great pleasure to be able to present to you the spectrum of modular solid state technologies.

The core themes of the institution such as silicon technology, 3D integration, polytronics and MEMS technology are gradually becoming merged based on our core focus on modular solid state technology, with the aim of refining multifunctional system integration in concert with industry.

The integration of additional functions at the wafer level has been extended via multifunctional on-top technologies (MOTT) as well as a welcome expansion of collaborative work with industrial partners. Integrated silicon circuits with MOTT-integrated sensors, detectors with MOTT-integrated driver transistors and more efficient, more cost-effective or even smaller silicon MEMS micropumps for a diverse range of applications, also comprising integrated electronic control units, are practical examples of the current range of applications and provide some idea of the diverse potential offered by the MOTT concept.

There is a growing international trend towards the merging of and modular approach towards front-end technologies for components as well as structuring and connection technologies for system integration, confirming the validity of the Fraunhofer EMFT’s objectives in the field of modular solid state technologies.

The driving forces here are rising demands in terms of the performance capacity of information and communication systems as well as the trend towards increasing automation, including the requirement for systems to be multifunctional while maintaining a high degree of reliability. At the same time, marginal factors such as low energy consumption, environmental compatibility and production costs are growing in significance.

Polytronics has reached the first more widespread applications in the field of displays and flexible conductor path technologies. System integration of multifunctional flexible polytronic systems has also produced high-performance demonstrators, which is why interest in these technologies is growing on the part of industry. The materials for printed functionalities with their better availability and higher performance capacity are the main cause of this.

Innovative additive structuring processes such as ink jet or screen printing, nanoimprint and microcontact printing create the basis for the use of foil substrates in a range of sophisticated sensor applications, opening up new application scenarios in medical technology, navigation, IT and telecommunications engineering.

Here, foil technologies happily dovetail with classic silicon and MEMS technologies. It is already apparent that modular combination will offer significant benefits, especially in the field of multifunctional system integration and 3D system integration.
Well into its second year, the aims of the Fraunhofer EMFT have clearly been validated. As a team we have been able to tackle the demanding tasks and challenges facing us, meeting our objectives and successfully expanding our institution in line with our guiding theme of modular solid state technologies, which has included making larger-scale investments in equipment for submicrometer structuring methods. I offer my sincere thanks to our entire team of staff for their exemplary dedication and commitment.

I now hope to have aroused your curiosity in taking a more detailed look at modular solid state technologies and wish you a stimulating and informative read. I would very much encourage you to contact us directly should you wish to do so.

Yours sincerely,

[Signature]

*Acting Director of the Fraunhofer Research Institution for Modular Solid State Technologies EMFT*
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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 more than 80 research units in Germany, including 60 Fraunhofer Institutes. The majority of the more than 20,000 staff are qualified scientists and engineers, who work with an annual research budget of €1.8 billion. Of this sum, more than €1.5 billion is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft’s contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

Affiliated international research centers and representative offices provide contact with the regions of 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.
FRAUNHOFER GROUP FOR MICRO-ELECTRONICS

The Fraunhofer Group for Microelectronics VµE has been coordinating the activities of Fraunhofer Institutes working in the fields of microelectronics and microintegration since 1996. Its membership consists of thirteen institutes as full members and three as associated members, with a total workforce of around 2,700 and a combined budget of roughly € 307 million. The purpose of the Fraunhofer VµE is to scout for new trends in microelectronics technologies and applications and to integrate them in the strategic planning of the member institutes. It also engages in joint marketing and public relations work.

The activities of the group concentrate largely on establishing joint focal research groups and projects contributing to the grand societal challenges and supporting the business regions Germany and Europe. In this way, the group is able to provide innovative small and medium-sized enterprises, in particular, with future-oriented research and application-oriented developments that will help them gain a decisive competitive edge. The group pools the core competences of its member institutes in the following:

Cross-sectional fields of competence:

- Technology – from CMOS to Smart System Integration
- Communication technologies
- Safety & Security

Application-oriented business areas:

- Ambient Assisted Living & Health
- Energy Efficiency
- Mobility
- Smart Living

Member institutes:

Fraunhofer Insitutes for
- Applied Solid State Physics IAF
- Digital Media Technology IDMT (guest)
- Electronic Nano Systems ENAS
- High Frequency Physics and Radar Techniques FHR
- Integrated Circuits IIS
- Integrated Systems and Device Technology IISB
- Microelectronic Circuits and Systems IMS
- Telecommunications, Heinrich Hertz Institute, HHI
- Open Communication Systems FOKUS (guest)
- Photonic Microsystems IPMS
- Silicon Technology ISIT
- Non-Destructive Testing IZFP (guest)
- Reliability and Microintegration IZM

Member institutions:

Fraunhofer Research Institutions for
- Modular Solid State Technologies EMFT
- Communication Systems ESK

Member center:

 Fraunhofer Center for
- Nanoelectronic Technologies CNT

The central office of the Fraunhofer Group for Microelectronics in Berlin is the main coordination centre. Acting in close collaboration with member institutes, it forms the link between science, industry and politics.
Keyboard on foil substrate made using roll-to-roll foil processes
The Fraunhofer EMFT originates from the Fraunhofer Institute for Solid State Technology IFT, which was founded in 1974. Here, technologies were developed for the manufacture of semiconductors. Other areas of activity were sensor technology, communication technology and microstructure technology. In 1999 the Fraunhofer IFT was dissolved and split into three independent sections. The section located in Hansastrasse, Munich - today's Fraunhofer EMFT - initially became part of the Berlin-based Fraunhofer Institute for Reliability and Microintegration IZM.

The Fraunhofer EMFT was founded on July 10, 2010 as an independent institution once again, created from the Fraunhofer Institute for Reliability and Microintegration IZM, Munich branch.

The Fraunhofer Research Institution for Modular Solid State Technologies EMFT develops application-oriented system technologies, in particular in the field of microelectronics and microsystems engineering, with the aim of offering its clients a tailor-made portfolio of products, solutions and services.

Value creation in technology development is shifting increasingly to the system as a whole and associated services. There is therefore a demand for modular and multifunctional system technologies geared towards application-specific systems from the outset and comprising an adapted range of manufacturing and refinement technologies. Fraunhofer EMFT scientists are involved in this development as part of a long-term strategy, with cooperations seeking to further extend the development of multifunctional and modular technology as the institution’s guiding principle.

The Fraunhofer EMFT has four core competences: multifunctional on-top technologies for 3D system integration, polytronics, biosystem integration and microfluidics. The integration concept of the Fraunhofer EMFT consists of the conflation of these core competences and their structuring into ten research fields. This dovetailing generates valuable synergy effects which are the hallmark of the Fraunhofer EMFT’s multifunctional, application-oriented system solutions for industry and society.
// OVERVIEW

Flexible multifunctional patient wristband
Life Science products

Disposable sensor systems

Bio-implantable components

Chemical and biological sensor systems

Multifunctional on-top technologies MOTT

Polytronic

Microfluidics

Biosystem integration

Radiation detectors
Vacuum-suitable electron- and ion-sources

Cell processor
Research fields

- Multifunctional on-top technologies for 3D system integration
- Silicon-based technologies, nanomaterials and components
- Micro electro mechanical systems (MEMS)
- Microfluidics and micropumps
- Biosystem integration and biosensorics
- Polytronic technologies and microsystems
- Analysis and test of integrated systems
- Manufacturing and handling techniques for very thin semiconductor substrates
- Surface structuring and self-assembly
- Sensor materials and fluorescent nanosensors

In continuing to refine the integration concept of the Fraunhofer EMFT, interfaces between the core competences have been completed, thereby establishing a platform for modular solid state technology. Here, system integration - so-called assembly and interconnection technology, or "electronic packaging" - is increasingly merging with front-end technologies such as CMOS and MEMS, resulting in highly efficient and cost-effective system solutions for industry. The transitions between component technologies and packaging technologies will become interconnected and modular. Based on this belief, the Fraunhofer EMFT develops open, modular and therefore closely application-oriented system technologies - modular solid state technologies - which can be combined with one another at precisely defined interfaces. This orientation allows the Fraunhofer EMFT to complement the institutes of the Fraunhofer Group for Microelectronics, dovetailing harmoniously with the latter’s research and development strategies.
Since 2009, two divisions have been operated at the Fraunhofer EMFT with their respective departments and working groups.

"Nano Materials and Si Technology (NDS)" division

This division under the direction of Professor Ignaz Eisele has two departments:
The department "Device und 3D Integration (D3D)" with the following working groups:
• "Integration Technology"
• "Process and Design Integration"
The areas of work are the development and optimization of CMOS-compatible technologies for the production of three-dimensionally integrated microelectronic systems (Vertical System Integration – VSI®), as well as the integration of functional layers on ready-processed silicon wafers. The department "Nanomaterials and Devices (NMD)" with the groups
• "Device Technology"
• "Functional Layers"
looks into the application and process integration of novel materials such as silicon/germanium (SiGe) and is involved in the development of innovative components such as radiation detectors with integrated evaluation electronics and nano electro mechanical systems (NEMS).

"Polytronics and Multifunctional Systems (PMS)" division

This division under the direction of Professor Karlheinz Bock also has two departments.
The department "Polytronic Systems (PS)" with the working groups:
• "Sensor Materials"
• "Polytronic Technologies"
• "Substrate Preparation & Treatment"
• "Electronics & Biomedical Solutions"
• "Analysis and Test of Integrated Systems"
This department develops components and heterointegration technologies for large area electronics, focusing on the field of ubiquitous systems and combining electronics with sensors, batteries or microfluidic systems, for example. Active handling of tiny quantities of fluids and gases is the central area of expertise of the "Micromechanics, Actuators and Fluidics (MAF)" department.
A development platform for microfluidic actuators is also being developed and realized.
The institution in figures

Operating budget

The operating budget of the site has developed positively, i.e. business volume has increased continuously. The Fraunhofer EMFT’s operating budget in 2011 was approx. EUR 9,757,000. Industry contract generated a total volume of EUR 2,014,000. The percentage of earned revenue was therefore 20.8%. The planned operating budget for 2012 is EUR 10,583,000, which involves a further increase in the institution’s industrial earnings.

Staff development

The Fraunhofer EMFT currently employs a staff of 92. Of these, 74 work in the scientific area and another 18 in the areas of administration, IT, workshop and technology. On average there are also over 20 students and graduate assistants from a wide range of institutions working on their doctoral thesis, dissertation or master’s thesis at the Fraunhofer EMFT who are involved in the respective research areas.

Infrastructure

The following infrastructure is available at the Fraunhofer EMFT:

Cleanrooms: (640 m²)
according to DIN EN ISO 14644-1, ISO class 5 (previously 100 US FED Standard) and 4 (previously 10 US FED Standard)
• 200 mm line with complete range of standard silicon CMOS equipment
• 150 mm line with complete range of standard silicon MEMS equipment

Laboratories: (1600 m²)
Polytronics, microfluidics, bioanalytics, ATIS, guest companies

Office areas and meeting rooms: (2760 m²)
• Offices (1520 m²)
• 3 seminar rooms (50 m², 55 m² and 80 m²)
• 4 meeting rooms (190 m²)
• 1 video conference room for 15 people (50 m²)
Artistic shot of multifunctional on-top technologies for 3D system integration
Board of Trustees

The Boards of Trustees are external advisory bodies attached to the institutes and research institutions. They are made up of representatives from science, business and public life. There are approximately twelve members for each institute who are appointed by the Executive Board in agreement with the institute management. At least one member of the Executive Board attends the annual meetings. The Boards of Trustees advise the institute management on issues of research orientation and structural change.

The Board of Trustees of the Fraunhofer EMFT is being reconstituted in the course of 2012. Up to June 30, 2011, the members of the Board of Trustees of the Fraunhofer IZM, from which the Fraunhofer EMFT emerged, were as follows:

Dr. W. Schmidt, Plantcare AG, Russiko, Switzerland (Chairman of the Board of Trustees)
Dr. H.-J. Bigus, Hirschmann Laborgeräte GmbH & Co KG, Eberstadt
M. Boeck, A.S.T. Angewandte System Technik GmbH, Wolnzach
M. Bothe, VDE Testing and Certification Institute, Offenbach
W. Effing, Giesecke & Devrient GmbH, Munich
Dr. S. Finkbeiner, Robert Bosch GmbH, Stuttgart
C. Gehring, Federal Ministry of Education, Science, Research and Technology (BMBF), Bonn
U. Hamann, Bundesdruckerei GmbH, Berlin
Prof. Dr. K. Kutzler, President of Technische Universität, Berlin
Senate Councillor B. Lietzau, Senate Committee for Science, Research and Culture, Berlin
Dr. M. Meier, Advanced Technology Management, Hilterfingen, Switzerland
Dr. F. Richter, Thin Materials AG, Eichenau
Dr. G. Ried, Bavarian Ministry for Trade, Infrastructure, Transportation and Technology, Munich
Prof. Dr. Ir. Albert L.N. Stevels, TU Delft, Delft, Netherlands
M. Stutz, Dell GmbH, Frankfurt a.M.
Dr. T. Wille, NXP Semiconductors GmbH, Hamburg

1 Plasma deposition on VON ARDENNE CS850
// HIGHLIGHTS

Spray coating on the SÜSS Gamma
EVENT FOR IMPROVED HEALTH - "SENSORS AND MICROSYSTEMS IN MEDICAL TECHNOLOGY"

The market for sensors and microsystems in medical technology is currently seeing sharp growth, especially due to innovations in the field of mobile systems for patient monitoring and diagnosis as well as age-appropriate assistance systems for a healthy, independent life (AAL).

In this connection, the 8th BAIKEM cooperation forum "Innovations in microsystems" was held on May 15, 2012 in Nuremberg, organized by Bayern-Innovativ in collaboration with the Fraunhofer EMFT. Here, well-known experts from industry and science presented key development trends in the use of sensors and microsystems in medical applications.

Approx. 120 users and customers from the innovation fields of sensors, MEMS and medical technology attended the forum to find out about these trends and engage in cross-disciplinary talks with the expert speakers.

The forum also featured an exhibition directly linked to the talk series, illustrating to potential users and customers the current state of technology and providing an impetus for future cooperations in the innovative field of microsystems engineering.

