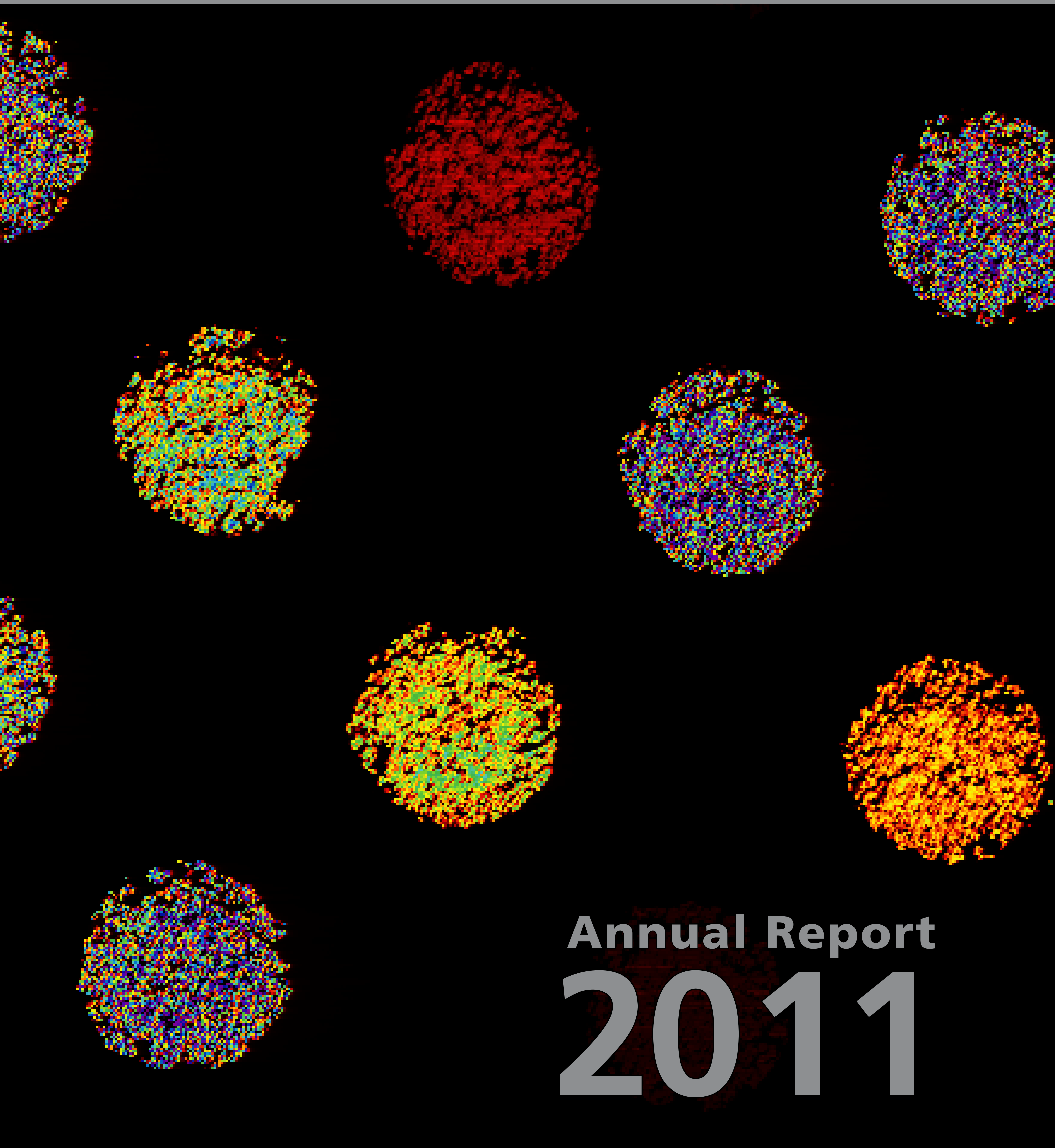
Fraunhofer
ENAS

FRAUNHOFER INSTITUTE FOR ELECTRONIC NANO SYSTEMS ENAS



Annual Report 2011

Front page: Integration of carbon nano tubes (CNT) in copper damascene interconnects: current-sensing AFM image of vias filled with CNTs after chemical mechanical polishing – different colors belong to different currents within the single CNTs

Photo: H. Fiedler in cooperation with M.Toader, Prof. M. Hietschold, Institute of Physics , Chemnitz University of Technology

CONTENTS

PREFACE

Dear friends and partners of the Fraunhofer Institute for Electronic Nano Systems, dear readers,

The year 2011 was a very successful one after the evaluation in 2010. The Fraunhofer ENAS belongs now to the well-established Fraunhofer Institutes and was able to increase the third party funds as well as the number of projects.

Metallization and interconnect systems for micro and nano electronics, the development of high-precision and respectively polymer based sensors, printed functionalities like antennas and batteries, material and reliability research for micro electronics as well as micro system technology and especially smart systems for different applications belong to the wide range of topics of Fraunhofer ENAS.

Smart systems can be found in many common products. Smart systems of the first generation consist of single sensors, actuators and their signal processing unit. Such products already exist as airbag systems or ESP in automotive applications since the nineties of the last century. Smart systems of the second generations just have a communication unit, work partly autonomously and have an increased functionality. The third generation of smart systems is currently under development. Such systems are the basis for the internet of things, the smart home, smart city and smart production. This generation will be able to take over complex human perceptive and cognitive functions, to establish self-organizing networks and to work completely energy autonomously. They will frequently act unnoticeably in the background and intervene visibly only when human capabilities to act and to react are reduced or cease to exist. Moreover smart systems of the third generation are the basis for a connection of the real world with the virtual cyber physical world.

The Fraunhofer Institute for Electronic Nano Systems works on such visionary products together with national and international research and development partners and especially industrial partners. So an autonomous sensor network for power line monitoring was successfully tested in the field in 2011. The system has been developed together with partners from the Chemnitz University of Technology, the Fraunhofer IZM, from industry and energy provider.

The department Advanced System Engineering in Paderborn convinced with the SUPA technology for wireless data and energy transmission at the ideas competition Fraunhofer Venture. They also got the first prize at the ideas competition Fraunhofer Netzwert in 2011. The idea has been implemented itogether with partners in a writing desk. This desk which wirelessly energizes a computer monitor was shown at the CeBIT 2011.

Also in 2011 the strategic alliance between the Fraunhofer Institute for Electronic Nano Systems and the Center for Microtechnologies of the Chemnitz University of Technology ensured strong synergies in technology and device development.

Fraunhofer ENAS works international. It cooperates very actively within in the European platform for smart systems integration EPoSS and is member of numerous groups, networks and alliances. Our representatives in Japan, China and Brazil support our international activities.

In our capacity as a institute of Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V., research and development for industrial applications are our prime and natural concern. R&D work is carried out on behalf of large national and international companies as well as small and medium-sized enterprises, network operators and the public sector, such as Free State of Saxony, the Federal Government and the EU. The institute's success is rooted in the minds of its employees and their knowledge of details and relationships, products, technologies and processes. The institute's performing power is based on our staff's creativity and optimizm as well as the support of many our business partners and sponsors. I would like to express our thanks to all of them.

Today, we look with happiness and pride on what we have achieved. However, it also serves as an incentive to keep up the competent and reliable service for our project partners and customers.

Prof. Dr. Thomas Gessner
Director of the Fraunhofer Institute for Electronic Nano Systems

VORWORT

Liebe Freunde und Partner des Fraunhofer-Instituts für Elektronische Nanosysteme, sehr geehrte Leserinnen und Leser,

das Jahr 2011 verlief für das Institut nach der Evaluierung im Vorjahr sehr erfolgreich. Das Fraunhofer ENAS zählt seit dem 1. Januar 2011 nun endgültig zum Kreis der etablierten Fraunhofer-Institute und konnte seinen Ertrag an Drittmitteln im Vergleich zum Vorjahr ebenso deutlich steigern wie die Zahl der bearbeiteten Projekte.

Das Themenspektrum reicht von Arbeiten im Bereich der Metallisierungs- und Interconnectsysteme für die Mikro- und Nanoelektronik, über die Entwicklung von hochpräzisen bzw. polymerbasierten Sensoren, gedruckte Funktionalitäten wie Antennen oder Batterien, die Material- und Zuverlässigkeitsforschung für die Mikroelektronik und Mikrosystemtechnik bis hin zu smarten Systemen für verschiedene Anwendungen.

Smart Systems, sogenannte intelligente Systeme, sind Bestandteil vieler alltäglicher Produkte. Die erste Generation der smarten Systeme besteht aus einzelnen Sensoren, Aktoren und zugehöriger Elektronik zur Signalverarbeitung. Derartige Produkte sind bereits seit den 90er Jahren im Automobil als Airbagsysteme oder ESP zu finden. Die zweite Generation der Smart Systems verfügt bereits über Kommunikationsmöglichkeiten, arbeitet teilweise autonom und ist gekennzeichnet durch eine erhöhte Funktionalität. Die dritte Generation ist gegenwärtig weltweit in der Entwicklung. Sie stellt die Basis für das Internet der Dinge, das Smart Home, die Smart City sowie die Smart Production dar. Diese Generation von Systemen wird in der Lage sein, komplexe humane perzeptive und kognitive Funktionen zu übernehmen, selbstorganisierende Netzwerke aufzubauen und komplett energieautonom zu arbeiten. Sie wird häufig unbemerkt im Hintergrund agieren und sichtbar nur einschreiten, wenn die menschlichen Möglichkeiten, zu agieren und zu reagieren, reduziert sind oder aufhören zu existieren. Sie sind die Grundlage der Verbindung der realen physischen Welt mit der virtuellen Welt.