MICROSYSTEMS FOR EVERYDAY USE

The cooperation forum Man and Microsystems provides a dialogue platform for SMEs to allow active discussion of innovations with scientists from the field of microsystems engineering in relation to socially relevant topic areas. The cooperation forum "Innovations in microsystems, system integration – from technology to product" was held at the Fraunhofer EMFT on May 10, 2011. Prestigious speakers from research and industry provided insights into potential future developments in system integration in the field of microsystems engineering.

Companies such as Siemens AG, Rohde&Schwarz and Landshut Silicon Foundry obtained information on the latest developments in the field of microsystems engineering. Examples of applications in medicine and healthcare, communication and mobility, energy and industry as well as the environment and drive systems reflected the practical orientation of current developments.
INTERNATIONAL EXCHANGE ON THE TOPIC OF FLEXIBLE ELECTRONICS

This workshop, which has been organized by the Fraunhofer EMFT for over 10 years, has long been an internationally recognized forum for the presentation and discussion of the latest R&D results and applications in the areas of thin semiconductor devices and flexible electronic systems. In 2011 once again, scientists, manufacturers and users made the most of the two-day workshop to share their findings and forge personal contacts within the international research community. As before, the conference hotel Le Meridien in Munich provided a pleasant setting for this highly informative event.

In 2012 the workshop forum Be-Flexible will be held from November 21 - 22 at the Fraunhofer EMFT, see: www.be-flexible.de.

INTELLIGENT TEXTILES BASED ON SENSOR TECHNOLOGIES

230 experts from six countries representing the textile, sports, electronics and automotive industries as well as medical technology and science attended the first cooperation forum entitled “Textile and sensors” on October 25, 2011 in Regensburg to find out about development potential and establish contacts with potential cooperation partners. The cooperation forum was organized jointly by Bayern Innovativ and the Fraunhofer EMFT. Other partners were BioPark Regensburg and the Sensorics Cluster.

Promising fields of application for textile sensors are medicine and healthcare, protection and automobile construction (especially in the context of electromobility) as well as sports and Ambient Assisted Living (AAL). Potential future uses of sensoric textiles include monitoring vital signs or the environment, and they may ultimately enable products to be equipped with entirely new functions.
MICROFLUIDICS TO THE BENEFIT OF PATIENTS

On October 26, 2011 Fraunhofer EMFT collaborated with Bayern Innovativ to organize the workshop “Medication dosage systems” on the premises of the Fraunhofer EMFT. The efficient transport of a pharmaceutical to its site of action by means of innovative drug delivery systems improves both effectiveness and tolerance in patients. Numerous key medical technologies are used here, from microsystems engineering to materials science and nanotechnology. The workshop presented technological innovations from a range of areas of application of drug delivery, including solutions developed at the Fraunhofer EMFT for medication dosage.

FRAUNHOFER EMFT WINS THIRD PLACE IN IDEAS COMPETITION

Fraunhofer EMFT representatives gave talks at the second Fraunhofer Netzwerk Symposium on November 28 - 29, 2011 on the topics “Tumor therapy with implantable microdosage systems independent of power supply” and “3D integration technologies for the manufacture of microelectronic foil systems”. 12 sessions with 48 scientific talks provided an insight into the entire breadth of the Fraunhofer portfolio. An ideas competition was held with a live vote in which the audience selected six winners from a total of 20 ideas presented - running across all the Fraunhofer institutes and institutions. 3rd place went to the project idea “Training dogs with microdosage systems for applications in medical technology and security technology” developed by Sebastian Kibler, a Fraunhofer EMFT scientist. The aim is to train tracker dogs more effectively and make their performance measurable using a dosage system for tiny fragrance concentrations developed by Fraunhofer EMFT. In this way it might be possible to use specially trained dogs for the early detection of lung cancer, for example.
The COSMIC Summer School und Workshop “Printed Electronics and Foil Assembly” was held from June 7 - 10, 2011 at the Fraunhofer EMFT. 40 young scientists from industry and universities were provided with insights into the latest research activities in the area of organic and large-area electronics. Participants also had the opportunity to develop their professional skills and extend their network. The program included a mixture of scientific presentations and practical work. Scientists working on the EU projects Polaric, Cosmic, Interflex and Smart-EC presented the latest results of their projects. Some presentations also demonstrated how partner collaboration on EU projects works and how such projects contribute to feeding new technologies to industry and applications. The practical section included preparation and characterization of organic thin-film transistors, roll-to-roll processing and foil-to-foil lamination. The intensive discussions were followed by an evening event and dinner at the Oktoberfest Museum in Munich.

A lithography cluster was founded at the Fraunhofer EMFT in November 2011 with the installation and commissioning of SÜSS Microtec AG’s MA8Gen3. This means that contact exposure, double-sided exposure, nanoimprint and proximity is now available for 200 mm wafers too, in addition to the existing i-line and electron beam lithography. Focused Ion Beam (FIB) analysis has been available since 2010 with the Helios Nanolab. All equipment is located in an ISO Class 5 or ISO Class 3 (MA8, Canon stepper) cleanroom.
Silicon photomultipliers (SiPM) in 200 mm technology were developed with the company Ketek GmbH. Due to the excellent results achieved, this collaboration is to be continued. Ketek’s aim is to refine the jointly developed silicon photomultipliers for serial production. Fraunhofer EMFT is also evaluating use for other applications such as detection of weak light signals in the field of analytics.

A strategic cooperation was initiated with the company SÜSS Microtec AG on November 1, 2011. The project is due to run for three years in the first instance. Initial assignments have already been defined and started. For example, selective states (e.g. hydrophobic) are to be created on freely chosen surfaces by means of a plasma. These properties are used to attempt to place chips using the self-aligning process.

**STRATEGIC COOPERATION WITH SÜSS MICROTEC AG**

**SILICON PHOTOMULTIPLIER**
// COOPERATION

FEI Helios Nanolab for Focused Ion Beam
Microelectronics and microsystems engineering are key innovation drivers in virtually all product areas and sectors of the economy. For this reason, there are widely diverse fields of application at the Fraunhofer EMFT, ranging from mechanical engineering, automotive electronics, LED lighting, cell phones and consumer electronics to medical technology and chemical process engineering. Benefits to companies in collaborating with Fraunhofer EMFT include the capacity to develop new types of functions and areas of applications, increased miniaturization, enhanced energy efficiency, low production costs and a high degree of reliability. What is more, Fraunhofer EMFT supports its clients throughout the entire development process from the initial idea right through to implementation. The Fraunhofer EMFT offers the following services:

**Studies**
- Technology analyses
- Feasibility studies
- Assessment in the case of damage claims

**Technology concepts and design**
- Industrial contract research and development
- Customer-specific adaptations

**Modeling and simulation**
- Manufacturing processes
- Prototype development up to small series production

**Analysis and testing**
- Problem cause and risk analysis
- Robustness and reliability
- Electrical and physical characterization and load (e.g. ESD)
- Development of ESD protection structures and concepts

**Seminars and training programs**
- Orientation talks
- Customer-specific workshops

**Joint research and development projects**
Highly experienced staff, an excellent record of achievements to date, state-of-the-art infrastructure, a broad range of technologies and a network with industry, the public sector and universities make the Fraunhofer EMFT an attractive partner for SMEs and industry when it comes to research and development. Marketing is generally handled by the corporate partners themselves. Since 2007, Fraunhofer EMFT has also offered high-tech companies the opportunity to hire and utilize the institution’s high-quality facilities (such as cleanrooms, laboratories, workshops and equipment). Several companies have entered into strategic cooperations with the the Fraunhofer EMFT - including Siemens AG, Ketek GmbH, Panasonic, Süss MicroTec GmbH, Thin Materials and TÜV Süd. Framework contracts are being prepared with a number of others companies. Here is a selection of technological facilities available to the Fraunhofer EMFT and its customers and partners on site:
200mm lithography cluster in cleanroom

- Nanoinprint
- Proximity exposure
- Double-sided exposure
- Contact exposure
- Electron ray exposure
- Ion ray exposure
- i-line stepper

Analytics and material characterization

- Atomic force microscope (AFM): measurements of surface roughness and stage measurements of up to 6 µm
- Scanning electron microscopy (REM) incl. energy-dispersive x-ray spectroscopy (EDX)
- In-line REM (Schottky emitter) and focused ion beam (Ga-FIB) with EDX and gas injection system (GiS)
- Spectral ellipsometer: measurement of thin layers and transparent materials
- Spectrometer: measurement of layer thickness in silicon (thick layers) and infrared-permeable layers
- Target grinding device for sample preparation (grinding accuracy: ±2 µm)
- X-ray diffractometry (XRD): measurement of SiGe content
- CVD epitaxy system: quality control of ultrapure gases
- Plasma-supported etching and separating systems to test gas compounds

Application of large-area electronics and flexible substrates to foil sheets and using the roll-to-roll method

- Hot roll laminator for double-sided lamination
- In-line coating system for liquid coatings such as photoresist, dielectrics and passivation
- Sputter system for double-sided metallization of chrome and copper
- UV lithography with high resolution (5 – 15 µm structure width)
- Wet-chemical etching techniques for structuring metals
- Screen printing on foil sheets or using the roll-to-roll method
- Galvanic deposit of copper on premetallized foils
- Laser processing for cutting, marking and drilling various materials
- Plasma process for surface conditioning and reactive etching of polymers with nitrogen, oxygen and CF4
- Foil mounting and bonding technology
Si-MEMS technology

- Cleanroom technology for 150 mm wafers (silicon, ceramics, glass)
- Metal coating (Cu, Ti, TiW, Pt, Au, Ni)
- Dielectric layers (SiO2, Si3N4, SiC, PI)
- Wafer bonds, bonding technique by means of adhesion
- Structuring with mask aligner 2µm

Analysis and test

- Semiautomatic wafer samplers up to 300 mm with Thermochuck (-55°C - +300°C) and laser
- Semiconductor parameter analyzers
- Network analyzers from MHz to 110 GHz and Agilent ADS simulator
- Generation and measurement of high-current pulses in the ps and ns range
- Electrostatic discharge characterization and load (CDM, HBM, TLP, VF-TLP, CC-TLP)
- 160 cc climatic chamber
- Gas measurement station

1. High-frequency characterization of components directly on a 200 mm silicon wafer
2. Matrix of printed reversible color change indicators for pH value made of sensor materials
In order to enable efficient and effective collaboration with industry, three different networks come together in the Fraunhofer EMFT:
the Bavarian Polytronic Demonstration Center (BDP),
the Development Center for Multifunctional On-Top Technologies (MOTT) for standard silicon and CMOS and the Center for Microsystem Integration Munich (CMM).

**Bavarian Polytronic Demonstration Center (BDP)**

Providing a networked environment geared towards human needs (Ambient Assisted Living, AAL) requires cost-effective, multifunctional, ubiquitous systems. In order to establish the infrastructures needed for this purpose, electronic systems have to be produced economically in high volumes on large-area substrates.

The Bavarian Polytronic Demonstration Center is a technology cluster which collaborates with industry to develop the necessary production processes, including low-cost Microsystems. A large number of coating and structuring processes on foils are developed in industry-related research projects and development activities for flexible organic and large-area electronics (FOLAE).

The equipment used is consistently designed to process rolls of foil. Current focus areas are functional integration via active organic materials, the assembly of sensors in polymer technology and the creation of large-area, flexible wiring systems.

**Multifunctional On-Top Technologies MOTT**

The development center for Multifunctional On-Top Technologies (MOTT) for standard silicon and CMOS was founded in 2009. Building on the results of previous research into CMOS circuits and 3D-integration, the Munich site offers a technology platform for Microsystems and nanosystems engineering which is designed to enable industry to carry out rapid system development closely geared towards end products. The platform supports modular integration of new functions and components in existing silicon standard technologies, resulting in cost-effective solutions even for small and medium-sized companies.

**Center for Microsystem Integration Munich (CMM)**

Together with leading Bavarian companies, the Fraunhofer EMFT initiated the founding of the Center for Microsystem Integration Munich in 2010. Pooling of the extensive expertise of prestigious partners in the field of technology and product development makes the CMM a high-performance, efficient technology network in the field of Microsystems engineering. The CMM acts as the nucleus for a Microsystems engineering center, open to further expansion by additional experts.
THE FRAUNHOFER EMFT'S INVOLVEMENT IN EUROPEAN COMMUNITY PROJECTS

Fraunhofer EMFT is involved in a number of European Commission projects, collaborating with partners from science and industry to research into and develop future-oriented solutions to tackle major challenges facing society today.

i-Tex - ICT 288262

The project i-Tex (intelligent and self-illuminating textiles) researches into and develops adaptable, energy-efficient solutions for large-area intelligent lighting. These lighting systems are based on intelligent, coated textiles and open up a whole new range of application scenarios for both indoor and outdoor use, as well as novel possibilities for design and user interaction. The aim is to develop a low-cost, reliable roll-to-roll manufacturing process which integrates sensor and lighting systems in coated textiles.

POLARIC - ICT 247978

The aim of the project is to create high-performance organic, integrated circuitry on large substrate areas. This means increasing switching frequency into the MHz range and reducing the supply voltage to battery level as well as reducing power consumption and increasing production yield. A key element of the POLARIC project is the miniaturization of organic circuits in the sub-µm structure range using new structuring methods such as nanoimprint or microcontact printing. At the same time, the manufacturing process is being optimized with a view to achieving higher throughput with roll-to-roll methods and large-area substrates.

Interflex - ICT 247710

Interflex is a project which targets the development of structuring and interconnection technologies for heterointegrated, multilayer foil systems. Here Fraunhofer EMFT is developing a foil-based, flexible sensor system which allows various air parameters to be monitored in interior spaces such as humidity, temperature and CO₂ concentration. The sensor foil is integrated in a flexible foil system which performs the functions of energy harvesting and storage, data collection and analysis, and wireless data exchange via RF. As part of this project, AVT techniques are being developed which allow both thinned silicon ICs and large-area foil-based subsystems to be assembled and electrically contacted on a foil substrate.
COLAE - ICT 288881

Commercialisation Clusters of OLAЕ (Organic and Large-area electronics) (COLAE) is a European initiative which promotes the commercial use of organic and large-area electronics. OLAЕ technology provides opportunities for new product ideas, combined with low-cost manufacture, energy-efficiency and environment-friendly materials and processes. Since it is a young technology, there are very few companies in Europe at the present time able to manufacture OLAЕ-based end products so market demand is urgently needed yet still sluggish. COLAE therefore aims to raise the profile of OLAЕ among potential end users in Europe and point the way forward to potential new product developments. In order to achieve this aim, demonstrators are developed and training programs organized for potential industrial clients. COLAE also seeks to identify the main needs and challenges in the area of research and development.

COSMIC - ICT 247681

The project COSMIC has set itself the goal of moving the electrical performance capacity of organic semiconductors into the range required for application in RFID tags, display drivers and integrated circuits. A key element of the project is the development of a complementary and significantly more robust circuit technology with p-type and n-type conductive organic materials. Another important focus is the development of low-cost manufacturing techniques suitable for mass production on a range of manufacturing platforms. The results of the project can be deployed in a diverse range of application areas such as medical technology, environment, energy, leisure, security and mobility.

NanoClear - ICT 280581

The project NanoClear is dedicated to the development of new technologies to reduce micro-defects and nanodefects on thin, coated, large-area foil substrates. Surfaces defects can arise in various phases of the manufacturing process and have a negative impact on the efficiency and yield of the process as well as product quality and lifetime of the products.
Thin silicon on flexible substrate

These are used in manufacturing such items as flexible illuminants, flexible voltaics, coated packaging materials, billboards and screens.

**e-BRAINS - ICT 257488**

The Fraunhofer EMFT is involved in the large-scale integrated project e-BRAINS being run by the European Commission. e-BRAINS stands for "Best-Reliable Ambient Intelligent Nanosensor Systems by Heterogeneous Integration". The aim is to provide technologies for future applications in the field of Ambient Assisted Living requiring integration of heterogeneous technologies. One of the main tasks here is to develop suitable, reliable 3D integration technologies for future MEMS/IC products. The e-BRAINS project also includes selective evaluation of medical applications (DNA sensors and active implants) and safety applications.

The project partners are Infineon Technologies (Project Coordinator), eesy-ID, ELA Medical, IQE, Magna Diagnostics, SensoNor, Siemens, Vermon, DMSC (majority owned by Intel Mobile Communications), CEA, EPFL, IMEC, ITE, SINTEF, TUC, TUG, Fraunhofer IIS-EAS and Fraunhofer EMFT (Technical Manager).

**SMART-EC - ICT 258203**

The aim of the SMART-EC project is to develop energy self-sufficient electrochrome (EC) components. For this purpose, thin foil-based EC transistors are integrated on flexible substrates, with functions for energy harvesting and storage. The primary aim is to improve the components’ energy efficiency, resulting in increased convenience and safety in various applications. The results of the project can be used in such areas as automotive, ID cards and smart packaging.
The Fraunhofer EMFT is involved in collaborative research and projects with a number of universities. Strategic cooperations exist with Technische Universität Berlin, Universität der Bundeswehr München and the University of Regensburg.

Technische Universität Berlin and the Fraunhofer EMFT are linked by the Professorship for Polytronic Microsystems under Professor Karlheinz Bock. This department is dedicated to research into polymeric coating technologies and the characterization and control of polymeric surfaces and boundary layers in polymeric material composites as well as in hybrid multilayer technologies. Increased mobility of the semiconductive polymer layers is of key importance here and can be achieved by improving the short-range order of the semiconductive molecules. This can be brought about by applying technological methods to influence surface states, e.g. microstructuring and nanostructuring of the technological surfaces by depositing molecular interface layers. Other research topics are in the areas of adhesion, interdiffusion barriers, electrical contacting of polymers and the self-arrangement and selective electronic alignment of semiconductive polymers. The more stable and more capable layer systems thereby created serve to enhance the stability and reliability of the components of which they form a part - after all, many problems of reliability can be traced back to uncontrolled or impaired boundary layers within the synthetic composite.

In collaboration with the Universität der Bundeswehr München, two appointment procedures have been agreed on which provide a link to executive positions at the Fraunhofer EMFT.

The management of the Fraunhofer EMFT is linked to the Universität der Bundeswehr München based on a joint appointment procedure for the Polytronic Systems department, and the head of the "Nano Materials and Si Technology (NDS)" division is linked to the Universität der Bundeswehr München by means of a W3 professorship.

The "Sensor Materials" working group was founded at the University of Regensburg in May 2009, based at BioPark Regensburg. In collaboration with the University of Regensburg, this working group is being set up at the University of Regensburg with the financial support of the Bavarian Ministry for Trade, Infrastructure, Transportation and Technology through the regional government of the Upper Palatinate. Its aim is to develop reliable polymer-based sensor materials for a broad range of applications. In combination with the relevant optical/electrochemical transducer modules and microfluidic throughput systems, these new materials enable continuous detection of a wide range of key system parameters. The latter include:

- oxygen (in medicine, automotive technology, process control, biotechnology, environmental analytics)
- carbon dioxide (automobile emissions, greenhouse gases, air conditioning systems, bioprocess control, blood gas analysis etc.)
- pH value (tumor research, marine research, medical diagnostics, bioprocess control, chemical industry)
- ammoniac (automobile emissions, sewage)
- ethanol (respiratory gas analysis, brewing industry)
- toxic compounds (organophosphates, chemical warfare agents, pressure measurements)
VISITORS AND DELEGATIONS

- Delegation of the Government of the Basque Country, Spain, on a trade mission to Germany, June 7, 2011: Department of Industry, Innovation, Commerce and Tourism: Mr. Bernabé Linda Barturen, Minister of Industry, Innovation, Commerce and Tourism, Mr. Juan Ignacio Goicoeia, Vice Minister of Innovation and Technology, Mr. Xabier Garmendia Martínez, Vice Minister of Industry and Energy, Mr. Pedro Gómez Damborenea, Vice Minister of Public Relations, Planning and Strategy, Ms. Pilar Zorrilla, Vice Minister of Trade and Tourism, Ms. Isabel Muela, Director of Tourism, Ms. Catalina Chamorro, Director of Internationalisation, Ms. Maite Valmaseda, Director of Commerce, Mr. David Fernández, Director of Internationalisation, SPRI (Business Development Agency of the Basque Country)
  Parliamentary Commission of Industry, Innovation, Commerce and Tourism: Mr. Francisco de Borja Semper Pascual (President), Ms. Estibaliz Hernaez Laviña (Member), Mr. Oscar Rodríguez Vaz (Member), Mr. Carmelo Barrio Baroja (Member), Mr. Mikel Basabe Kortabarria (Member), Mr. Josu Osés Abando (Lawyer)
  TECNALIA Technology Corporation: Mr. Javier Ormazabal (President), Mr. Joseba Jauregizar (Managing Director)

- International visitors to the Cosmic Summer School, June 7 - 10, 2011: Mr. Luca Milan, Università di Brescia, Italy, Mr. Joachim Steinke, Mr. Stuart Higgins und Mr. Nikolay Vaklev, Imperial College London, Great Britain, Ms. Nikola Perinka, University of Pardubice, Czech Republic, Pawel Jerzy Wojcik, UNINOVA / University of Lisbon, Portugal, Prof. Arto Maaninen, VTT, Finland

- Danish delegation Nordic MedTech Caravan June 8, 2011

- Field trip by ID TechEx participants at the “International conference and exhibition assessing the applications, technologies and opportunities for energy harvesting and storage”, June 20, 2011

- Delegation of VeITech University, Avadi, Chennai, India Chancellor Professor R. Rangarajan, Honorary Adviser Mr. R. Prabhakar und Secretary to Chancellor & Vice Principal Mrs. P. Sarasu, June 21, 2011

- Professor Dr. Joachim Wegener and Professor Dr. Frank-Michael Matysik, University of Regensburg, Institute of Analytical Chemistry, Chemosensors and Biosensors July 8, 2011

- Assoc. Prof. Ciprian Ionescu, Ph.D., “Politehnica” University of Bucharest, Romania, Center for Technological Electronics and Interconnection Techniques, November 21 - 26, 2011

- Advanced Industrial Science and Technology (AIST), Dr. Kazuhiro Murata, Team Leader, Senior Researcher, Functionalizing process team, Flexible Electronics Research Center, November 30, 2011

- Student delegation, Postech Pohang University of Science and Technology, Korea, February 3, 2012

- Prof. Peter Lieberzeit, Professor for Analytical Chemistry at the University of Vienna, Austria, February 10, 2012

- Prof. Paul Svasta, Ph.D., Dr. h.c., “Politehnica” University of Bucharest, Romania, Head of Center for Technological Electronics and Interconnection Techniques, March 19, 2012

- Assoc. Prof. Norocel Codreanu, Ph.D., “Politehnica” University of Bucharest, Romania, April 13 - 18, 2012

- Center for Technological Electronics and Interconnection Techniques, April 13 - 18, 2012
3D-integrated MEMS/IC system for Infineon’s tire pressure monitoring system (TPMS)
RESEARCH FIELDS AND EXAMPLES OF PROJECTS

The Fraunhofer EMFT develops manufacturing strategies which are currently used to support production techniques and future-oriented approaches combining conventional silicon and MEMS technologies with biosystem integration and polytronics.

Technology and system demonstrators, applicable techniques and services are efficiently researched and developed in the areas of
- polytronics
- micromechanics, actuators and fluidics
- silicon technology
- system integration
- nanotechnology
in collaboration with industrial partners.

The focus here is not solely on miniaturization but primarily on heterogeneous technology integration. In other words, the best and most cost-efficient technologies for each purpose are brought together to develop intelligent systems.

An optimum process technology is used to produce the system components as required for a specific application, thereby enabling significant improvement of functionality, flexibility and cost effectiveness.

The Fraunhofer EMFT pursues this approach in particular based on modular solid state technologies and Multifunctional On-Top Technologies (MOTT) for the 3D system integration of semiconductor components in combination with polytronic technologies.

The aim is to achieve modular integration of innovative functions and new components in existing silicon technologies and MEMS standard technologies so as to make microsystems products smaller, more powerful and more energy-efficient.

The fields of research and development in which the Fraunhofer EMFT is active are set out below. They indicate the range of activities in the field of modular solid state technologies, reflecting the required diversity of system and functional components for multifunctional systems, from silicon CMOS technology and MEMS through to microfluidics, polymer components and sensor dyes.
MULTIFUNCTIONAL ON-TOP TECHNOLOGIES
FOR 3D SYSTEM INTEGRATION

Research field

Building on the results of previous research into CMOS circuits and 3D system integration, the development center for Multi-functional On-Top Technologies (MOTT) for standard silicon and CMOS at the Munich site offers a technology platform for microsystems and nanosystems engineering which is designed to enable industry to carry out rapid system development closely geared towards end products. The platform being developed supports modular integration of new and innovative functions and components in existing silicon standard technologies, resulting in cost-effective solutions even for small and medium-sized companies. Examples include ultra-high frequency components and optical components (e.g. photodetectors) as well as biological and chemical sensors and actuators. The client strategy of the MOTT development center is to establish a platform which allows potential clients to develop their products with new functionalities and if necessary produce them in small numbers.

Competence

In order to ensure compatibility with standard silicon, standard MEMS and CMOS technologies, technological development is conceptually divided into three key areas:

- Components and circuits
- Functions
- System integration

In the components and circuits area, only CMOS-compatible processes and a strictly limited spectrum of materials are used to develop novel, silicon-based components such as sensors, actuators as well as the relevant evaluation and adaptation circuits.

A modern CMOS technology cleanroom with standard semiconductor manufacturing equipment is available for processing 200 mm silicon substrates. The capacity of the R&D technology line enables small series production of the relevant system demonstrators. The functions area covers system integration on ready-processed wafers. Here, functional layers can be deposited which also contain alternative and non-CMOS-compatible materials so as to enable integration of additional functions. Examples of this include various sensors and passive components such as inductivities and capacities. The system integration area is based on longstanding expertise in three-dimensional (3D) system integration. The chief source of potential of 3D integration by means of through-silicon vias (TSV) lies in increasing the performance capacity of mobile information and communication systems based on highly parallel signal processing, minimal wiring lengths and the elimination of speed-limiting chip connections. 3D integration gives system manufacturers maximum flexibility in combining existing mainstream technologies with new and innovative functionalities.

Low parasitic losses reduce the power consumption of the system as a whole. Component layers - produced and tested independently of one another - are vertically integrated in a 3D chip (wafer level 3D system integration) using standard CMOS-compatible slice production processes. This offers the system manufacturer maximum flexibility in terms of combining existing mainstream technologies. Various chips - produced and tested independently of each other - are integrated in a 3D chip stack using standard manufacturing processes. This approach is especially tailored to the needs of small and medium-sized companies, since the „relaxed“ design rules which apply here obviate the need or
extremely cost-intensive processes such as those required for stepper lithography. The flexibility of these technologies allows the Fraunhofer EMFT to develop and realize entire system solutions for its clients. Since the expertise ranges from monolithic integration through to 3D integration, the spectrum of potential applications is extremely broad, with interesting possibilities emerging for client-specific developments.

Project example: 3D integration of heterogeneous MEMS/IC systems (e-BRAINS)

The Fraunhofer EMFT is involved in the large-scale integrated project “e-BRAINS”, being run as part of the European Commission’s ICT FP7 program. e-BRAINS stands for “Best-Reliable Ambient Intelligent Nanosensor Systems by Heterogeneous Integration” [www.e-brains.org]. The aim is to provide technologies for future applications in the field of ambient living, requiring

- Integration of heterogeneous technologies (such as CMOS, bipolar, storage, MEMS/NEMS)
- High-performance sensors
- Miniaturization
- Wireless communication
- A high degree of reliability

The project coordinator is Infineon Technologies, while the Fraunhofer EMFT is responsible for certain key project assignments: Dr. P. Ramm is the Technical Manager of the integrated project and Dr. A. Klumpp is the head of the project section “3D Integration Technologies”. One of the main tasks here is to develop suitable, reliable 3D integration technologies for future MEMS/IC products. Building on the European 3D technology platform, which emerged from the predecessor project e-CUBES, the main tasks include optimization and application of components specifically for the heterogeneous integration of innovative nanosensors.