Gemeinsam mit nationalen und internationalen Forschungs- und Entwicklungspartnern und vor allem der Industrie arbeitet das Fraunhofer-Institut für Elektronische Nanosysteme an derartigen visionären Produkten. So konnte 2011 zum Beispiel erfolgreich ein autonomes Sensornetzwerk zur Überwachung der Auslastung von Hochspannungsleitungen, welches gemeinsam mit den Partnern Fraunhofer IZM und der TU Chemnitz, Industriepartnern sowie Energieunternehmen und einem Netzbetreiber entwickelt wurde, im Feld getestet werden.

Die Paderborner Abteilung Advanced System Engineering des Fraunhofer ENAS überzeugte mit der SUPA-Technologie zur drahtlosen Energie- und Datenübertragung beim Ideenwettbewerb von Fraunhofer Venture und erhielt den 1. Platz beim Ideenwettbewerb Fraunhofer Netzwert 2011. Die Idee wurde gemeinsam mit Partnern umgesetzt und auf der CeBIT 2011 als ein Schreibtisch präsentiert, der kabellos einen Monitor mit Strom versorgte.

Auch 2011 sicherte insbesondere die strategische Allianz zwischen dem Fraunhofer-Institut für Elektronische Nanosysteme und dem Zentrum für Mikrotechnologien der Technischen Universität Chemnitz Synergien in der Technologie und Systementwicklung.

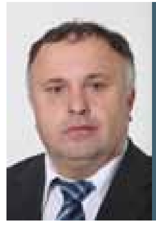
Durch die Mitarbeit im Rahmen der Europäischen Plattform für Smart Systems Integration EPoSS, der Mitgliedschaft in Verbünden und Verbänden aber auch Repräsentanten in Japan, China und Brasilien ist das Fraunhofer ENAS international aktiv.

Als Institut der Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. ist für uns Forschung und Entwicklung für industrielle Anwendungen ein selbstverständliches Anliegen. Die Forschungs- und Entwicklungsarbeiten werden im Auftrag nationaler und internationaler Großunternehmen und KMUs, der öffentlichen Hand, des Freistaates Sachsen, des Bundes und der EU durchgeführt. Der Erfolg eines jeden Unternehmens steckt in den Köpfen der Beschäftigten, ihrem Wissen über Details und Zusammenhänge, Produkte, Technologien und Verfahren. Die Leistungskraft des Instituts beruht auf Kreativität, Leistungsbereitschaft und Optimismus der Mitarbeiterinnen und Mitarbeiter sowie der Unterstützung durch zahlreiche Geschäftspartner und Förderer. Ihnen allen gilt mein besonderer Dank.

Wir blicken mit Stolz und Freude auf das Erreichte. Es ist uns aber auch Ansporn, unseren Projektpartnern und Auftraggebern auch in Zukunft kompetent und zuverlässig zur Seite zu stehen.

Prof. Dr. Thomas Gessner
Leiter des Fraunhofer-Instituts für Elektronische Nanosysteme

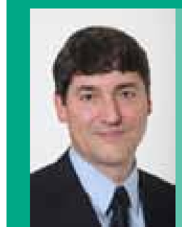
Director
Prof. Dr. Thomas Gessner



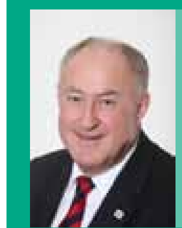
Head of Administration
Dipl.-Ing. Gottfried Höppner

Business Units

Micro and Nano Systems
Prof. Dr. Thomas Otto



Micro and Nano Electronics / Back-End of Line
Prof. Dr. Stefan E. Schulz

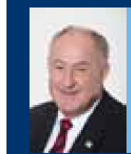


Green and Wireless Systems
Prof. Dr. Reinhard R. Baumann

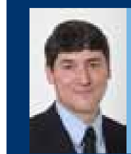
Departments

Multi Device Integration
Prof. Dr. Thomas Otto

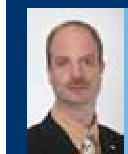
Micro Materials Center
Prof. Dr. Bernd Michel
Dr. Sven Rzepka



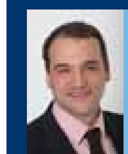
Printed Functionalities
Prof. Dr. Reinhard R. Baumann



Back-End of Line
Prof. Dr. Stefan E. Schulz



System Packaging
Dr. Maik Wiemer



Advanced System Engineering
Dr. Christian Hedayat

FRAUNHOFER ENAS

FRAUNHOFER ENAS

Smart Systems Integration by Using Micro and Nano Technologies

The Fraunhofer Institute for Electronic Nano Systems ENAS is a reliable partner for research and development of innovative solutions. In the focus there are smart systems based on micro and nano technologies. Smart systems integrate not only components of different functionality, like sensors, actuators, biochips, batteries, passive and active electronic devices, they are able to capture and identify complex situations. They can decide something, interact with the surrounding, work energy autonomously and cross-linked. The technologies for smart systems and their integration have a significant impact of entire sectors as aeronautics, automotive, security, logistics, medical technology, process engineering and mechanical engineering.

With the working field smart systems integration Fraunhofer ENAS is able to support strongly the research and development of many small and medium size companies as well as large scale industry in nano and micro electronics and micro system technology. By integration smart systems in different applications Fraunhofer ENAS addresses semiconductor industry as well as the above mentioned branches of industry.

In order to focus the activities and to ensure a longterm scientific and economic success Fraunhofer ENAS has defined three business units:

- Micro and Nano Systems,
- Micro and Nanoelectronics / Back-end of Line as well as
- Green and Wireless Systems.

They address different markets, different customers and moreover different stages of the value added chain depending on the required research and development services.

The foci of Fraunhofer ENAS are strongly affected by developments of nanotechnology and ensured by the following unique features of Fraunhofer ENAS within the Fraunhofer-Gesellschaft:

- High-precision MEMS and NEMS,
- digital pilot station (Inkjet-Technikum), adaptive printing technologies inclusively material development and characterization,
- nano systems: system design, technology development and nano reliability,
- wafer bonding for 3D system integration,
- interconnect technologies, back-end of line for nano electronics and nano systems.

Six departments belong to Fraunhofer ENAS:

- Multi Device Integration
- Micro Materials Center
- Printed Functionalities
- Back-end of Line
- System Packaging
- Advanced System Engineering.

FRAUNHOFER ENAS

Smart Systems Integration unter Nutzung von Mikro- und Nanotechnologien

Das Fraunhofer-Institut für Elektronische Nanosysteme ENAS ist ein zuverlässiger Forschungs- und Entwicklungspartner für innovative Lösungen. Im Fokus der Entwicklungen stehen smarte Systeme unter Nutzung von Mikro- und Nanotechnologien. Diese intelligenten Systeme integrieren nicht nur Komponenten unterschiedlicher Funktionalität, wie Sensoren, Aktoren, Biochips, Antennen, Batterien, passive und aktive Bauelemente, sondern sind in der Lage, komplexe Situationen zu erfassen und zu erkennen. Sie können Entscheidungen treffen, mit der Umwelt interagieren, arbeiten energieautonom und vernetzt. Die Technologien für intelligente Systeme und ihre Integration beeinflussen signifikant die Wettbewerbsfähigkeit verschiedener Branchen wie die Luft- und Raumfahrt, den Automobilbau, die Sicherheitsbranche, die Logistik, die Medizin- und Prozesstechnik sowie den Maschinenbau.

Mit der Ausrichtung Smart Systems Integration ist das Fraunhofer ENAS in der Lage, die Forschungs- und Entwicklungstätigkeit von vielen kleinen und mittelständischen Firmen sowie der Großindustrie in der Nano-/ Mikroelektronik und Mikrosystemtechnik nachhaltig zu unterstützen. Durch die Integration intelligenter Systeme in verschiedenartige Anwendungen adressiert das Fraunhofer ENAS neben der Halbleiterindustrie die oben aufgeführten Branchen.

Um die Aktivitäten des Fraunhofer ENAS zu fokussieren, wurden die Schwerpunkte im Technologieportfolio und in der Marktbearbeitung auf die drei Geschäftsfelder gelegt:

- Micro and Nano Systems,
- Micro and Nanoelectronics / Back-end of Line,
- Green and Wireless Systems.

Jedes Geschäftsfeld verfügt über ein eigenes Kundenprofil, das in Abhängigkeit der benötigten Forschungs- und Entwicklungsleistungen verschiedene Stellen der industriellen Wertschöpfungsketten anspricht.

Die Entwicklungen des Fraunhofer-Instituts für Elektronische Nanosysteme ENAS werden stark durch Impulse der Nanotechnologien geprägt und sind vor allem durch die folgenden Alleinstellungsmerkmale innerhalb der Fraunhofer-Gesellschaft gesichert:

- Hoch-präzise Silizium-MEMS und -NEMS,
- Inkjet-Technikum, adaptierte Drucktechnologien inklusive Materialformulierungen,
- Nanosysteme: Systemdesign, Technologie und Nanoreliability,
- Waferbonden für die 3D-Systemintegration,
- Interconnecttechnologien, Back-end of Line (BEoL) für Nanoelektronik und Nanosysteme.