The e-BRAINS project also includes selective evaluation of medical applications (DNA sensors and active implants) and safety applications.
SILICON-BASED TECHNOLOGIES, NANOMATERIALS AND COMPONENTS

Research field

In the cleanroom of the Fraunhofer EMFT, individual CMOS-compatible technological processes are developed and characterized on 200 mm wafers, and novel components are designed such as silicon-based sensors and actuators together with the relevant evaluation and adaptation circuits. Application areas for the development of sensors and sensor components are emerging in the field of radiation detection for material analysis and medical technology. The spectral range used here can be covered by the properties of the silicon material. The use of silicon-germanium (SiGe) allows extension of the spectral range into the near infrared domain. The production of application-specific barrier layer transistors or CMOS transistors supplements the radiation sensor system with the addition of preamplification stages or simple digital circuit components. The possibilities of nanostructuring are to be used to adapt surface properties on parts or passive components so as to create new sensor properties. This significantly extends the range of application of the components, e.g. moving into the area of biological or chemical sensors. Low-temperature processes can be used to add extra functional layers to finished components. The use of silicon structuring or CVD deposition in the MEMS/NEMS (Micro/Nano Electro Mechanical Systems) area expands the field of development for customer-specific sensors, moving into the area of actuators.

Competence

One focus area is the development and analysis of functional layers which can be integrated in standard silicon technology, keeping the thermal budget as low as possible so as to enable application on ready-processed wafers. Innovative techniques and new materials in semiconductor technology such as silicon and SiGe epitaxial layers are integrated in an overall process both with a view to enhancing performance and for the purpose of cost-effective production of microelectronic systems. The CVD epitaxy well established within the department has a key role to play here. Novel components in microsystems engineering such as NEMS (Nano Electro Mechanical Systems) can be realized by means of process integration of SiGe layers. These are of particular interest to SMEs since new products can be created with increasing market potential. The development of sensors, actuators and components for integration in microsystems continues to be an important field of activity. A 200 mm CMOS line is available for this purpose. In combination with extensive device and process simulation facilities and using special processes in the front-end area of the technology line, concepts for novel components with improved properties are created which are adapted to industry requirement profiles. The technological focus areas are the epitaxy of silicon and SiGe as well as low-temperature deposition processes for isolators and metals. A structuring cluster has been set up to develop highly efficient techniques for processing thin layers designed for use in industry. The main focus in terms of components is on radiation detectors for various wavelength ranges, MEMS and passive components.

Project example 1: High-quality components

In collaboration with KETEK GmbH as part of the HESDEK project funded by the Bavarian Chamber of Industry and Commerce (HESDEK = „Hoch Empfindliche Strahlungs-Detektoren“ - highly sensitive radiation detectors), a low-noise barrier layer
field-effect transistor (JFET) was produced for the first time in 2010 for use as a preamplification stage for silicon drift detectors (SDD). When used in the standard application, the transistor responded in the same way as the transistor in commercial use. It is thus possible to replace the commercial JFET currently used in the silicon drift detectors marketed by Ketek. Optimization of the JFET will also be advanced after completion of the HESDEK project, in particular in the field of higher frequencies into the GHz range.

**Project example 2: Radiation detectors**

So-called silicon photomultipliers (SiPM) in 200 mm technology were produced in collaboration with Ketek GmbH as part of the HESDEK project funded by the Bavarian Chamber of Industry and Commerce. These are to be used to replace photomultiplier tubes in highly sensitive detector applications such as nuclear medicine technology (e.g. positron emission tomography - PET). This will make it possible to operate a PET even within the powerful magnetic field of a magnetic resonance tomograph (MRT). As compared to others available on the market, the SiPMs produced displayed good dark count rates, good photon detection efficiency (PDE) and a very low level of optical crosstalk. Temperature sensitivity at the point of operation is low. The collaboratively developed SiPM are now produced and marketed by Ketek.

**Project example 3: Components for high-frequency applications**

The fundamental idea of the MST Bayern project HRFET (low-noise field-effect transistors with high-frequency capability) is to develop FET transistors which can be used in the GHz range and are extremely low-noise. Existing transistor concepts are not capable of meeting both these criteria. The project is pursuing two concepts: firstly, the refinement of so-called JFETs (Junction FETs), which HESDEK already achieved excellent results within the MHz frequency range, and secondly a new type of CMOS concept with buried-channel MOS transistors. Both concepts are based on self-adjusting processes, enabling active channel length to be heavily reduced. Since reduced channel length also means a higher transit frequency, this enables access to the GHz range. What is more, the planned concept means that lead resistance can be reduced, thereby also increasing maximum oscillation frequency.
MICRO ELECTRO MECHANICAL SYSTEMS (MEMS)

Research field

Micro electromechanical systems have been produced and further developed at the Munich site as prototypes for many years. There is great interest in a low-cost MEMS-based 3D technology to enable SMEs to electrically and mechanically combine sensor components with conventional Si-based ASIC chips. Microvalves and micropumps in silicon technology are mainly used in the medical field, for example, but are also increasingly required for process engineering in the area of ultrafine dosage of fluids and solutions (microfluidics). Another field of application of MEMS technology at the Fraunhofer EMFT is that of silicon-based miniaturized microphones for use in cell phones. In order to do justice to increasing miniaturization, NEMS (Nano Electro Mechanical Systems) with a nanogap are tested for their product suitability.

Competence

In order to do justice to the growing demands in terms of miniaturization and the combination of different silicon-based components, the existing wide range of MEMS-specific process technologies at the Fraunhofer EMFT is being constantly expanded and improved. The institution has longstanding experience and expertise in such areas as plasma-based techniques for silicon etching using the Bosch process, for example. This includes etching deep cavities, manufacturing TSVs with aspect ratios of well over 10:1 and large-area relaxation etching of thinned, highly even silicon surfaces. In-house production of 200 mm BESOI substrates (Bond and Etchback Silicon on Insulator) for freely selectable layer thickness parameters was also carried out during the reporting period and will continue to be perfected. Reliable and low-cost electrical insulation of through-etched TSVs in pre-thinned silicon wafers (400 µm thick) with relatively large side surfaces was realized by deposition of an O3/TEOS SACVD oxide. For MEMS-specific technologies, a cleanroom area is available specially for 150 mm MEMS production. Initial MEMS production runs are currently being transferred to 200 mm wafer technology and tested with the aim of being able to supply virtually all the relevant MEMS processes in 200 mm technology in the future.

Project example 1: MEMS microphone

Microphones - converters of acoustic energy to electrical signals - are used in a number of different areas. MEMS technology opens up new potential applications for low-cost, miniaturized manufacture of capacitive microphones with improved sensitivity and low power consumption. A novel silicon-based MEMS microphone is being developed at the Fraunhofer EMFT in collaboration with the industrial partners EPCOS, Müller BBM and Munich University of Applied Sciences. The finished device consists of a capacitive microphone and a matching ASIC circuit. The two main goals of the project are to miniaturize the microphone and enable low-cost 3D integration of the microphone and the associated ASIC circuit. The entire design for the manufacture of a capacitive MEMS microphone is being created by the Fraunhofer EMFT. Microbumps or SLID technology (Solid Liquid Inter Diffusion) are used for 3D integration of the microphone and ASIC chip. This reduces the housing size and the volume of the finished component.

This project is funded by the Bavarian Ministry for Trade, Infrastructure, Transportation and Technology.
Project example 2: NanoFET

The project title “NanoFET” refers to a field-effect transistor whose gate is mechanically movable and which is placed a few nanometers above the channel area. Mechanically oscillating tongues and membranes as sensors for acceleration and pressure have been familiar elements since the start of MEMS technology, but the NanoFET project refines these elements to an even more sophisticated level. Since these structures are monocrystalline, they have identical thermomechanical properties to those of the substrate, as well as being much more stable than conventional polysilicon oscillating structures.

Since these oscillating structures are just a few nanometers above the substrate, even the very slightest mechanical deflections of the gate result in marked changes in the electrical properties of the field-effect transistor. This makes the system considerably more sensitive than conventional systems such as those using piezoactive components. This principle can also be scaled down well below one µm. The combination of these benefits - which have only recently become technologically feasible - enables mechanical sensors to be created which will surpass those available today in terms of quality. What is more, the new technology is entirely compatible with the CMOS technology standardized in the semiconductor industry.

Originally developed at the Fraunhofer EMFT, the concept has given rise to a joint industrial project with the partners Infineon Technologies, Siemens CT and Micro-Epsilon. This cooperation is initially working to produce a chemosensor as a demonstrator, for example to monitor room climate. However, the sensor concept does not have to be limited to chemosensors. Scalability and complete compatibility with CMOS processes will make it possible to produce low-cost sensors to measure acceleration, frequency standards and many derivative parameters.
MICROFLUIDICICS AND MICROPUMPS

Research field

Piezoelectrically powered microfluidic actuators such as micropumps have wide-ranging potential in many industrial applications. The requirements here such as precise dosing, resilience to counterpressure, small size, low energy consumption, particle resistance and free flow protection call for a whole series of technological solutions to turn the micropump into a prototype with the potential for serial production. On request the micropump user can be provided with a complete system which solves all the above problems.

Competence

Work is being done at the Fraunhofer EMFT on a “black box” system which meets all the above requirements, solving the customer’s entire microfluidic problem once and for all. The “black box” has several or all of the following features to address the issues mentioned, in some cases using patented innovations.

Dosage accuracy, bubble tolerance and resilience to counterpressure:

A micropump has been developed at Fraunhofer EMFT which has a particularly high compression ratio, making dosage precision insensitive to gas bubbles in the fluid. This micropump has a counterpressure capacity of over 6 bar with water and over 1 bar with air - making it a worldwide best. The respective patent has been applied for. Micromembrane pumps are dependent on counterpressure by dint of their design. In addition to the high compression ratio, the above-mentioned micropump also has a very resilient actuation membrane and is therefore independent of counterpressure within the relevant range.

Small size and low energy consumption:

This silicon micropump is the smallest pump in the world, measuring 7 x 7 x 1 mm³. The development of a miniaturized electronic control system enabled the creation of a complete “pump-cube” which is smaller than 1 cm³. The electronic control units were optimized in terms of energy management to a level between 30 mW (standard pump) and 800 mW (high-performance pump) depending on piezo capacity, control voltage and operating frequency - making them perfect for self-sufficient battery operation.

Particle resistance:

Particles sucked in by the pump in the fluid can get trapped and cause the pump to fail. For this reason, a hydrophilic particle filter is normally required with a small pore size. However, this has the inherent drawback of a high bubble point, i.e. a large gas bubble can block the filter, likewise causing pump failure. This problem was solved at the Fraunhofer EMFT by means of a patented bubble-tolerant filter which is not blocked by gas bubbles.

Free flow protection:

In many applications, such as medical technology, the micropump is required to stop the flow whenever there is excess pressure acting on the intake. Here a number of solutions were developed, realized and patented at the institution; the “normal double closed (DNC)“ microvalve as well as a novel security valve. Both valves are passive components, autonomically closing. This means that excess pressure in the chamber causes closing of the valve.
Flow sensors:

Various flow sensors have been developed at the Fraunhofer EMFT. The latest microfluidic principle for low flow rates and dosage quantities was patented in 2010 and is currently being applied to a medication dosing system requiring volumes of 20 µl with a precision of 3%.

Project example: Microdosage system for medication dosage in tumor therapy

220,000 people die of cancer every year in Germany, many of whom have inoperable tumors during the final phase of the illness. The cycostatic drugs used systemically as part of chemotherapy cannot be administered in higher doses to these patients without poisoning the entire body. For such patients at an advanced stage of therapy, the new microdosage system could be used for a new therapy method to treat inoperable tumors. A highly concentrated cytostatic compound is fed directly to the tumor by means of micropumps. This administration of medication can cause tumors to shrink to a size at which it is possible to perform surgery. A key criterion here is the dosage accuracy of the microdosage pump. Pumps currently available on the market are inappropriate. The above project aims to significantly increase both the counterpressure resilience of the pump and the compression ratio of the piezoelectrically driven micropump. The pump is thus able to transport fluid solutions virtually independently of back pressure and unaffected by gas pockets in the pump chamber. An electronic control system is being developed which provides the required high voltage within a minute space but requires less than 100 mW power input even under full load. This enables self-sufficient operation to be maintained over several months. Furthermore, a novel dosage method is being developed which can deliver volume packages of just a few microliters to a high degree of precision. A meniscus created by means of an injected air bubble serves as an air piston, the movements of which can be measured precisely using a capacitive electrode. After a volume package has been administered, the air bubble is removed from the fluid path by means of a bubble trap. The entire system weighs less than 10 grams including the filled medication tank and casing. The integrated control system activates the pumps, reads out the sensors and implements the dosage mode. The result is a fully controlled microdosage system offering a high degree of dosage precision: it is small and light enough to provide evidence that the therapy method is effective in animal experiments. In addition to tumor therapy, this system also has potential for other medical applications.
For swift on-site diagnostics in medical technology it is becoming increasingly important to use small, portable and automated devices so as to obtain diagnostic findings quickly without having to send in samples to a central laboratory. Such diagnostic devices enable the attending doctor to initiate an expedient therapy within a very short time, thereby minimizing delays during which the wrong medication might be applied or none at all. It is also possible to network these on-site diagnostic devices so as to make the results available to a central LIS (Laboratory Information System).

An additional type of portable medical diagnostic device is used in the area of patient self-tests, allowing patients to monitor certain parameters themselves. The basic requirements for diagnostic devices used by patients are simple handling, secure usability and reliable diagnosis results, achieved by means of optimum system integration of bioanalytics and electronics.

Diagnosis and analysis devices are being developed by a highly qualified interdisciplinary team at the Fraunhofer EMFT as part of publicly funded projects and industrial contract research. The entire fluidic, mechanical and optical system is designed as well as the device electronics and control system. The Fraunhofer EMFT thus possesses the expertise required for system integration of optics, fluidics, electronics and information technology with analysis and medical technology.

Fraunhofer EMFT develops and produces portable „hand-held“ devices for Point-of-Care diagnostics and analytics. Biochip systems to measure blood clotting have been produced, as have systems to detect the concentration of viruses, bacteria and toxins, and systems to carry out drinking water tests and multiparameter immunotests. Small, high-capacity and user-friendly devices are made based on system integration of biosensorics, fluidics and intelligent electronic control.
Amine-sensitive dyes have been developed at the Fraunhofer EMFT which can be used to monitor the freshness of meat and fish. These indicator dyes change color in the presence of amines. One project involved the development of special optoelectronic analysis systems which allow the end consumer and intermediate traders to check the freshness of sensitive foods.

The measuring modules developed can also be used by the food industry and packaging industry to monitor transport and storage conditions.

The optical analysis system examines several wavelength ranges at the same time. Optical density changes of better than 0.01 D can be captured and displayed, depending on the color channel. Various versions of the analysis systems were realized for different applications. One option is to measure the food sample in a small glass container fitted with a lid containing the sensitive dye while also shutting out the light, while a second version of the device analyses the sensitive dye foil when it is simply held up against the food. This makes it possible to analyze a dye foil integrated in packaging.

Additionally, a smartphone app was also developed which will also allow the end consumer to precisely analyze the state of food in amine-sensitive packaging. Here a digital image is taken of the sensitive dye and then subjected to analysis. The camera fitted in the smartphone is used for this purpose, with an algorithm to calculate the color value. The app analyzes the result, compares it against a defined threshold level and informs the consumer of the state of the packaged food.
POLYTRONIC TECHNOLOGIES AND MICRO-SYSTEMS

Research field

Polytronics is the production of electronic components in which active organic materials have a key role to play. The field has made significant advances in recent years and there are now a large number of components being developed such as organic solar cells, integrated polymer circuits and polymer sensors. The central issue of polytronics is the manufacture and integration of electronic functions using layering techniques. This is the continuation of a development in assembly and interconnection technology to increasingly replace rigid substrates such as printed circuit boards with flexible and thinner systems. The use of plastic foils is an obvious option here since they offer several advantages as a large-area substrate material. Firstly, they provide a large-area, low-cost substrate enabling the creation of flexible, bendable or rollable systems. This opens up a whole range of new applications in the area of OLAE (Organic and Large-Area Electronics) such as electronic paper,rollable displays and also in the area of sensors with applications such as “intelligent” floors.

Another important advantage of foils is the fact that they can be processed in rolls. This allows for techniques in which foils can be processed as a continuously through-fed substrate. This type of roll-to-roll technique enables highly efficient manufacturing methods, providing high production volumes especially in the area of low-cost electronics. A now classic example of this type of application is the manufacture of RFID systems in which aerial coils are printed and fitted using a through-feed method. However, the technique can also be used effectively in the field of medical technology, for example for the production of disposable sensor systems.

Competence

The Bavarian Polytronic Demonstration Center (BDP) was established in 2002 for the research field of polytronics and in recent years it has gradually been fitted with state-of-the-art near-production equipment for the microfabrication of foils. For research projects and development work contracted by industry there are machines which allow modular processing of foil sheets or rolls with a width of 210 mm. A microsystems engineering line is also available which enables production of microsystems on a substrate size of Ø150 mm in a cleanroom. This is used as a standard method of processing silicon wafers on a service basis, but it is also well suited to effective prototyping of foil processes under ideal environmental conditions. Current focus areas in R&D are functional integration via active materials such as organic semiconductors for manufacturing plastic transistors or integrated polymer circuits. Here the entire spectrum of integration options is represented, ranging from large-area, flexible wiring systems and the assembly of optical and sensor components in foil technology to producing organic printed circuits.
Project example 1: Multilayer and through-plating processes

Fraunhofer EMFT has many years of experience in the production of high-density wiring systems on foils with conductor path grids of 30 µm and less, allowing direct chip integration. However, several conduct path systems usually have to be applied to achieve an efficient layout and further increased packaging densities. Essentially there are two options here: a multilayer structure on one side of the substrate or use of the rear side of the foil for double-sided wiring.

A process technique has been developed for the latter which allows continuous manufacture using the roll-to-roll method. Key process stages here are boring vias, achieved by means of a combination of laser processing and plasma etching, and galvanic processes to create several copper conductor paths of several µm thick as well as the wall metallization of the through-platings.

It was possible to produce these successfully both by means of a multilayer thick film structure and in a front and rear-side set-up. In the latter, the boreholes had to be etched using a clean plasma etching process using the roll-to-roll method due to the fact that there were so many of them. Measurements taken at the thermogenerator chains confirmed successful processing, with the maximum error frequency level of 100 ppm.

Project example 2: Organic electronics

Alongside classic silicon technology, organic electronics is developing as an additional basic technology for the integration of electronic functions in everyday products. The main difference and benefit here is the direct manufacture of the components using layering techniques, thereby avoiding highly elaborate assembly stages. The applications range from simple, extremely low-cost transistors to complex circuits which are highly flexible (e.g. for rollable displays).

Research and development in organic electronics is currently focused primarily on two aims: to increase process capability and manufacturability to a level which will enable serial production and to significantly enhance the performance capacity of organic transistors. The two areas are covered by the projects COSMIC (ICT 247681) and POLARIC (ICT 247978) and funded by the EU. The main development objective of COSMIC is to create a complementary circuit logic, made possible by the new development of n-type semiconductive organic molecules. This complementary logic (CMOS) has already become broadly established in conventional IC technology. A breakthrough to higher manufacturability is also anticipated for organic electronics.
Through-contact chains for printed thermogenerator

Organic thin-film transistor with printed carbon electrodes

A breakthrough to higher manufacturability is also anticipated for organic electronics. The joint project COSMIC is examining various production platforms to address different levels of circuit complexity, depending on the method of substrate handling (carrier, sheet, roll). Fraunhofer EMFT develops these using the roll-to-roll manufacturing method for non-contact smart sensor applications.

The switching frequencies of an organic transistor currently cover a range up to 100 kHz, depending on the manufacturing method used. In addition to the semiconductor material, this key parameter mainly depends on geometric dimensions. It is for this reason that miniaturization of organic components in the μm and sub-μm range is so crucial. However, the problem is to achieve this with low-cost production. The project POLARIC addresses this challenge by means of novel structuring techniques such as nanoimprinting and microcontact printing. The contribution of Fraunhofer EMFT to this joint project is the development of the microcontact printing and ultrathin polymeric dielectric layers. When scaling transistor geometry to smaller dimensions, particular importance is attached to the dielectric medium for gate insulation, since error-free electrical insulation and a high voltage rating have to be ensured with increasingly thin layers. Currently it is possible to produce layers with a thickness of 200 nm and an extremely high level of dielectric strength.
Project example 3: Optical sensor systems

The research project PolyOpto successfully demonstrates the functional integration possibilities of polytronics and the simplification of assembly and interconnection technology which can be achieved by foil system technology. In this system, the individual components for an optical sensor system - light source, photo transistor and fluid channel - are produced on foil using layering techniques. The light source used here is an electroluminescence component made by means of multilayer screen printing. An organic transistor based on TIPS pentacene as a semiconductor serves as a light-sensitive detector. The two components are produced on the same foil surface, with several coating processes used for each. The ultimately three-dimensional arrangement of the sensor system is achieved by folding over the foil, causing the light source and phototransistor to be horizontally opposite each other so that they can be optically coupled. This means that changes in the optical absorption between the components can be electrically detected and measured. Sensor layers can be inserted in the absorption path for this purpose. In this particular case, laser processing of foils was used to create a fluid channel enabling a change in optical absorption in fluids to be detected.

Since this optoelectronic system can be almost entirely created without the assembly of individual components and using a one-sided process only, it is well suited for use in a low-cost, disposable sensor system, e.g. in the field of environmental analytics or medical technology. Roll-to-roll production is essentially possible too, increasing manufacturing efficiency so as to be able to handle large volumes.

This research is funded by the sponsors German Federal Ministry of Education and Research (BMBF) and VDI/VDE Innovation + Technik GmbH, Project PolyOpto FKZ 16SV3870.
ANALYSIS AND TEST OF INTEGRATED SYSTEMS

Research field

Electrical and physical tests of varying complexity are applied to establish whether or not an electronic component meets specified requirements. The limits are defined by characterization tests. The manufacturing process of the component is controlled by means of interim tests on special test structures and on the component itself. In addition, reliability and robustness have to be tested.

Durability tests adapted to the respective application address fault mechanisms and allow modeling and lifetime prediction. Insights from such tests are increasingly drawn up not just for design and processing but also for in-situ monitoring of operating states, providing advance warning of malfunction. In addition to experience, high-capacity chemical-physical analysis of functioning and defective components is required for the correct localization and interpretation of error symptoms.

Competence

For over 20 years, Analysis and Test of Integrated Systems (ATIS) has provided support for the development of manufacturing processes and design rules in industrial cooperations, searching for the cause of failure in components (LED, IC, MEMS, ...) and systems. The multidisciplinary experience and methodological expertise of the core team along with a worldwide network of experts allow even complex problems to be solved methodically. The focus is on protection from and identification of electrostatic discharge and electrical overload.

Modular test systems for pulsed ns-range high-current characterization VF-TLP and ESD qualification according to the Charged Device Model (CDM) have been developed and applied both for internal use and for industrial clients. Network analysis up to 110 GHz and ps measuring technology is applied in combination with simulation tools for linear and non-linear characterization of components and transmission lines.

A Fraunhofer EMFT miniature climatic chamber with a volume of 160 cc allows multiparametric characterization and observation of miniaturized components by means of windows and electrical feedthroughs.

ESD qualification of integrated circuits using the Charged Device Model (CDM) mainly suffers from a lack of reproducibility of air discharge, inaccuracies of impulse measurement technology and not least a low level of test efficiency.

The modular automatic ATIS testing system was refined based on a wafer sampler made to the specifications of industrial clients. It not only allows load currents to be applied according to existing standards by means of air discharge but is also capable of identifying CDM weak points with a higher degree of reproducibility and precision by means of capacitively coupled transmission line pulsing (CC-TLP).

Here the discharge is effected in a relay after the contact has been made with wafer sampler precision. Complete database integration from the housing to the test parameters and load currents and their extracted parameters significantly increases test efficiency. The large, easily accessible electrode also permits application of current to special designs including printed circuit boards.
Project example

At data transfer rates of several tens of GHz, bandwidth and signal quality are mainly determined by dispersion, which means signal transmission on the transmission lines depends on frequency. Rosenberger Hochfrequenztechnik GmbH based in Tittmoning, one of the world market leaders in the field, contracted the Fraunhofer EMFT to carry out comparative studies of low-dispersion, impedance-controlled lines on flexible foil substrates. Here the Fraunhofer EMFT’s semiadditive ultradine conductor technology was compared to commercial etched lines and measurements were validated by means of simulation and physical analyses.

The conventional subtractive circuit board process involves oxidization of a thin copper foil in order to increase adhesive strength, after which it is laminated onto the foil substrate. Surface roughness in the copper foil is embossed into the substrate. This copper layer is photolithographically structured, wet-etched and coated with nickel and gold without electrical current. Fraunhofer EMFT’s semiadditive process derived from thin-film technology uses a thin copper layer which is sputtered onto an adhesive layer in a vacuum for full area coverage so as to deposit copper in photolithographically created coating grooves. The coating is then removed and the foil is etched back onto the blank polyimide with raised conductor paths. This creates lines with a particularly high resolution of up to 10 µm width and spacing with very steep and precise slopes.

Resonator test structures are used to determine fundamental material properties. Microstrip, coplanar and grounded coplanar of differing lengths were created on polyimide foil substrates with a thickness of 50 µm.

The electrical characterization of Fraunhofer EMFT grounded coplanar microstrip lines with a conductor width of 100 µm and 60 µm spacing in the frequency range up to 67 GHz provides a 3dB bandwidth four times larger of 40 GHz. The much flatter group delay curve in the frequency range up to 20 GHz, corresponding to information transmission speed, promises a significantly improved bandwidth and transmission characteristics of the lines created using Fraunhofer EMFT technology. The eye pattern crucial for telecommunications technology and functional testing of integrated circuits remains open, thereby ensuring more robust systems.

The most important causes of these differences are the thickness of the conductor paths and in particular the roughness of the surface, which is a result of the process.
MANUFACTURING AND HANDLING TECHNIQUES FOR VERY THIN SEMICONDUCTOR SUBSTRATES

Research field

Many microelectronic products require an increasing reduction in the thickness of their semiconductor components. This includes silicon chips for the application areas of power electronics, solar cells, 3D-integrated chip stacks, micromechanical sensors (MEMS) and also very thin silicon components as have been used for many years in smart labels for logistics applications and identification systems. A whole new field of applications is now opening up with the development of multifunctional electronics applied to flexible foil substrates.

Competence

Fraunhofer EMFT develops new manufacturing and handling techniques for very thin silicon wafers. The thinning techniques include mechanical grinding, wet chemical and dry chemical etching as well as polishing processes (CMP: chemical mechanical polishing). The selection of processes for wafer thinning is based on insights gained from material analytics and the flexure and fracture response of thinned semiconductor substrates, as developed at the Fraunhofer EMFT over many years. A further important aspect is the hip separation technique for extremely thin semiconductor wafers. Here Fraunhofer EMFT offers the patented technique of „Dicing-by-Thickness“, enabling efficient manufacturing of single ultra thin chips with optimum resistance to bending. With these techniques it is possible to manufacture thin flexible silicon components with a thickness of 10 µm – 30 µm. Given the institution’s lab equipment and technological experience in the field of polytronic technologies, especially roll-to-roll manufacturing, Fraunhofer EMFT has at its disposal a unique technology platform for the development of multifunctional electronic systems.

Mobile electrostatic carrier

With its patented concept of the mobile electrostatic carrier, the Fraunhofer EMFT offers a technical solution which enables simple and secure handling of very thin semiconductor wafers. The so-called ‘e-carriers’ draw on electrostatic forces to reversibly fix a fragile circuit substrate. The carrier itself consists of a silicon wafer, while the electrode surfaces on the front can be electrically charged and discharged by means of through silicon via (TSV) technology by contacting surfaces on the back. In 2011 these carriers were also applied to silicon wafers with a diameter of 200 mm for the first time (see picture) with bipolar electrode configuration.