Organisatorisch ist das Fraunhofer ENAS in sechs Abteilungen gegliedert:

- Multi Device Integration
- Micro Materials Center
- Printed Functionalities
- Back-end of Line
- System Packaging
- Advanced System Engineering.

FRAUNHOFER-GESELLSCHAFT

Research of Practical Utility

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 Euros. Of this sum, more than 1.5 billion Euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and Länder governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

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-GESELLSCHAFT

Forschung für die Praxis

Forschen für die Praxis ist die zentrale Aufgabe der Fraunhofer-Gesellschaft. Die 1949 gegründete Forschungsorganisation betreibt anwendungsorientierte Forschung zum Nutzen der Wirtschaft und zum Vorteil der Gesellschaft. Vertragspartner und Auftraggeber sind Industrie- und Dienstleistungsunternehmen sowie die öffentliche Hand.

Die Fraunhofer-Gesellschaft betreibt in Deutschland derzeit mehr als 80 Forschungseinrichtungen, davon 60 Institute. Mehr als 20.000 Mitarbeiterinnen und Mitarbeiter, überwiegend mit natur- oder ingenieurwissenschaftlicher Ausbildung, bearbeiten das jährliche Forschungsvolumen von 1,8 Milliarden Euro. Davon fallen 1,5 Milliarden Euro auf den Leistungsbereich Vertragsforschung. Über 70 Prozent dieses Leistungsbereichs erwirtschaftet die Fraunhofer-Gesellschaft mit Aufträgen aus der Industrie und mit öffentlich finanzierten Forschungsprojekten. Knapp 30 Prozent werden von Bund und Ländern als Grundfinanzierung beigesteuert, damit die Institute Problemlösungen erarbeiten können, die erst in fünf oder zehn Jahren für Wirtschaft und Gesellschaft aktuell werden.

Internationale Niederlassungen sorgen für Kontakt zu den wichtigsten gegenwärtigen und zukünftigen Wissenschafts- und Wirtschaftsräumen.

Mit ihrer klaren Ausrichtung auf die angewandte Forschung und ihrer Fokussierung auf zukunftsrelevante Schlüsseltechnologien spielt die Fraunhofer-Gesellschaft eine zentrale Rolle im Innovationsprozess Deutschlands und Europas. Die Wirkung der angewandten Forschung geht über den direkten Nutzen für die Kunden hinaus: Mit ihrer Forschungs- und Entwicklungsarbeit tragen die Fraunhofer-Institute zur Wettbewerbsfähigkeit der Region, Deutschlands und Europas bei. Sie fördern Innovationen, stärken die technologische Leistungsfähigkeit, verbessern die Akzeptanz moderner Technik und sorgen für Aus- und Weiterbildung des dringend benötigten wissenschaftlich-technischen Nachwuchses.

Ihren Mitarbeiterinnen und Mitarbeitern bietet die Fraunhofer-Gesellschaft die Möglichkeit zur fachlichen und persönlichen Entwicklung für anspruchsvolle Positionen in ihren Instituten, an Hochschulen, in Wirtschaft und Gesellschaft. Studierenden eröffnen sich an Fraunhofer-Instituten wegen der praxisnahen Ausbildung und Erfahrung hervorragende Einstiegs- und Entwicklungschancen in Unternehmen.

Namensgeber der als gemeinnützig anerkannten Fraunhofer-Gesellschaft ist der Münchner Gelehrte Joseph von Fraunhofer (1787–1826). Er war als Forscher, Erfinder und Unternehmer gleichermaßen erfolgreich.

FRAUNHOFER GROUP MICROELECTRONICS

Since the foundation Fraunhofer ENAS belongs to the Fraunhofer Group for Microelectronics VµE. The Fraunhofer Group for Microelectronics 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 Euros. Full members are Fraunhofer CNT, EMFT, ENAS, ESK, FHR, HHI, IAF, IIS, IISB, IMS, IPMS, ISIT and IZM. Fraunhofer FOKUS, IDMT and IZFP-D belong to the associated members. 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.

Further activities of the group concentrate largely on establishing joint focal research groups and projects. 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.

There are five application-oriented business areas (Ambient Assisted Living, Energy Efficient Systems and eMobility, Light, Safety and Security, Entertainment) and two cross-sectional business areas (Communication Technologies and Technology – from CMOS to Smart System Integration).

Contact:

Chairman of the Board of Directors
Prof. Dr. Hubert Lakner
Phone: +49 (0)351 8823-0
Fraunhofer Institute for Photonic Microsystems IPMS
Maria-Reiche-Strasse 2
01109 Dresden
Germany

Deputy Chair
Prof. Dr. Anton Grabmaier
Phone: +49 (0)203 3783-0
Fraunhofer Institute for Microelectronic Circuits and Systems IMS
Finkenstrasse 61
47057 Duisburg
Germany

Fraunhofer Group for Microelectronics
SpreePalais at the Berlin Cathedral
Anna-Louisa-Karsch-Strasse 2
10178 Berlin
Germany

Managing Director of the Business Office
Dr. Joachim Pelka
Phone: +49 (0)30 6883759-6100
Email: joachim.pelka@mikroelektronik.fraunhofer.de

Head of Press and Public Relations
Christian Lüdemann
Phone: +49 (0)30 6883759-6103
Email: christian.luedemann@mikroelektronik.fraunhofer.de

FRAUNHOFER-VERBUND MIKROELEKTRONIK

Das Fraunhofer ENAS ist seit seiner Gründung Mitglied im Fraunhofer-Verbund Mikroelektronik VµE. Dieser koordiniert seit 1996 die Aktivitäten der auf den Gebieten Mikroelektronik und Mikrointegration tätigen Fraunhofer-Institute. Zum Verbund gehören Fraunhofer CNT, EMFT, ENAS, ESK, FHR, HHI, IAF, IIS, IISB, IMS, IPMS, ISIT, IZM sowie als Gäste Fraunhofer FOKUS, IDMT und IZFP-D. Das sind dreizehn Institute (und drei Gastinstitute) mit ca. 2.700 Mitarbeiterinnen und Mitarbeitern. Das jährliche Budget beträgt etwa 307 Millionen Euro. Die Aufgaben des Fraunhofer VµE bestehen im frühzeitigen Erkennen neuer Trends und deren Berücksichtigung bei der strategischen Weiterentwicklung der Verbundinstitute. Dazu kommen das gemeinsame Marketing und die Öffentlichkeitsarbeit.

Weitere Arbeitsfelder sind die Entwicklung gemeinsamer Themenschwerpunkte und Projekte. So kann der Verbund insbesondere innovativen mittelständischen Unternehmen rechtzeitig zukunftsweisende Forschung und anwendungsorientierte Entwicklungen anbieten und damit entscheidend zu deren Wettbewerbsfähigkeit beitragen. Die Kernkompetenzen der Mitgliedsinstitute werden in seinen Geschäftsfeldern gebündelt.

Die Aktivitäten der Verbundinstitute unterteilen sich in zwei Querschnittsgeschäftsfelder (Halbleitertechnologien und Technologien der Kommunikationstechnik) und fünf anwendungsorientierte Geschäftsfelder (Ambiente Assistenzsysteme, Energieeffiziente Systeme und eMobility, Licht, Sicherheit und Unterhaltung).

Kontakt:

Vorsitzender des Direktoriums
Prof. Dr. Hubert Lakner
Telefon: +49 (0)351 8823-0
Fraunhofer-Institut für Photonische Mikrosysteme IPMS
Maria-Reiche-Straße 2
01109 Dresden

Stellvertretender Vorsitzender des Direktoriums
Prof. Dr. Anton Grabmaier
Telefon: +49 (0)203 3783-0
Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme IMS
Finkenstrasse 61
47057 Duisburg

Fraunhofer-Verbund Mikroelektronik
SpreePalais am Dom
Anna-Louisa-Karsch-Straße 2
10178 Berlin

Leiter der Geschäftsstelle
Dr. Joachim Pelka
Telefon: +49 (0)30 6883759-6100
E-Mail: joachim.pelka@mikroelektronik.fraunhofer.de

Leiter Presse- und Öffentlichkeitsarbeit
Christian Lüdemann
Telefon: +49 (0)30 6883759-6103
E-Mail: christian.luedemann@mikroelektronik.fraunhofer.de

FRAUNHOFER NANOTECHNOLOGY ALLIANCE

Since 2009 Fraunhofer ENAS belongs to the Fraunhofer Alliance Nanotechnology. There are 20 institutes cooperating in this alliance (Fraunhofer ENAS, IAO, IAP, ICT, IFAM, IFF, IGB, IISB, IKTS, ILT, IPA, ISC, ISE, ISI, ITEM, IVV, IWM, IWS, IZFP, LBF).

The activities of the Nanotechnology Alliance cover the whole R&D value chain and are focused on e.g. multifunctional coatings for use in the optical, automotive and electronics industry, the design of special nanoparticles as fillers (carbon nanotubes, metals, oxides etc), nanocomposites, functional materials e.g for biomedical applications and CNT-based structural materials and actuators. The alliance also treats questions regarding toxicology and operational safety when dealing with nanoparticles.

Nanotechnology is a cross-section technology concerned with research and construction in very small structures. A nanometer corresponds to a millionth of a millimeter. It is a discipline which offers more potential for innovative applications than any other, as special physical laws apply on the nano-level. The optical, electrical or chemical properties of established materials can be altered completely by manipulation of the nanostructure.

The alliance focuses its activities on the following main topics:

- Nanobiotechnology
- Nanomaterials
- Technology transfer and consulting
- Nano processing / handling
- Nano optics and electronics
- Measuring methods / techniques.

Contact:

Spokesman of the Fraunhofer Nanotechnology Alliance
Dr. Karl-Heinz Haas
Phone: +49 (0)931 4100-500
Email: haas@isc.fraunhofer.de
Fraunhofer Institute for Silicate Research ISC
Neunerplatz 2
97082 Würzburg
Germany

Deputy Spokesman of the Alliance
Dr. habil. Günter Tovar
Phone: +49 (0)711 970-4109
Email: guenter.tovar@igb.fhg.de
Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB
Nobelstraße 12
70569 Stuttgart
Germany

Fraunhofer ENAS is represented by:
Prof. Dr. Stefan E. Schulz
Head of the department Back-end of Line
Phone: +49 (0)371 45001-232
Email: stefan.schulz@enas.fraunhofer.de

FRAUNHOFER-ALLIANZ NANOTECHNOLOGIE

Fraunhofer ENAS ist seit 2009 Mitglied der Fraunhofer-Allianz Nanotechnologie. Zur Allianz gehören 20 Fraunhofer-Institute (Fraunhofer ENAS, IAO, IAP, ICT, IFAM, IFF, IGB, IISB, IKTS, ILT, IPA, ISC, ISE, ISI, ITEM, IVV, IWM, IWS, IZFP, LBF).

Die Arbeiten der Fraunhofer-Allianz Nanotechnologie decken die gesamte Wertschöpfungskette von der anwendungsorientierten Forschung bis zur industriellen Umsetzung ab. Hierbei werden zum Beispiel multifunktionale Schichten für optische Anwendungen, den Automobilbau und die Elektroindustrie entwickelt. Metallische und oxidische Nanopartikel, Kohlenstoff-Nanoröhren und Nanokomposite werden in Aktuatoren, strukturellen Werkstoffen und biomedizinischen Anwendungen eingesetzt. Darüber hinaus beschäftigt sich die Fraunhofer-Allianz Nanotechnologie mit Fragen zur Toxizität und dem sicheren Umgang mit Nanopartikeln.

Nanotechnologie ist eine Querschnittstechnologie, die sich mit der Forschung und Konstruktion in sehr kleinen Strukturen beschäftigt. Kaum eine andere Disziplin bietet mehr Potenzial für innovative Anwendungen, denn auf Nanoebene gelten besondere physikalische Gesetze. Durch Manipulation der Nanostruktur lassen sich die optischen, elektrischen oder chemischen Eigenschaften gängiger Materialien völlig verändern.

Die Allianz fokussiert die Aktivitäten auf die nachfolgend formulierten Leitthemen:

- Nanobiotechnologie
- Nanomaterialien
- Technologietransfer und Politikberatung
- Prozesstechnik / Handhabung
- Nanooptik und -elektronik
- Messtechnik und -verfahren.

Kontakt:

Sprecher der Fraunhofer-Allianz Nanotechnologie
Dr. Karl-Heinz Haas
Telefon: +49 (0)931 4100-500
E-Mail: haas@isc.fraunhofer.de
Fraunhofer-Institut für Silicatforschung ISC
Neunerplatz 2
97082 Würzburg

Stellvertretender Sprecher der Fraunhofer-Allianz
Dr. habil. Günter Tovar
Telefon: +49 (0)711 970-4109
E-Mail: guenter.tovar@igb.fhg.de
Fraunhofer-Institut für Grenzflächen- und Bioverfahrenstechnik IGB
Nobelstraße 12
70569 Stuttgart

Fraunhofer ENAS vertreten durch:
Prof. Dr. Stefan E. Schulz
Leiter der Abteilung Back-end of Line
Telefon: +49 (0)371 45001-232
E-Mail: stefan.schulz@enas.fraunhofer.de

DEPARTMENTS

PROF. DR. THOMAS OTTO

FRAUNHOFER ENAS DEPUTY DIRECTOR
HEAD MULTI DEVICE INTEGRATION

PHONE: +49 371 45001-231
FAX: +49 371 45001-331
EMAIL: THOMAS.OTTO@ENAS.FRAUNHOFER.DE

DEPARTMENT MULTI DEVICE INTEGRATION

Head of the Department: Prof. Dr. Thomas Otto

The strategic direction of the Multi Device Integration department is focused on the integration of MEMS and NEMS into functional modules and the development of MEMS and NEMS using silicon based and non-silicon materials (nanocomposites, ceramics and polymers). In terms of smart systems integration, the department combines primarily the activities in the areas of:

- MEMS/NEMS design and Electronics design
- Microoptics
- Fluidic integration
- Nanocomposites
- RF-MEMS
- Inertial sensors and measurement
- Measurement, test and characterization
- System integration.

The aim of the research is to develop and apply integration technologies taking into account of different materials and components to provide products which are able to fulfill the users' needs under different conditions by means of smart systems integration.

MEMS/NEMS Design

Novel modeling and simulation techniques are essential for designing innovative micro and nano electromechanical systems. Subsequent development processes require an understanding of the coupling of different physical domains at multiple levels. For this process, commercial and customized software tools are deployed for design, analysis and optimization of MEMS and NEMS. An effective linkage of these tools enhances the work of a design engineer to a great extend.

Coupled field analyses enable accurate predictions of MEMS and NEMS functional components and devices behavior. In consideration of process-induced geometric tolerances, the whole simulation chain is feasible. This includes the layout, process emulation, behavioral modeling of components with the help of the Finite Element Method and model order reduction up to system design. The model of the device can be used to optimize the layout for a mask fabrication and the final device is ready for the test within a virtual development environment and for measurement purpose. Extracted values from parameter identification are used to improve further models for the optimization of e. g. test structures, resonators or whole MEMS and NEMS devices.

We own the following core competences:

- Modeling, multiphysics simulation, design and optimization of conventional MEMS and future-oriented NEMS,
- Application-oriented MEMS/NEMS conceptual, component, device and system design,
- Combination of numerical simulation and characterization methods for parameter identification,
- Development of simulation methodologies for multiscale modeling of NEMS,
- Design of RF-MEMS,
- Design of MOEMS and optical design,
- Mask design, layout and technology support.

Electronics plays a crucial role for the operation of sensors and actuators. Only the concentrated interplay can lead the individual elements to an overall optimal functioning system. The main points of the electronics development are analog and digital circuits and mixed signal, PCB layout and software programming.

Microoptics

The Fraunhofer ENAS develops micro system based optomechanical setups and packages using a parameterized design, including thermal and mechanical simulations. Furthermore, the development of low-noise signal processing electronics is subject to these researches. Other priorities include testing and qualification on the component level as well as on the system level. One example for the activities in the field of microoptics is the development and validation of infrared MEMS spectrometers. Such systems can be configured for different wavelength bands and hence be used in various applications. Food studies, environmental monitoring, medical diagnostics, metrology or the physical forensic analysis belong to the fields of application.

Fluidic Integration and System Technologies

Microfluidics has become an important tool for many applications, e.g. in the fields of health care, chemical processing and consumer products. Microfluidic systems enable faster analyses, lower sample and reagent volumes, new methods of detection, advanced cooling mechanisms and the processing of macroscopically difficult to control chemical reactions. The integration of additional functionality into such microfluidic systems leads to smart, autonomous devices, reduces fluidic interfaces and requires less complex control and readout instrumentation.

The competencies include:

- Microfluidic modeling and system design,
- Fabrication of microfluidic devices in multiple materials such as polymers, glass and silicon,
- Integration of functionalities such as pumping, valving, temperature control and sensors into microfluidic systems,
- Sensors and actuators for active flow control,
- Microfluidic and thermal characterization.

Nanocomposites

As modern hybrid materials, nanocomposites combine polymeric matrices with nanoscale inclusions such as particles, fibers or tubes. Different functions are realized by different nano-fillers, while the matrices ensure mechanical stability and electrical connection to the environment. In current work we deal with the development of humidity sensors, piezoresistive composite sensors for the detection of forces and with the use of semiconductor nanocrystals for nano-sensors or in light-emitting systems.

Polymer-based nanocomposite systems are particularly suitable for the material-integrated functionalities, e. g., sensors such as in the field of condition monitoring. Currently we are developing layered systems in which semiconductor nanocrystals are embedded in various polymer matrices. The aim is to detect, for example, overloading of mechanical components, as changes in fluorescence of the nanocrystals.

RF-MEMS

The use of MEMS in microwave circuits as a replacement for conventional semiconductor devices can make a vital contribution to the optimization regarding DC-power consumption and signal attenuation. The proprietary Air Gap Insulated Microstructure (AIM) process is now optimized for the use of high-resistivity substrates and low-loss conductors. This leads to devices with very good RF performance. Due to their high temperature stability, hermetic packaging technologies can be applied. The high quality of a hermetic chip scale package for frequencies over 60 GHz has been demonstrated.

Inertial Measurement

Inertial sensors are used to measure acceleration, vibration, inclination, shock and angular velocity. An advantage of the micro mechanical inertial sensors is that the manufacturing costs are much cheaper than for other mechanical or optical alternatives. The areas of application are industrial electronics, automotive, aviation and aerospace and medical technology. The main end products are navigation systems, stabilized antennas, condition monitoring systems for machinery, equipment and vehicles as well as medical monitoring devices.