Project example: Structuring and interconnection technologies for flexible foil systems

The project Interflex, sponsored by the EU as part of the Seventh Framework Programme, targets the development of structuring and interconnection technologies for multilayered, flexible foil systems. The focus here is on assembly techniques which allow both mechanical and electrical bonding of thinned silicon ICs (for instance radio chips), as well as large-area components such as foil sensors, foil batteries and foil-based solar cells with a flexible foil substrate as a wiring level. For example, Fig. 2 shows the foil-mounted radio module used for wireless data transfer. This picture impressively demonstrates the difference in height between the conventionally fitted SMD components and the laminated silicon radio chip in the middle with a thickness of just 25 µm. The aim in the future will be to replace SMD parts with flat, printed components, for the first time allowing flexible, flat electronic systems with...
a virtually plane-parallel form factor.
A number of different through-plating techniques have been developed so as to be able to interconnect several wiring foils. So-called viafill technology allows two foils which have been laminated to each other to be electrically connected by filling laser-drilled via holes with a conductive material. Another viafill technology in which the via holes are selectively filled by means of a sputter process combined with a masking process allows the realization of wiring foils with front and rear-side metallization and through-plating. The manufacturing process for complex microelectronic foil systems can be simplified by means of homogeneous integration of the passive components, obviating the need for subsequent application of SMDs. Printing techniques are being developed for this purpose which enable resistances to be applied directly to the wiring foil, for example. The technological challenge lies in adhering to the required tolerances even with these printed components. Extensive studies have been carried out to evaluate the reliability of the newly developed packaging technologies, especially under flexure stress.

By way of a demonstrator, a flexible sensor system is being developed which allows various air parameters to be measured in interior spaces. The demonstrator is powered by a flexible photovoltaic module, the power for which is stored in a flexible battery. There are four sensors to measure temperature, dew point, air humidity and CO$_2$ concentration. The sensor system communicates with its environment via a flexible RF module which is also integrated in the system. The entire system is to be approximately the size of an A4 sheet and allow a bend radius of 5 cm. The project partners are Robert Bosch GmbH, CEA, ST Microelectronics, Henkel AG, Infotech and the Fraunhofer EMFT. The project is due to continue until the end of 2012.
SURFACE STRUCTURING AND SELF-ASSEMBLY

Research field

The assembly of very small electronic components in large numbers, for example for RFID labels (item tracking), will in future require new technical concepts to supplement or replace today’s pick and place assembly. An interesting new approach for concept for component placement is that of self-assembly techniques for silicon chips. Fluidic self-assembly techniques use capillary forces to position, align and electrically contact components. This requires techniques for surface programming which allow selective wetting of predefined surface areas.

Competence

The Fraunhofer EMFT focuses on research into plasma-based techniques for surface programming, applying these to production-oriented, fluid-based self-assembly techniques for assembling and contacting microelectronic modules on foil substrates. The self-alignment process for these types of components is based on preprogrammed wettability of liquids on a substrate (foil or wafer) which has structured metal surfaces in an otherwise polymeric environment. A homogeneous fluorine plasma allows selective wettability of aqueous media on metal target areas. If a thin chip is then dropped onto the assembly medium, the surface tension forces cause the chip to move into a position of minimum surface energy. This is achieved when the chip is precisely centered on the target area.

In 2011 a test series was carried out to evaluate the impact of sample thickness and size on the self-alignment precision of thin silicon chips on a programmed base substrate. To this end, silicon wafers were prepared with special alignment marks, thinned to target thicknesses of 25 µm to 100 µm and separated by means of plasma-etched grooves according to the dicing-by-thinning concept. The structuring technique also allows chip sizes to be varied with a range of 1 mm x 1 mm to 10 mm x 10 mm. Silicon wafers with the appropriate target areas (metal pads) and complementary alignment marks were also produced as the base substrate for the alignment tests. The tests showed that for certain chip sizes, it was possible to achieve self-alignment accuracy in the 1 µm range.

Project example: Sensor filters

Surface structuring on foil substrates is a technological focus in the field of polytronic systems. The following report relates to the development of a novel microfilter stack which is capable of monitoring its current load state. The microfilters previously used in technical systems do not allow simple detection of filter content or clogging of the filter membrane. Only filters with an advanced degree of clogging can be detected due to the pressure drop in the system. However, for many applications it would be desirable to monitor the load process of a microfilter and record the results on an online basis. This would enable clogging to be prevented or the state of the filter to be monitored, for example. What is more, the integration of a sensor allows characterization of the filter load process and therefore process monitoring.

Monitoring of load processes is achieved by means of a sensor filter by combining sensorics and filter technology in a foil layer system (foil MEMS). This sensor filter consists of two sensor foils with capacitive electrode structures (interdigital capacitors) and a filter membrane (sensor filter stack) placed in between which is specifically tailored to the application. The sensor foils bearing the electrodes are perforated so that the medium can flow through the sensor filter stack.
Here, the hole geometry is adapted to the spacing of the electrode fingers. During operation, the cells and/or particles caught in the filter alter the dielectric/electric properties of the through-flowing medium on the flow side of the filter, thereby allowing capacitive measurement of the load state. In principle the method can be used to selectively measure the filtered substances.

A specialized micromeasurement chamber was constructed at the Fraunhofer EMFT to characterize the filter stacks. This set-up allowed capacitive monitoring of polystyrene beads (10 µm Ø or 1 µm Ø) and yeast cells in a microfilter (pore size 0.4 µm). The sensor filter can be integrated in technical facilities and microfluidic systems for online measurement and offers a wide range of uses: monitoring of filter content and state of the microfilter, collection and concentration of substances in sensor filter modules and their subsequent analysis. This additional benefit opens up a wide range of potential applications in the areas of life sciences / cell culture, process control and production monitoring, for example in fermentation and food technology. Application to gas filtration is likewise conceivable.

The project was funded by the German Federal Ministry of Research and Technology (FKZ 16SV5019, project executing organization VDI/VDE IT, Berlin).
Research field

The research field is mainly focused on optical sensors consisting of dyes which are stably bonded to polymer layers or particles. The dyes used are able to indicate the presence of certain analytes by changing color or fluorescence. This enables for carrying out qualitative and quantitative analyses of oxygen, carbon monoxide, biogenic amines, various ions and relevant biomolecules. The appropriate sensor materials can also be used for 3D imaging of pressure and temperature on the surfaces of motor vehicles and machines. Furthermore, the sensors are used in medical diagnostics, biotechnology, environmental analytics, process characterization and product authentication, for example by integrating fluorescent indicators in production goods for the purposes of verifying their identity. In the textile industry, sensor materials are becoming increasingly important: examples here include protective clothing in the field of occupational safety which displays contamination with aggressive acids or bases. The integration of freshness sensors in food packaging (especially fish and meat) continues to be highly important in terms of the fact that frequent “rotten meat” scandals in past years have damaged consumer trust.

In biomedical research, the use of fluorescent nanosensors is relevant since the nanosensors are so small they can be integrated in living cells without causing damage. They enable continuous detection of biorelevant molecules such as ATP, saccharides and pH level. When printed on foil, the nanosensors can also be used as test strips, reflecting the sheer diversity of their potential applications.

Competition

The Fraunhofer EMFT is experienced in the development of tailor-made sensor dyes to detect ions and biomolecules as well as their stable immobilization on surfaces of varying textures. For example it is possible to selectively develop new indicator dyes which meet the relevant requirements in terms of stability and optical properties and plan the relevant synthesis strategies. The receptor-analyte reactions of the dyes and their absorption properties (color) can be adapted to the intended application or client request. Immobilized in an appropriate polymer, the dyes can be applied to foil on a large scale using a wide range of fabrication techniques including inkjet and screen printing, dispensing, web coating or spray coating by means of the Fraunhofer EMFT roll-to-roll technologies. In this way, the sensor materials can either be printed on a large-area basis with a very regular coat thickness or else be finely structured. The latter option allows sensor array systems to be developed which are able to detect various analytes within a minute space.
Project example: Manufacture of a sensor for foodstuff packaging

Techniques can be used for the structured application of print media containing sensor material which produce drops within the microliter and nanoliter range and place them on a substrate surface with high precision. Examples of this include the widespread inkjet printer, large-scale industrial printers and microdispensers used especially in the field of medical technology and biotechnology. Inkjet printers are able to print tiny drops on a picoliter scale, while the minimum dosage volume for microdispensers is in the nanoliter range.

In this particular example, sensor materials were developed to monitor the freshness of foods. Firstly a polymer solvent mixture was developed with suitable viscosity, then sensor dyes or sensor nanoparticles were added. The print medium then underwent structured application to a substrate using the microdispenser. Once the solvent evaporates, the dyes or nanoparticles are immobilized in polymer spots bonded to the substrate surface. The polymer spots should preferably be of constant layer thickness across the entire cross-section and the surface should have an even profile in order to ensure that measurements are reproducible.

If the relevant analytes are present, the fluorescence or color of the sensor elements in the polymer matrix changes. Spectroscopic methods can then be used to quantify the color change, and the measurements can be used directly to determine analyte concentration after calibration. The color change in the sensor element can also be seen with the naked eye, making it easy for the consumer to monitor food freshness.
Automated fluidic characterization of 200 micropumps on wafer stack
In addition to organizing scientific events on its own premises, the Fraunhofer EMFT is also represented at numerous external events with talks, presentations and demonstrations. The institution regularly presents its research and development work at international trade fairs and congresses, for example. Such events serve to attract new industrial projects and cooperation partners, as well as allowing an exchange of information with potential clients, interested members of the public and experts from other scientific institutions.

Examples of our events:

- The cooperation forum “Innovations in microsystems and system integration – from technology to product” was held at Fraunhofer EMFT on May 10, 2011. Organized in collaboration with Bayern Innovativ, the forum featured insights into potential future developments in the field of system integration in microsystems engineering, presented by prestigious speakers from various research institutes and companies. Examples of applications in medicine and healthcare, communication and mobility, energy and industry as well as the environment and drive systems reflected the practical orientation of current developments.

- Fraunhofer EMFT opened its doors to interested members of the public for the “11th Munich Science Days” on October 25, 2011, focusing on the theme of “The Challenge of Health”. The results of research such as “Biochip systems for protein tests” and “Optical systems to measure blood clotting” were presented to visitors in the form of an exhibition. Guided tours through the institution provided further insights into the work of the Fraunhofer EMFT.

- The cooperation forum entitled “Textile and sensors” was held on October 25, 2011 on the premises of the Fraunhofer EMFT in Regensburg. The event was organized in collaboration with Bayern Innovativ and addressed a range of topic focus areas relating to the integration of microsystems engineering and sensors in textiles.

- On October 26, 2011 the Fraunhofer EMFT collaborated with Bayern Innovativ to organize the workshop “Medication dosage systems”. The efficient transport of a pharmaceutical to its site of action by means of innovative drug delivery systems improves both effectiveness and tolerance in patients. Numerous key medical technologies are used in the development of these systems - from microsystems engineering to materials science and nanotechnology. The workshop presented technological innovations from various areas of application of drug delivery, including solutions from Fraunhofer EMFT for medication dosage.

- The workshop “Advanced Packaging Trends for Medical Electronics”, organized by Fraunhofer EMFT in collaboration with Techsearch Inc. on November 14, 2011, was attended by guests from Europe, the USA, China, Taiwan and Japan. The presentations examined various aspects of microelectronics and microsystems engineering in relation to medical applications.

- The „be-flexible“ forum, which has been run by the Fraunhofer EMFT for over 10 years, was once again held in Munich on November 23 and 24, 2011. 120 participants attended the two-day event to find out about and discuss the latest R&D results in the areas of thin semiconductor devices and flexible electronic systems.
In order to support partners and customers, the Fraunhofer EMFT offers seminars for professional development, training and information purposes which are either open to the public or else can be exclusively tailored to companies’ needs as in-house training programs.

Here is a small selection of topics:

- ESD Device & Design Seminar: basics of characterization of integrated circuits in relation to electrostatic discharge
- Microfluidics for cells
- Training in cleanroom technology and cleanroom practice, in cooperation with VDI and TÜV SÜD
- Manufacture and handling of thin silicon wafers
- Tensile strength testing of semiconductor materials
- Self-assembly and surface programming
- Nanoparticle production and characterization
TRADE FAIRS

**Selection 2011**

**Smart Systems Integration**  
Dresden, March 22 - 23, 2011

**Life Science Forum**  
Garching, March 23 - 24, 2011

**Printed Electronics Germany**  
Düsseldorf, April 5 - 6, 2011

**Techtextil 2011**  
Frankfurt am Main, May 24 - 26, 2011

**Sensor + Test**  
Nuremberg, June 7 - 9, 2011

**LOPE-C**  
Frankfurt am Main, June 28 - 30, 2011

**Printed Electronics**  
Dresden, October 11 - 13, 2011

**Productronica**  
Munich, November 15 - 18, 2011

**Compamed**  
Düsseldorf, November 15 - 19, 2011

**Selection 2012**

**3rd Landshut Symposium for Microsystems Engineering**  
Landshut, March 13 - 14, 2012

**Smart Systems Integration**  
Zurich, March 21 - 22, 2012

**Hannover Messe**  
Hannover, April 23 - 27, 2012

**Sensor + Test**  
Nuremberg, May 22 - 24, 2012

**LOPE-C**  
Munich, June 19 - 21, 2012

**1 Smart System Integration, Zurich 2012**

**2 Hannover Messe, Hannover 2012**
Visits by school and university students

Many school and university students - both from Bavaria and from all over the world from Europe to Asia - visit the Fraunhofer EMFT every year to find out about the institution’s work. The young visitors are not only interested in the technologies and current research topics, they are also keen to find out about scientists’ assignments and working conditions. By selectively inviting school and university students of different ages and disciplines, the Fraunhofer EMFT is able to inspire potential future staff, thereby helping to counter the lack of specialists in technology and science which is anticipated in the future.

Work experience for school students

Fraunhofer EMFT also offers 5-day work experience placements for school students. Here the institution cooperates with various high schools, lower secondary schools and comprehensive schools in Munich and the surrounding area. In March 2012, students from the Willy-Brandt-Gesamtschule and Samuel-Heinicke-Realschule visited the Fraunhofer EMFT in Munich to get a first-hand impression of the institution’s work and the everyday working lives of scientists with a mixture of talks and practical tasks in the lab.

Talent School

In the Fraunhofer-Gesellschaft Talent Schools, scientists offer a range of workshops for young people with an interest in technology who enjoy tackling current scientific issues. Discussions with Fraunhofer management team members provide insights into the everyday work of scientific researchers, both nationally and internationally.

As in past years, a Talent School was once again held by the Fraunhofer EMFT in 2011, this time under the title “Utopia of moving images - on wallpaper, on the cornflakes packet or in a photo album” with 12 school students selected to take part from all over Germany. After an intensive weekend involving both theory and practice in the labs of the Fraunhofer EMFT, the youngsters were able to take away with them an organic electronic display which they had created themselves.