Measurement, Test and Characterization

A method for the extremely fast determination of dimensional and material parameters based on a combination of the Finite Element Method (FEM) and the measurement of Eigenfrequencies has been developed in recent years and is now improved and adapted to different classes of MEMS devices. In fabrication sequence, the Eigenfrequencies are measured by optical vibration detection and electrostatic excitation of the sample by external optical transparent electrodes. A further step calculates the dimensions or material parameters by estimation algorithms, being performed in less than two seconds and at wafer level.

Amongst others, the following instrumentation is available:

- MEMS motion test stage including wafer probe station,
- Topography measurement instrumentation and white-light interferometer including stroboscopic illumination,
- RF-MEMS test bench including wafer probe station up to 110 GHz.

Microstructur Vario Laser

Laser micromachining is a powerful tool. New designs can be rapidly implemented through direct writing (no masks needed) and processing of computer-generated files. Especially picosecond pulse laser machining is capable of delivering high precision, short processing times and outstanding quality at the same time for nearly every material using a 10 W-picosecond laser machine with four different wavelengths (1064 nm, 532 nm, 355 nm and 266 nm) and additionaly a continuous wave Thulium fiber laser (1908 nm). By manipulating a range of parameters, like power, pulse frequency, mark speed, focal spot diameter etc., an optimal result can be achieved.

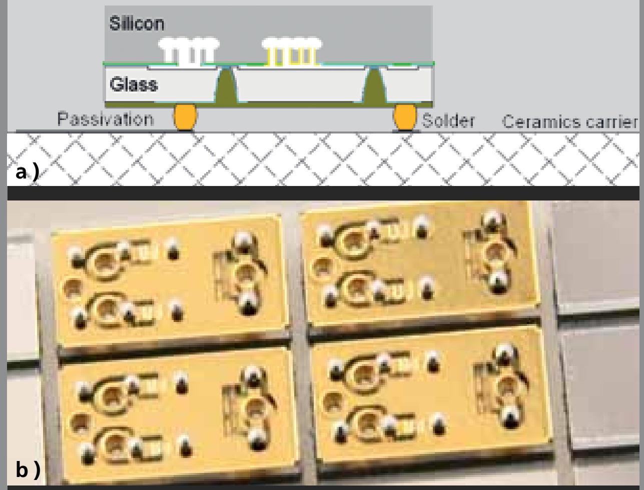


Fig. 1: a) Cross-sectional view of the micro-wave switch mounted on carrier, b) hotographic view of the samples.

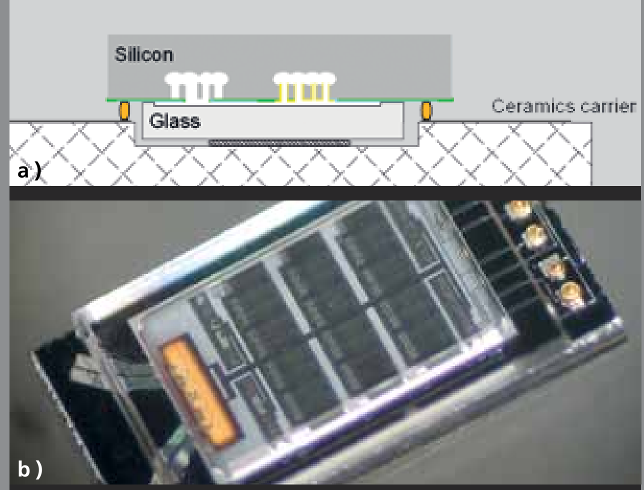


Fig. 2: a) Cross-sectional view of the mm-wave switch and mounting on carrier, b) photographic view of the samples.

OHMIC RF-MEMS SWITCHES

Steffen Kurth

Switches are deemed to be key components among the RF-MEMS, and are used for manifold applications e. g. TX/RX selection, reconfiguration of filters, of phase shifters or of antennas. One of the main concerns is the reliability, particularly the dielectric charging which may lead to undesired shift of the actuation voltage, but contact sticking and unstable contacts also.

This report shows the design, and measurement results of a electrostatically actuated Ohmic RF-MEMS switch with in plane actuation. A novel high aspect ratio MEMS fabrication sequence in combination with wafer level packaging is applied for fabrication of the samples and allows for a relatively large actuation electrode area, and for high actuation force. Devices in series switch single pole single throw (SPST) configuration for DC up to 4 GHz signal frequency and in shunt switch SPST configuration for a frequency range from DC up to 80 GHz are shown.

The switch design is based on separate areas for the actuator and for the signal that has to be handled. Two different concepts for signal interconnection between the contacts and the terminals of the devices were followed. In case of the lower frequency series type switch device that is capable to handle signals of frequencies up to 4 GHz, via holes in the glass cover are used (Fig. 1). In case of the mm-wave shunt type switch device for signal frequencies up to 75 GHz, a lateral feed through of coplanar strip lines on top of the silicon part has been chosen (Fig. 2).

Large actuation electrode area and a particular design feature for electrode over travel and dynamic contact separation lead to high contact force in the closed state and to high force for contact separation to overcome sticking. The special design of the mechanical system including an elastic part between the contact and the driving electrodes makes it possible to enhance the contact closing force and the force for contact separation. A static contact force of more than 100 µN and a dynamic force enhancement by electrode over travel with more than 250 µN were achieved.

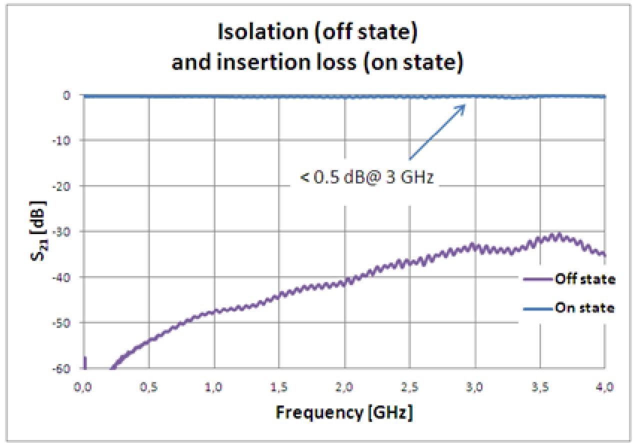


Fig. 3: Isolation and insertion loss of the 3 GHz SPST switch

The on-response time was measured with 10 µs and off-response time with 6 µs at less than 5 V actuation voltage. The switch devices are hermetically sealed by wafer level packaging. A defined vacuum pressure leads to optimized response time and no contact ringing.

The measurements of the scatter parameters resulted in < 0.5 dB insertion loss, 30 dB isolation in case of the 3 GHz series switch (Fig. 3) and in < 1.2 dB insertion loss, 18 dB isolation at 60 GHz in case of the 75 GHz shunt switch.

The switch contacts that are consisting of noble metal, are made in one of the latest process steps. This minimizes contamination of the contact surfaces by fabrication sequence residuals. A lifetime of one billion switch cycles has been achieved. Long term lifetime tests showed that the electrostatic drive system is free of charging.

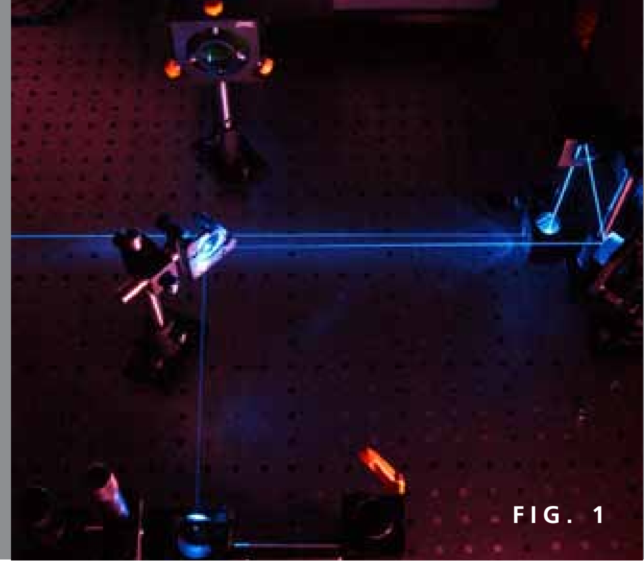


FIG. 1

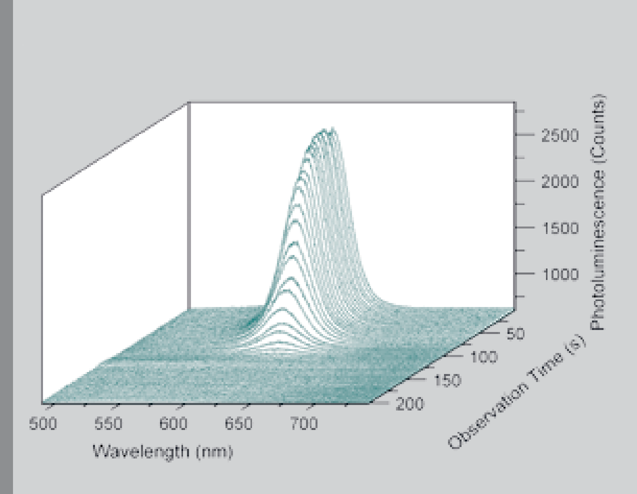


FIG. 2

OPTICAL AND NANOCOMPOSITE-BASED SYSTEMS

Joerg Martin

Polymeric nano- and microcomposites combine properties of the surrounding (polymer) matrix material as well as the embedded micro- or nanoscale fillers. Previously investigated materials were, beside different polymers filled with metal oxide and rare earth compounds, primarily nanocomposites based on conducting polymers and quantum dots (nanocrystals) for optical applications. Quantum dots show several advantages compared to organic light emitters. Among them are excellent chemical stability and narrow emission bands. Additionally the emission wavelength can be tuned in a broad spectral range only by changing the size of the nanoparticles. This is a large benefit for integration of these emitters into micro systems since incompatibilities between different organic materials can be avoided.

We managed to excite the nanocrystals electrically in two different ways – first as light emitters in an all-spin-coated quantum dot LED (QD-LED) and second as nanosensors with charge dependent fluorescence properties.

The produced thin-film-composites consist of CdSe/ZnS core/shell nanoparticles, which are embedded between charge transport layers. External charges are transferred to the composite film and injected into the nanocrystals, causing non-radiative exciton recombination. This results in photoluminescence quenching, which can be detected as local optical contrast. Fluorescence depletion as result of external applied voltages has been investigated by means of time-resolved confocal microspectroscopy. Excitation of the nanocrystals is done by a solid state laser at 475 nm wavelength (B&WTek Inc.). The fluorescence is collected by a 63x, 0.75 N. A. Zeiss objective and imaged onto the entrance slit of a grating monochromator (Shamrock 303i) with attached CCD (ANDOR Newton). A part of the confocal setup is displayed in Fig. 1.

A typical series of subsequent recorded quantum dot photoluminescence spectra is shown in Fig. 2. An external voltage ramp with a slope of 0.5 V per second was applied on a quantum dot sample. At the beginning of the voltage ramp the nanocrystal fluorescence stays roughly constant until a voltage of 20 V is reached. Then with increasing voltage the luminescence of the sample decreases steadily. Obviously, charge injection into the particles is easily achieved with the selected materials ensuring non-radiative recombination of excitons and thus the "dark state" of the respective particle.

Experiments show that the character of the matrix plays an important role with respect to charge storage and hence the light emitting properties of quantum dots. It was possible to store electrical charges in the nanocrystals, and hence the dark state, for several hours. Intensity ratios between photoluminescence on and off state up to 1:125 were detected.

Legend:

Fig. 1: Confocal microspectroscopy setup based on a grating monochromator with attached CCD (image by A. Morschhauser and C. Spudat).

Fig. 2: CdSe/ZnS nanocrystal photoluminescence quenching as result of an applied voltage ramp.

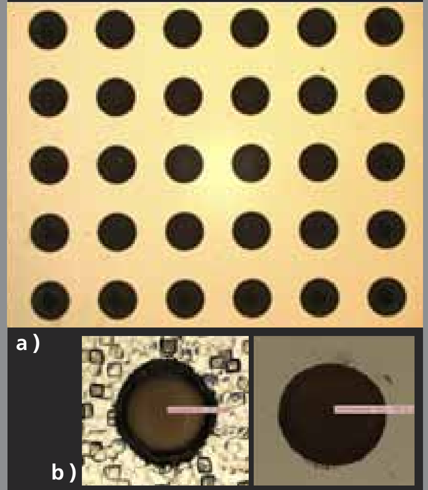


FIG. 1

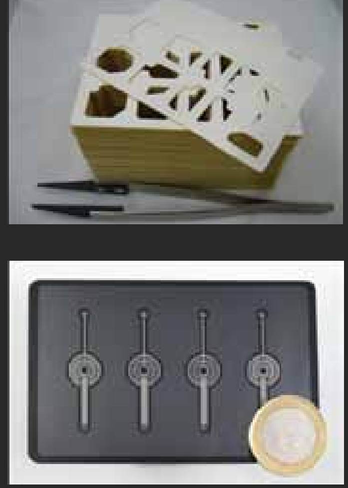


FIG. 2

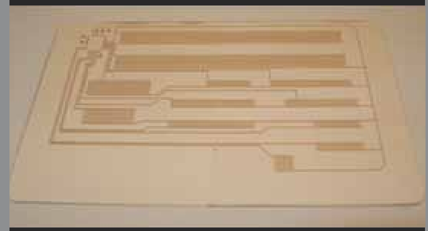


FIG. 3

LASER MICROMACHINING AS A VERSATILE TOOL FOR LAB-ON-A-CHIP AND MEMS DEVELOPMENT

Thomas Otto, Joerg Nestler, Andreas Morschhauser, Tom Enderlein

This article presents several examples of using a single picosecond laser workstation with four wavelengths (266 nm, 355 nm, 532 nm, 1064 nm) for structuring and bonding in microfluidics but also for various MEMS applications. Giving an example from the microfluidic area, typical components of a Lab-on-a-Chip are a fluidic substrate with channels, reservoirs and through-holes, and a layer with electrodes. During final assembly these components need to be bonded together.

Laser Structuring

Besides the prototyping of microfluidic channels and reservoirs in various polymers (Fig. 2b), there exists the need for structuring a wide range of other materials for different parts and processing steps in both Lab-on-a-Chip and MEMS applications. The most common applications are through-holes in glass or silicon for fluidic interconnections or electrical vias. Both can be precisely structured using picosecond laser micromachining. Fig. 1a shows a part of an array of holes in a 1 mm thick glass with a diameter of 1 mm, processed with a wavelength of 1064 nm and within a time of 10 s/hole. In the same manner silicon through-holes for interconnects are possible to be manufactured. The two pictures in Fig. 1b show a hole drilled from the backside (left, non-polished) of a 4 inch wafer with a thickness of 525 µm. The hole has a diameter of about 150 µm with a sidewall angle of less than 0.5°.

In addition to bulk material structuring also thin layers of various materials can be structured selectively to the substrate. Typical examples are metals or ITO on glass or polymers (Fig. 3). For all of these tasks, the main advantage of using a picoseconds laser source is the small heat affected zone due to the short pulse durations of about 9 ps.

Laser-Assisted Bonding

The final step of assembling all the parts of a polymer based Lab-on-a-Chip System can either achieved by an intermediate layer such as an adhesive tape, or by direct bonding without any intermediate layer. For both applications, the picoseconds laser workstation has been used.

The advantage of assembly with adhesive tapes is the ability to bond two different kinds of materials. Especially the laser cutting of medical grade adhesive tapes (Fig. 2a) is a fast precise process for manufacturing of even larger quantities within minutes. If similar materials need to be joint, direct laser welding can be used being a fast and precise process without contamination of active areas (Fig 2b).

Legend:

Fig. 1: a) Through-holes with diameter of 1mm in a 1 mm thick glass wafer, b) Through-holes in a 525 µm silicon wafer (diameter of 150 µm, sidewall angle < 0,5°)

Fig. 2: a) Laser cut medical grade adhesive tape, b) Laser-welded transparent PC on black PC with microfluidic channels [1]

Fig. 3: Structured thin-film gold layer on PET [1]

[1] Enderlein, T., et al., Proc. Smart Systems Integration 2012

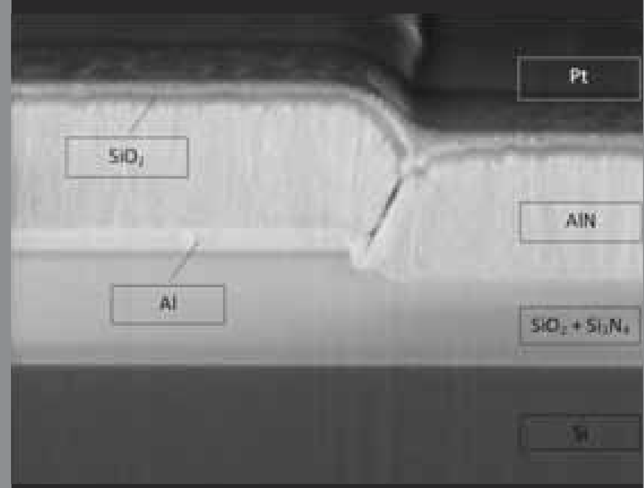


FIG. 1

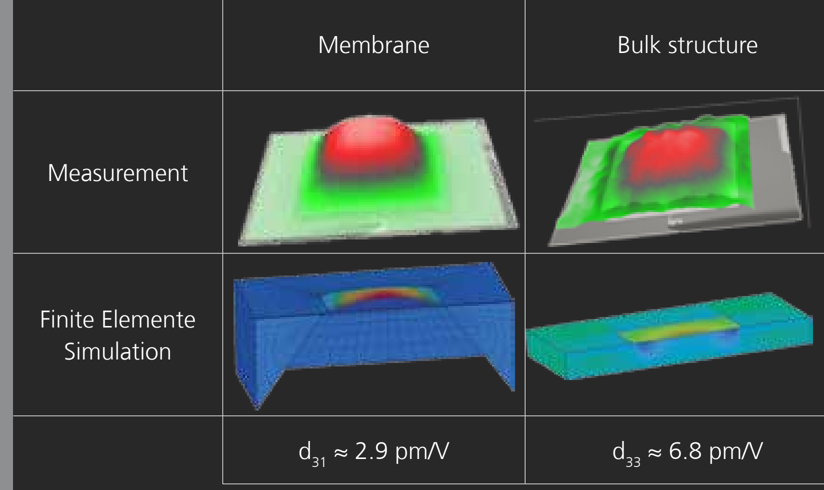


FIG. 2

INTEGRATION OF PIEZOELECTRIC ALUMINUM NITRIDE IN MEMS/NEMS

Chris Stoeckel, Ramon Hahn, Christian Kaufmann, Robert Schulze, Detlef Billep

Aluminum nitride (AlN) is an innovative material for MEMS and NEMS sensors and actuators. The coupling coefficient of the piezoelectric active principle is much higher than capacitive one. This allows down-scaling of smart systems as well as cost and energy consumption reduction which results in an increase of the number of fields of application. Therefore piezoelectric transducers have the potential to partly replace capacitive sensors and actuators to enhance the smart systems integration.Furthermore AlN is highly capable of being integrated into MEMS/NEMS technologies and CMOS processes.