PROMOTING WOMEN IN MINT PROFESSIONS

One of the purposes of career orientation weeks at the Fraunhofer EMFT is to train school girls to be contributors for other youth development projects. They are then able to go on and share their knowledge with other girls. The following activities in 2011-2012 were especially aimed at building enthusiasm for careers in technology and science among women.

Girls’ Day

Girls’ Day was once again held at the Fraunhofer EMFT, this time under the title “Chip cards and intelligent labels - an introduction to the world of microsystems”. Four school girls were given the opportunity to find out about the world of microdimensions in electronics at the Fraunhofer EMFT. They discussed the use of radio chips, sawed wafers into microchips and visited a cleanroom where they carried out spin coating.
Shadowing Day

Another interesting program in which the institution participates is the Shadowing Day organized by the European Commission in collaboration with leading companies with the aim of combating the lack of women taking up careers in the field of information and communication technologies (ICT) and showing young women that ICT is not just for computer freaks. Information technology is everywhere: it enriches our lives, connecting people all over the world - everywhere and all the time. It even helps save lives! Yet there are still not enough young people opting for a career in information and communication technologies - in particular, there are too few women.

In 2011, as in previous years, a school girl once again shadowed a female scientist for an entire working day, later reporting on her experiences in Brussels.

Girls from Memmingen find out about the activities of the Fraunhofer EMFT

Female teachers with a group of 53 girls from two Memmingen high schools came to the Fraunhofer EMFT on July 13, 2011 to attend an information day. In addition to a guided tour of the institution, there was also a thematic focus on specific questions. These were: What does it mean to work for the Fraunhofer-Gesellschaft and at the Fraunhofer EMFT, Microsystems Engineering division? In which areas are technologies developed at the Fraunhofer EMFT put to use? What activities does the Fraunhofer-Gesellschaft run to attract more female scientists? Aid for diabetics - faster tumor detection - how does an EU project work? The girls were provided with answers to these questions by two female engineers who work at the Fraunhofer EMFT.

The girls had the opportunity to find out about current work going on at the institution with examples from silicon technology and foil electronics presented at a demonstration table. The visitors were especially interested in the personal careers of female staff at the institution and were keen to find out why they opted to study engineering.

An overview was also provided of the institution’s longstanding activities aimed at encouraging girls to take an interest in technology. After the successful Girls’ Technology Congress at Kempten University in 2010, a range of other regional activities are to be offered for girls in rural areas. The aim is to instill lasting enthusiasm for technical and scientific themes and careers among girls at an early stage.
Foil sensor for the detection of CO₂ in the air
Rotes Signal bedeutet: Der Zelle geht’s schlecht


MÜNCHEN (eb), Forscher der Fraunhofer-Institut-Einrichtung für Medizinische Fertigungstechnologien EMFT in München haben eine Alternative zu Tierversuchen entwickelt. Mit neuentwickelten Nano-Oligonukleotiden wollen sie die Zahl der Tiereexperimente verringern.

Wir testen Chemikalien quasi im Reagenzglas auf ihre Wirksamkeit und ihr Risikopotential. Hierfür setzen wir lebende Zellen, die aus menschlichem und tierischem Gewebe isoliert und in Zellkulturen gezüchtet werden, der zu untersuchenden Substanz aus, erläutert Dr. Jennifer Schmidt vom EMFT. In einer Mitteilung der Fraunhofer-Gesellschaft ist der Wirkstoff in einer befristeten Konzentrationsprüfung für die Zelle, steht sie. Diese Änderung des "Weltbildvermögens" lässt sich mit Sensor-Nanopartikeln sichtbar manifestieren.

"Die Zellen speichern bekannterweise Energien in Form von ATP (Adenosintriphosphat)." Das nachwachsende Millennium der ATP-Gesellschaft ist der Wirkstoff in einer befristeten Konzentrationsprüfung für die Zelle, steht sie. Diese Änderung des "Weltbildvermögens" lässt sich mit Sensor-Nanopartikeln sichtbar manifestieren.


Beim Studium des Verhaltens der Zellgliederung können wir das Adenosintriphosphat detektieren und analysieren, in welchem Gesundheitszustand sich Zeilen befinden.

Diese neuen Nanopartikel sind einzigartig. Sie speichern weniger ATP und sind durch ihre hohe biologische Aktivität und Sensitivität für vernetzte, aber auch von singulärem ATP einzigartig.

Im Vergleich zu konventionellen Sensoren, die auf chemische oder physikalische Reaktionen reagieren, sind diese Nanopartikel auf Adsorptionseigenschaften von ATP in der Zelle spezialisiert. Sie können ATP in lebenden Zellen detektieren und quantifizieren, was zu einer verbesserten Verständnis der Zellinteraktion und des Stoffwechsels in der Zukunft führen wird.

Diese Technologie bietet eine revolutionäre Methode für die Studie von Zellinteraktionen und der molekularen Veränderungen in lebenden Zellen. Diese nanosensorischen Techniken eröffnen neue Perspektiven für die medizinische Forschung, die Pharmazeutik und die Pharmakologie.

**Arztezeitung**

**January 19, 2012**

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**VDI nachrichten | 16.12.2011**

Der Röntgenblick entdeckt gefährliche Stoffe

**Forschung: Röntgendetektoren können gefährliche Stoffe blitzschnell und mit besonders hoher Messgenauigkeit detektieren. Sind die Geräte zudem klein, genug, lassen sich sie sogar zu jedem beliebigen Ort aussetzen. Das macht sie interessant für die Materialprüfung beim Recycling, die Überwachung von Luft- und Wasserparametern oder die Qualitätssicherung von Nahrungsmitteln.**

VDI nachrichten, München, 16.12.2011


Wie die Forscher beschreiben, sind die Entwicklungsfelder dieses neuen Messgerätes besonders interessant, insbesondere für die Automobilindustrie, die Bauwirtschaft und die medizinische Forschung. Die Röntgenmikroskopie ermöglicht es, Details von Objekten mit hoher Auflösung zu erfassen, was die Fehlerdiagnose und die Qualitätssicherung enorm verbessert. Darüber hinaus kann das Gerät auch in der medizinischen Bildgebung eingesetzt werden, um Details von Geweben oder Organen mit hoher Genauigkeit zu erfassen.

**Danksagung:**


**Literatur:**


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**VDI nachrichten December 16, 2011**

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Überraschung im Messlabor

Es gibt Momente, da trau-
en Forscher ihren eigenen
Augen nicht: Dr.-Ing. Hein-
rich Wolf (44) von der Fraunhofer-
Einrichtung für Modulare Festkörper-
Technologien EMFT hat so ei-
en Moment erst vor Kur-
zem erlebt – als ihm seine
Messgeräte anzeigen, dass
die neu entwickelten Hoch-
frequenceleitungen gleich
viermal so viele Daten pro
Sekunde transportieren
cönnen wie ihre herkömm-
lchen Pendants! Wolfs posi-
tives Ergebnis war-
wartet, aber dass es gleich so
gut war, machte ihn skepti-
sch. Er überprüfte die Ver-
suchsanordnung, wieder-
holte die Messung, tauschte
sich mit Kollegen aus – und
schließlich wandelte sich die
Skepsis in Freude und Stolz.

Kein Wunder; Die Neu-
entwicklung – eine extrem
flache und flexible Leitung,
die man zusammenrollen
cann wie ein Stück Folie, hat
eine Menge Potenzial. Die
blitzschnelle Signalübertra-
gung kann zum Beispiel in
der Mobilfunktechnik zum
Einsatz kommen.

Wolf hat sie in Zusam-
menarbeit mit Rosenberger
Hochfrequenztechnik er-
arbeitet. Das Unternehmen
aus Fridolfing zählt welt-
weit zu den führenden An-
bietern von Hochfrequenz-
Koaxial-Steckverbindern.

Und genau das fasziniert
wolf: „Wir arbeiten hier
das Elfenbeinterrain, und
wir sind sehr nah an der Rea-
lität.“ Das wäre Wolf natürli-
ch auch, wenn er direkt in der In-
dustrie arbeite. Außerdem
würde er wohl auch
mehr verdienen – doch die
Freiheit, die er bei Fraunhofer
hat, ist ihm wichtiger. „Die för-
dert die Kreativität."

Technik ist für Wolf übri-
gens nicht nur Arbeit, sondern
auch Freizeitvergnügen: „Ich
habe erst vor Kurzem unsere
Waschmaschine repariert“, erzählt
der Familienvater schmunzelnd. Musik macht er
dauch, natürlich auch
elektronisch – mit einem
Synthesizer.

Und gibt es ein Rätsel,
das er gerne lösen würde?
„Ich wüsste gern“, meint er
nach kurzem Nachdenken,
„wie man die Schwerkraft
in den Griff kriegt. Auf ei-
mem Antigravitations-
Schild davon zuschweben,
das wäre doch eine tolle Sa-
che.“ Vielleicht wird ja auch
diese Vision einmal im
Rahmen der Forschung bei
der Fraunhofer-Gesell-
schaft wahr.
Nanotechnik soll Tierversuche ersetzen


Saarbrücker Zeitung February 2, 2011
Der harte Weg flexibler Innovationen

Mittelbayerische Zeitung / Mittelbayerische Zeitung für Regensburg (Hauptausgabe und Stadt Regensburg) / 25.10.2011

**Innovation Ein Shirt mit Pulsmessung, ein Teppich, der erkennt, ob ein Einbrecher auf ihn tritt - in Regensburg tagte die High-Tech-Textilienbranche.**


Diesen langen Weg beschrieben den Kopf des Philips-Konzerns, Dr. Stefan Sulzmann, am Beispiel einer Spezial-Decke für Babys mit Neugeborenschutz. Viele der von diesen Phänomenen betroffenen Kinder benötigen als Therapie die Bestrahlung mit blauem Licht. Trotzdem kann die spezifische Anwendung gefährdet und die Temperaturhauptsache von Neugeborenen durchmachen.


**Projekte für Schülerinnen**

Sabine Scherbaum gab einen Überblick über die langjährige Münden-Tech-Projekte am Institut und die Weiterentwicklung der Fraunhofer-Universität Darmstadt. Damit war die Zeitreise der Schülerinnen von derzeit 1.9 Prozent nachhaltig um eine halbe Minute gestoppt.

**Schülerinnen besuchen Technik-Labor**

Memminger Detaillierter Überblick über die Forschungsarbeiten am Institut und die Unterstützung der Schülerinnen mit den Innovationen der Industrie.

Memminger Zeitung

July 30, 2012

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Mittelbayerische Zeitung October 26, 2012
Nanosensor statt Tierversuch


Die Medien fordern eine schnellere Entwicklung von Alternativen, doch Tierversuche bleiben in vielen Fällen unerlässlich. Die Forscher sind jedoch unter Druck, sich auf andere Methoden zu konzentrieren.

Medizin

Der veraltete Polizei

Inkremental Schmerzerleichterung

Gegen Schmerzen können Medikamente am besten oder Chemikalien...

Handelsblatt January 12, 2012
Micromechanically processed wafers for high-frequency applications
ACADEMIC PUBLICATIONS AND TALKS

Publications (selection 2011)

Senft, C.; Iskra, P.; Eisele, I.; Hansch W.
Work Function-Based Gas Sensors: Schottky and FET-Based Devices

Growth of Highly Textured Aluminum Films on LiTaO3
Thin Solid Films 519, 2011

Landesberger, C.; Paschke C.; Bock K.
Influence of wafer grinding and etching techniques on the fracture strength of thin silicon substrates

Velten, T.; Bauerfeld, F.; Schuck, H.; Scherbaum, S.; Landesberger, C.; Bock, K.
Roll-to-roll hot embossing of microstructures
Microsystem Technologies 17, pp. 619-627, 2011

Quantitative analysis of energy transfer between fluorescent proteins in CFP–GBP–YFP and its response to Ca2+

März A.; Trupp S.; Rösch P.; Mohr G. J.; Popp J.
Fluorescence dye as novel label molecule for quantitative SERS investigations of an antibiotic
ANALYTICAL AND BIOANALYTICAL CHEMISTRY, DOI: 10.1007/s00216-011-5273-z (2011)

Nebrich, L.
Der Röntgenblick entdeckt gefährliche Stoffe
VDI-Nachrichten December 16, 2011

März A.; Trupp S.; Rösch P.; Mohr G. J.; Popp J.
Fluorescence dye as novel label molecule for quantitative SERS investigations of an antibiotic
ANALYTICAL AND BIOANALYTICAL CHEMISTRY, DOI: 10.1007/s00216-011-5273-z, 2011

Escudero D.; Trupp S.; Bussemer B.; et al.,
Spectroscopic Properties of Azobenzene-Based pH Indicator Dyes: A Quantum Chemical and Experimental Study
JOURNAL OF CHEMICAL THEORY AND COMPUTATION
Volume: 7, Issue: 4, pp.1062-1072, DOI: 10.1021/ct1007235

Klumpp, A.; Ramm, P.; Frant, G.; Rue, C.; Kwakman, L.
Reliability Testing and Failure Analysis of 3D Integrated Systems
Proc. Interconnect Technology Conference - IITC, 2011

Publications (selection 2012)

Garrou P.; Jian-Qiang Lu, J.; Ramm, P.
Three-Dimensional Integration

Klumpp, A.; Nebrich, L.; Eisele, I.
Heterogene Systemintegration von Halbleitersensoren
Ramm P.; Lu Jian-Qiang; Taklo M.M.V. (Eds.)
Handbook of Wafer Bonding

Klumpp, A.; Ramm, P.
Temporary Adhesive Bonding with Reconfiguration of Known Good Dies for Three-Dimensional Integrated Systems

Landesberger, C.; Klumpp, A.; Bock, K.
Temporary Bonding: Electrostatic

Endres, H.; Alberti M.; Landesberger C.
Intelligenter Mikro-Filter in Folientechnologie für Anwendungen in Prozesskontrolle und Zellkultur
Sensormagazin, March 2012, p. 38

Nettinger, K.; Schaber, U.; Drost, A.
Anwendung des Plasma-Ätzens in der Rolle-zu-Rolle Prozessierung von Folien

Nebrich, L.; Wiest, F.; Eisele, I.
Highly Sensitive Radiation Detectors for Medical Applications
Proc. Smart Systems Integration, Zurich, 2012