Fraunhofer ENAS develops sputtering technologies and characterization methods for piezoelectric AlN and integrate piezoelectric materials into MEMS/NEMS applications.

AlN is deposited between two electrodes and mechanically coupled with a movable silicon structure (Fig. 1). External mechanical excitations (e. g. acceleration) generate forces to deflect the movable silicon and thus AlN layer. Due to the piezoelectric effect an electrical charge generated. Otherwise utilizing the inverse piezoelectric effect for actuator applications an electrical voltage can be applied at the electrodes and the piezoelectric material is deflected.

AlN can be deposited and etched at different substrates. XRD, SEM and FIB-cuts are used show the crystal orientation as well as the etching results. In Fig. 1 a FIB-cut of highly c-axis oriented AlN had been done. As seed layer for the growth of aluminum nitride aluminum electrodes were used on top of the movable silicon structure.

A combined use of different measurement techniques and Finite Element simulations enable the determination of mechanical, electrical and piezoelectric material parameters. Mechanical coefficients were determined by nanoindentation measurements. For measuring the piezoelectric coefficients $e_{31,f}$ and $d_{33,f}$ specific test structures were designed. These measurement results were compared with simulation results to extract further parameters. With Laser-Doppler-Vibrometry dynamic displacements of membranes can be measured in the range of 1 – 2 nm with an excitation of 1 V (Fig. 2). Hence, the piezoelectric coefficient d_{31} and d_{33} were determinated with 2.9 pm/V and 6.8 pm/V.

Legend

Fig. 1: FIB-cut of a SOI-Wafer with aluminum seed layer and on top c-axis oriented aluminum nitride with etch mask.

Fig. 2: Comparison of measurement and FE simulation results of an electrical actuated membrane (1.4 nm/V) and a bulk structure (4 pm/V) structures for the identification of piezoelectric material parameters.

PROF. DR. BERND MICHEL

HEAD MICRO MATERIALS CENTER

PHONE: +49 371 45001-220
FAX: +49 371 45001-320
EMAIL: BERND.MICHEL@ENAS.FRAUNHOFER.DE

DR. SVEN RZEPKA

HEAD MICRO MATERIALS CENTER

PHONE: +49 371 45001-421
FAX: +49 371 45001-521
EMAIL: SVEN.RZEPKA@ENAS.FRAUNHOFER.DE

DEPARTMENT MICRO MATERIALS CENTER

Head of the Department: Prof. Dr. Bernd Michel, Dr. Sven Rzepka

The competence and experience in the field of reliability research available at Fraunhofer ENAS has been the result of 25 years of industry related work. It started with studies on fracture and damage mechanics for lifetime estimations of big pressure vessels at the Institute of Mechanics. After founding the Micro Materials Center, these methodologies could be transferred and expanded into the field of electronics packaging during the 90s and grown further into micro and nano technologies after the turn of the century. Becoming part of Fraunhofer ENAS, the logical next step has been made by comprehensively covering the needs of smart systems integration as well.

Today, the Micro Materials Center is able to assess and to evaluate the effects and interactions that lead to drift or degeneration of performance parameters and finally to the failure of the micro and nano systems. Strictly following the 'physics of failure' approach, potential yield distracters as well as risks concerning reliability, safety, and security of new technologies and products can be identified at the earliest time possible and lifetime models can be extracted. Being the result of direct cooperation, these findings directly support the development of new products and systems in industry (design for manufacturability and reliability). The ultimate goal of this effort is to fully optimize products based on numerical simulations avoiding all the time-consuming and expensive experiments prior to shipment qualification. This methodology of full 'virtual prototyping' would create new system solutions at a fraction of current time and cost. Therefore, the results of the numerical simulations must be as accurate as real sample tests. Key to achieving this is a truly symbiotic alliance between simulation and experiment. Prof. Bernd Michel and the Micro Materials Center at Fraunhofer ENAS have pioneered this approach and continue leading its advancement.

Competences:

- Microreliability and nanoreliability of components, systems and devices
- Reliability for micro- and nanotechnologies (Clean Micro- and Nanotechnologies)
- Thermo-mechanical reliability analysis
- Experiments and design for reliability of micro-nano-integration
- Crack avoidance strategies
- Reliability for avionics and space applications (JTI Clean Sky, ESA projects etc.)
- Microreliability for automotive electronics and smart sensor systems
- Reliability for batteries of electro automotive applications
- Solder reliability for micro-nano interconnects
- Reliability for packaging in the micro-nano integration field
- Reliability for micro and nanoelectronics (3D system integration, More than Moore)
- Local deformation analysis (microDAC, nanoDAC, fibDAC, nanotom, Raman, EBSD, X-ray etc.)
- Analsysis of internal stresses (in MEMS, wave analyses etc.)
- Physics of failure analysis, fatigue and creep analysis
- Reliability for solar applications and photovoltaics

Advanced Methods for Reliability Evaluation and Risk Management

- Local deformation analysis using various experimental techniques (e.g. FIB, nanotom etc.) combined with advanced simulation tools and lifetime prognosis (based on DIC digital image correlation strategies)
- Crack avoidance and crack detection methods for reliability and lifetime evaluation
- Complex loading and health monitoring techniques for combined testing (mechanical, thermal, vibration, humidity, diffusion, electrical fields)
- Crack and failure analytical methods
- Modular modeling applied to reliability analysis
- fibDAC, micro- and nanoRaman, and EBSD stress analysis

Research Highlights

New Lab for Material Characterization and Dynamic Fatigue Testing

In 2011, the Micro Materials Center has established a new lab dedicated to precise material characterization and fatigue testing of organic, composite, and laminate materials including those functionalized by the integration of smart systems. The lab is located on the Smart Systems Campus and operated jointly by Fraunhofer ENAS, Chemnitz University of Technology, and Berliner Nanotest & Design GmbH. It offers state-of-the-art tools for dynamic mechanical analyses (DMA), thermal mechanical analyses (TMA), and vapor sorption analyses (TGA-SA). In addition, it allows performing fatigue analyses exposing the specimen to forces up to 750 N in single shocks or ±1000 N in dynamic loads at frequencies up to 200 Hz within a wide range of environmental conditions (temperature: -70 °C … 350 °C – also at different levels of humidity between 5 °C and 95 °C). This way, reliability and lifetime of structural components functionalized by smart systems can be assessed and new test methods can be developed.

Reinvention of Lighting

Following the 'More than Moore' track of developments in micro-/nanotechnologies, first steps have already been made to greatly change the way we illuminate our homes, offices, and public places. The goal is to simultaneously save energy massively and to provide the light meeting the specific demands exactly all time. For example, your living room illumination shall rather be cozily indirect if you sit chatting with family and friends, rather focused when you read a book, and switched off right after you left the room. Solutions capable of automatically realizing such complex situations require smart systems with sophisticated sensing and data processing features in addition to the actual lighting elements. The lighting elements themselves shall rather be dispersed freely across the room than staying concentrated in bulb-carrying light sources of today. Hence, the smart systems integrated in the future lighting solutions also need communication abilities for organizing the illumination to really meet the demands of the specific situation. Micro Materials Center of Fraunhofer ENAS participates in the European project 'EnLight' lead by the global players in lighting industry like Philips, Orsam and

FRAUNHOFER ENAS

others. The project of 28 partners tackles the challenges as listed above in a comprehensive way. The contribution of Micro Materials Center focuses on reliability assessments and research with the goal of creating demonstrator systems that are designed for high yield in manufacturing and for proper reliability in future service right from the beginning.