Nebrich, L.
X-ray detectors to discover dangerous substances
Fraunhofer VuE Microelectronic News, March 2012, p.11

Talks (selection 2011)

Nebrich, L.; Fojt, R.
Optical and x-ray detectors
Cooperation forum "Man and Microsystems", Munich, Germany, February 16, 2011

Large area multilayer foil assembly for flexible electronic systems
Smart Systems Integration 2011, Dresden, March 22-23, 2011

Bock, K.
System integration in foil substrates,
Invited talk, Folie und Fahrzeug, February 16 - 17, 2011, conference at Wolfsburg Hanser Verlag

Application of the SLID-ICV Interconnection Technology for the ATLAS Pixel Upgrade at SLHC
Ramm, P.; Klumpp, A.; Franz, G.; Kwakman, L.  
**Failure Analysis and Reliability of 3D Integrated Systems**  

**Application of the SLID-ICV Interconnection Technology for the ATLAS Pixel Upgrade at SLHC**  
Proc. IEEE 3D System Integration Conf.– 3DIC 2010, Munich, April 2011

Hedler, H.; Scheiter, T.; Schieber, M.; Klumpp, A.; Ramm, P.  
**High Performance 3D Interconnects Based on Electrochemical Etch and Liquid Metal Fill**  
Proc. IEEE 3D System Integration Conf.– 3DIC 2010, Munich, April 2011

Klumpp, A.; Ramm, P.; Franz G.; Rue, C.; Kwakman L.  
**Reliability Testing and Failure Analysis of 3D Integrated Systems**  
Proc. Interconnect Technology Conference- IITC, May 2011

Bock, K.  
**Modular Solid State Technologies for a Multi-functional System Integration**,  
CS Mantech Conference, Indian Wells, paper 10a-4, published in the proceedings California, May 16 - 19, 2011

Bonfert, D.; Gieser, H.; Bock, K.; Svasta, P.; Ionescu, C.  
**Electrical stress on Thin Film TaN Resistive Structures**  
IEEE SIITME 2011, Timisoara, Romania, October 20 - 23, 2011

**Electrical stress on film resistive structures on different substrates**  
34th International Spring Seminar on Electronics Technology (ISSE), Tratanska Lomnica, May 11 - 15, 2011

Ohlander, A.; Burghart, M.; Strohhofer, C.; Bollmann, D.; Landesberger, C.; Klink, G.; Bock, K.  
**Polymer opto-electronic-fluidic detection module on plastic film substrates**  
Proceedings of ECTC, ECTC 2011, Lake Buena Vista (FL), USA, May 31 - June 2, 2011

Yacoub-George, E.; Bock, K.  
**Hetero-integration of foil components and printed circuit foils for flexible electronics**  
Fraunhofer EMFT Summer School, Munich, June 7 - 10, 2011

Syed, W.  
**Organic Schottky Diodes based on Pentacene Derivatives**  
Proceedings of LOPE-C 2011, Large-area, organic and printed electronics convention  
LOPE-C, Frankfurt am Main, June 28 - 30, 2011

Valdastri, P.; Susilo, E.; Förster, T.; Strohhofer, C.; Menciassi, A.; Dario, P.  
**Wireless Implantable Electronic Platform for Chronic Fluorescent-Based Biosensors**  
IEEE Transactions on Biomedical Engineering 58 (6), June 2011

Nebrich, L.; Hedler, H.; Fojt R.  
**Detectors for tomography with positrons**  
Cooperation forum Bayern-Innovativ; Munich, May 10, 2011
Klink, G.

**COSMIC – Challenges and Progress**

Herz, M.; Kibler S.; Söllner M.; Scheufele B.; Richter M.; Lueth T.C.; Bock K.

**Development of an energy-efficient piezoelectrical high-flux micropump for methanol fuel cells**
MST Kongress 2011, October 10 - 12, 2011 in Darmstadt

Klink, G.

**Manufacturing and Production Equipment for Printed and Polymer Electronics**

Ramm, P.

**Issues for 3D-TSV Production**

Yacoub-George, E.; Endres, H. E.; Faul, R.; Bock, K.; Kugler, A.; Mahlich, M.; Koyuncu, M.

**Interconnection technologies for a multilayer system in foil**
Plastic Electronics, Dresden, Germany, 11 - 13 October 2011

Richter M.

**New products with micro pumps - emerging applications and innovation barriers**
MIT-SLIM 2011 Conf., Fiesa, Slovenia, September 26 - 17, 2011

Bock, K.

**Multi-functional System Integration – A Merge of CMOS, MEMS and Polytronics?**
Invited talk, Plastic Electronics, Dresden, October 11 - 13, 2011

Bock, K.

**Opening talk: Quo vadis - visions for intelligent textiles?**
Cooperation forum with technical exhibition “Textile and sensorics”, Bayern Innovativ, Kolpinghaus Regensburg, October 25, 2011

Yacoub-George, E.; Bock, K.

**3D-Integration Technologies for the Fabrication of Flexible Foil Systems**
3rd Flexible & Stretchable Electronics Workshop 2011, Berlin, Germany; November 15 - 17, 2011

Yacoub-George, E.; Bock, K.

**On foil integration and foil to foil assembly in flexible electronics**
Forum be-flexible 2011; Munich, Germany; November 23 - 24, 2011

Landesberger, C.; Wieland, R.; Bock, K.

**Mobile electrostatic carriers – status and perspectives**
Forum be-flexible 2011; Munich, November 23 - 24, 2011

Bock, K.

**Advanced Packaging Trends for Medical Electronics,**
Opening talk, Techsearch Workshop - Advanced Packaging Trends for Medical Electronics, Fraunhofer EMFT, Munich, Germany, November 14, 2011
Yacoub-George, E.; Bock, K.
3D integration technologies to produce micro-electronic foil systems
Symposium Netzwerk 2011, Munich, November 28 - 29, 2011

Talks (selection 2012)

Yacoub-George, E.; Bock, K.
Multifunctional foil systems for textiles

Nebrich, L.; Wiest, F.
Highly sensitive radiation detectors for medical applications
3rd Landshut Symposium on Microsystems Engineering, Landshut, March 13 - 14, 2012

Wieland, R.; Xuan Anh Bui, T.; Merkel K.-R.; Al Kuzee, J.
Optimization of DRIE-based TSVs for 3D/MEMS
MAM 2012; Workshop Materials for Advanced Metallization, Grenoble, France, March 11 - 14, 2012

Klumpp, A.
Manufacturing of 3D integrated ICs
Design, Automation and Test in Europe, Dresden, March 12 - 16, 2012

Electrical Stress on Intrinsically Conductive Polymer Layer
ISSE 2012: 35th International Spring Seminar on Electronics Technology, Bad Aussee, Austria, May 9 - 13, 2012

Faul, R.
R&D for flexible polytronic systems
3rd Landshut Symposium on Microsystems Engineering, Landshut, March 13 - 14, 2012

Weber, J.; Klumpp, A.; Ramm, P.
3D-TSV integration of heterogeneous microsystems
3rd Landshut Symposium on Microsystems Engineering, Landshut, March 13 - 14, 2012

Endres, H.-E.; Rose, K.; Faul, R.; Yacoub-George, E.; Bock, K.
A flexible indoor air quality system
IMCS 2012 - The 14th International Meeting on Chemical Sensors, Nürnberg, Germany, March 20 - 23, 2012

Klumpp, A.; Ramm, P.; Franz G.; Rue, C.; Kwakman L.
Reliability Testing and Failure Analysis of 3D Integrated Systems
Proc. Interconnect Technology Conference - IITC, May 2011

Nebrich, L.; Wiest, F.; Eisele, I.
Highly Sensitive Radiation Detectors for Medical Applications
Smart Systems Integration, Int. Conference and Exhibition on Integration Issues of Miniaturized Systems, Zurich, Switzerland, March 21 - 22, 2012

Fabrication of Optical Sensor Materials and Modules for Food Quality Control
Europtode XI, XI Conference on optical chemical sensors and biosensors, Barcelona, Spain, April 1 - 4, 2012
The institution was granted the following new patents in 2011:

**Method for manufacturing a bending transducer, a micro pump and a microvalve**  
Markus Herz, Martin Richter, Martin Wackerle  
WO 2011 107 162 A1

**Valve, layer structure comprising a first and a second valve, micropump and method of producing a valve**  
Markus Herz, Martin Richter, Martin Wackerle  
WO 2011 107 157

**Dressing for monitoring wound healing**  
Gerhard Mohr, Matthias Stich, Markus Szeimies, Sabine Trupp, Otto Wolfbeis  
DE 10 2010 001 855.4

**Organic field-effect transistor and its method of production**  
Karlheinz Bock, Kornelius Tetzner  
DE 10 2009 047315.7

**Electrically functional foil system and method of production of an electrically functional foil system**  
Andreas Drost, Martin König, Christof Strohhöfer, Gerhard Klink  
DE 10 2009 015 706.9

**Method for the aligned application of components to a carrier substrate**  
Erwin Yacoub-George, Christof Landesberger, Sabine Scherbaum  
DE 10 2009 050 426.5

**Mobile, electrostatic carrier wafer with electrically insulated charge storage**  
Dieter Bollmann  
DE 10 2006 055 618.6

**Device and method for the electrostatic fixing of substrates with polarizable molecules**  
Christof Landesberger  
WO 2007/110192 A1

**Method for manufacturing a three-dimensional electronic system**  
Armin Klumpp, Peter Ramm  
US 2010/0289146
Tempress furnace for LP-CVD oxide
MEMBERSHIPS AND ACTIVITIES

Prof. Dr.-Ing. Karlheinz Bock

- AMA, AMA Council on Science and AMA Sensor Innovation Award: Member of the AMA, the AMA Sensor Innovation Award Committee and the AMA Council on Science
- Organic Electronics Association OEA, German Engineering Federation (VDMA): Member
- Federal Ministry of Education and Research, Leading-Edge Cluster Competition: Expert consultant
- Compound Semiconductor Manufacturing Technology, CS MANTECH, USA: Member of the technological program committee
- German Research Foundation DFG: Expert consultant
- EITI – European Interconnect Technology Initiative: Member
- European Commission: Specialist and project expert consultant
- FlexTech Alliance, USA: International Advisory Board
- Forum MedTech Pharma, Bayern Innovativ: Member
- Institute of Electrical and Electronics Engineers IEEE: Member
- IEEE Components, Packaging & Manufacturing Technology Society and Electron Devices Society: Member
- International Electronic Components and Technologies Conference, ECTC, USA: Sub-committee chair “Emerging technologies"
- International Electron Devices Meeting IEDM, USA: Member of the Executive Committee and European Arrangement Chair
- International Conference on Flexible and Printed Electronics (ICFPE), Japan: European Committee
- Microtechnology and Nanotechnology Journal of Bentham Science Publisher Ltd.: Member of the Board of Editors and expert consultant
- MRS - Materials Research Society: Member
- Plastic Electronics Conference: Session co-chair for Integrated Smart Systems
- VDI/VDE project sponsor: Expert consultant
- IEEE Electron Devices Letters EDL: Expert consultant
- German Israeli Foundation for Scientific Research and Development (G.I.F): Expert consultant
- German Aerospace Center e.V., project sponsor - environment, culture, sustainability: Expert consultant
- Electronics Systems Integration Technology Conference ESTC2, technical Program committee "Advanced and emerging technologies": Member
- Journal of Micromachines: Expert consultant
- VDE and core group of the working group for microelectronics and precision engineering: Member
- Smart Systems Integration Conference, SSI: Technical program committee and founding member

Prof. Dr. Ignaz Eisele

- Roth&Rau Muegge GmbH: Member of the Supervisory Board
- Robert Bosch Centre Reutlingen: Member of the Advisory Board
- IHP, Frankfurt/Oder: Member of the Academic Advisory Board


// MEMBERSHIPS AND ACTIVITIES

Dr. Martin Richter

- VDE/VDI Association for Electrical, Electronic & Information Technologies (GMM), Section 2; Microtechnology and Nanotechnology, Technical Committee 2.4 "Microactutors":
- Association Multi Material Micromanufacturing (4M):
  Head of Microfluidics Division, member
- MST Congress, involvement in program committee
- IOP Science, review work

Dr. Peter Ramm

- International Microelectronics and Packaging Society iMAPS:
  Fellow of Society and Life Member and Award Committee Member
- Sematech ITRS Interconnect Working Group (2010 update): Key contributor
- SEMI North America: Committee Standards 3DS-IC, Technical Committee
- Surface Mount Technology Association (SMTA): Technical Committee Member
- IWLPC – Co-Chair 3D Integration
- Advanced Metallization Conference (AMC): Executive Committee
- Electrochemical Society (ECS): Symposium Organizer
- Institute of Electrical and Electronics Engineers IEEE: Organizing Committee and Founding Member 3DIC Conference
- Future Fab International Magazine: Editorial Board Member

Dr. Horst A. Gieser

- ESD-FORUM e.V.: Board Chairman
- Industry Council on ESD-Target Levels: Member
- EOS/ESD Association, USA: Member
- EOS/ESD Symposium, USA: Technical Program Committee
- International Electrostatic Workshop IEW: Management Committee
Dr. Detlef Bonfert

- IEEE Components, Packaging & Manufacturing Technology Society and Electron Devices Society: Senior Member
- International Microelectronics and Packaging Society iMAPS: Member
- International Symposium for Design and Technology in Electronic Packaging SITME: Steering Committee, Scientific Committee, Technical Program Chair
- International Spring Seminar in Electronics ISSE: Steering Committee

Dr. Heinrich Wolf

- EOS/ESD Association, USA: Member
- EOS/ESD Symposium, USA: Technical Program Committee
- International Electrostatic Workshop IEW: Technical Program Committee

Dr. Armin Klumpp

- International Electron Devices Meeting IEDM, USA: Technical Committee

Robert Faul

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- Cluster-Offensive Bayern, Mechatronics and Automation Cluster: Member and technical adviser

Dr. Hanns-Erik Endres

- Cluster-Offensive Bayern, Sensorics Cluster: Member and technical adviser
- Fraunhofer Electrochemistry Network: Member

Christof Landesberger

- Cluster-Offensive Bayern, Power Electronics Cluster: Member and technical adviser
Atomic force microscope
Dimension 5000 by Digital Instruments for measuring surface roughness and height differences to 6 µm
PUBLISHING NOTES

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