Reliability of Modern Mobility Solutions

All modern mobility concepts assume the use of numerous smart systems and innovative material solutions as essential hardware basis. Today already, service conditions of automotive, aircraft, and space applications greatly exceed the reliability requirements to be mastered in typical office and industrial systems. Safety concerns related to the introduction of new features in electrical vehicles such as high-energy batteries, 'driving by wire' or even by wireless communication, and ultra-compact high-power control systems within the traction block further increase the level of challenges regarding thermal, mechanical, and thermo-mechanical integrity of the new smart power and communication systems involved. The Micro Materials Center actively contributes to the multifold research efforts taking place on national and European level targeting:

- Development of next generation battery management systems for fully electrical vehicles (EU project 'smartLIC'),
- Lifetime prognosis and design optimization of structural components of fiber reinforced materials under complex loadings in dry and humidity atmosphere (EU project "CleanSky – Eco Design"),
- Design for reliability of sensor networks for structural health monitoring of lightweight and fiber reinforced structures (national projects "Nanett", "CoolSilicon"),
- Reliability of components for active flow control: simulation, measurements, and characterization of the fluid/structure interaction in micro-jet nozzles (EU project "CleanSky – Smart Fixed Wing Aircrafts")

Measuring Mechanical Stress in Nano-Scale BEoL Structures

The fibDAC stress analysis method, which was developed by Micro Materials Center recently, has further been upgraded substantially in 2011. Applying the Auriga 60, which is the latest development of Zeiss Jena in the field of focused ion beam (FIB) analytical tools, the width of the trenches milled in to the surface of the specimen can be reduced to as little as 30 nm. Therefore, the deformation this tiny slit triggers in its vicinity allows characterizing the stress situation at nano-scale such as within BEoL structures as fabricated in latest technology steps. The deformations caused by the stress relief are captured by high-resolution SEM images before and after milling the trench. They are quantified by local digital image correlation and evaluated by numerical simulation. This way, the original stress can be determined precisely. In 2011, the fibDAC stress analysis method has been qualified for industrial use. The new method was benchmarked against the established wafer fab tools like bow measurement and R&D tools like Raman spectroscopy. The results show good agreement when single layer systems are assessed. Afterwards, the advantages of the fibDAC stress analysis method were demonstrated on samples with patterned structures. Substantial differences were found in the local stress field of typical BEoL systems. The fibDAC stress analysis method provides deep sub-micron resolution. It is applicable to all materials used on the wafer. Moreover, it offers the potential of detailed analyses within multi-layer stacks. Eventually, a fibDAC analysis will not take longer than regular FIB/SEM inspections. Applied to test patterns in the scrip line, the method may well become part of quality control in regular wafer production as well as of all R&D activities on 3D stacks to analyze the internal stress state and chip/package interactions.

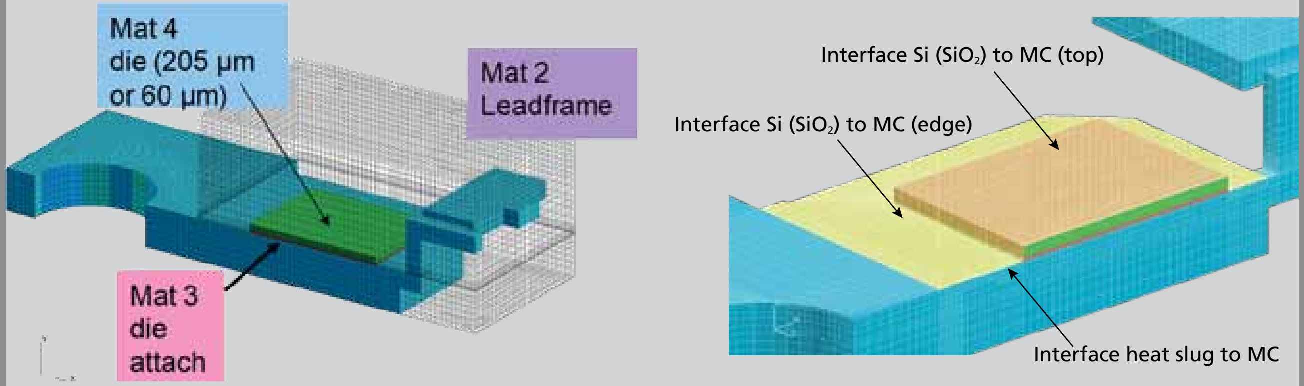


FIG. 1

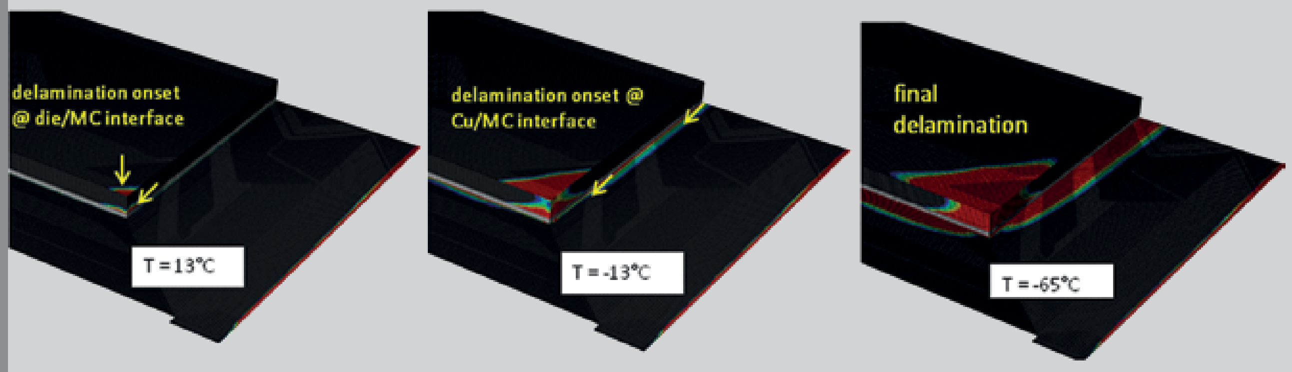


FIG. 2

DELAMINATION FAILURE PREDICTION BY ADVANCED DAMAGE MECHANICS MODELING

Rainer Dudek, Ralf Döring, Sven Rzepka, Bernd Michel

Interface delamination is one of the major sources of failure in smart system technology, as multi-material systems are exposed to thermal and mechanical loadings. Delamination failure can occur already after mounting, e.g. after soldering and subsequent cooling down, after thermal test cycling, or during service caused by active heating of the device and environmental temperature changes. But not only thermal exposure, but also moisture induced deformations of a multi-material system as well as mechanical loadings can cause this failure type in sensors and actuators and their packages, as well as in microelectronic and power packages.

Delaminations can occur at a variety of interfaces between dissimilar materials, e.g. chip metallizations, coating layers, and interfaces of plastic encapsulants. These reliability issues have long been recognized, however, they are difficult to handle theoretically to perform reliability and safety predictions. The difficulty is twofold: one needs a theoretical frame beyond standard theory of strength of materials and critical strength parameters for the interfaces under question.

For quantitative, predictive aims a theoretical framework based upon the cohesive zone method (CZM) has been applied to open up qualitatively new ways for delamination failure prediction. The methodology was first developed to enhance the failure prediction abilities for power packages, where standard theory based on the strength of materials background is limited due to stress singularities at sharp interface edges.

The methodology is situated between fracture mechanics and continuum damage mechanics. The fracture or delamination process is treated as a gradual process in which separation between materials surfaces is resisted by cohesive tractions over a finite separation length, the cohesive zone. Per definition, no sharp interface edges or crack tips obeying a singular asymptotic stress field exist within this method, as they are replaced by a kind of process zone in vicinity of the singular stress point. The growing crack or delamination can be followed in a numerical realization on predefined paths. Limitation to predefined paths makes the method most suitable for analysis of delamination between dissimilar materials, as the potential area of crack extension is known beforehand and other methods, like X-FEM, are not well-suited for such applications. Additionally, the methodology is not confined to a class of materials, but can be used for arbitrary materials. The cohesive law can be assumed independently of the materials properties of the materials adhering to the interface as a model of the separation process. The interface properties are introduced by considering the fracture energy needed for interface separation and the fracture strength of the interface.

Tests were performed to determine the critical interface strength. Various tests are known to study this strength or the interface adhesive fracture of a bi-material system. One of them is the so called "shear test", where a small button of one material adhering to another one is sheared away and the interface adhesion is measured analyzing the maximum shear force.

In our first approach, the interface strength between moulding compound (MC) and copper has been studied, as this interface type occurs frequently in smart system packages. To determine critical adhesion properties for the MC-copper interface a linear traction-separation approach was developed. The damage evolution law describes the rate of material stiffness degradation vs. separation progress after the damage initiation criterion has been reached. The scalar damage field representing the local damage variable D reflects the separation progress and lies between 0 (damage initiation) and 1 (total damage). The cohesive parameters were chosen such that quasi-brittle fracture, which describes the physics of failure best in the selected case.

One of the investigated packages was a power packages P-TO 220 with highly refined cohesive model shown in Fig. 1.

Different cohesive interface areas require description of separate interface fracture properties; however, they differ significantly with regard to the materials and processing history. A parametric study was undertaken to find out critical interface adhesion properties. For a parameter set with critical adhesion properties, delamination is visualized by the damage variable D (red, $D > 0.95$) in Fig. 2. It is obvious from the figure that delamination starts at the die edge (top and edges), develops there while later a second delamination initiates at the MC-heatsink interface edge. No delamination is seen at the peripheral edge of the package in this case. It turned out that delamination failure is not an issue for good adhesion properties. For medium and low adhesions, the package tends to delaminate.

By use of this methodology and the critical adhesion parameters derived from shear tests a new quality of delamination failure prediction has been reached. For the first time delamination failure can be predicted quantitatively inclusive the prediction of the delaminated area.

In that way e.g. failure predictions of power packages under different thermal shock and thermal cycle conditions were made. A high acceleration of thermal shock testing as well as optimized devices could be worked out [1] with a high potential of cost saving. By further developments of the methodology simulation will be capable of replacing highly expensive tests to a great extend.

[1] Dudek, R.; Pufall, R.;Seiler, B.; Michel, B.: Studies on the Reliability of Power Packages Based on Strength and Fracture Criteria. Proceedings EuroSimE 2011, Linz, Austria, April 2011 (to appear in journal "Microelectronics Reliability").

Legend

Fig. 1: Finite element model for delamination failure analysis by the cohesive zone approach at a power package.

Fig. 2: Delamination progress from left to right: delamination onset (red) at the peripheral parts of the die/MC interface, delamination onset (red) at heatslug/MC interface, and delaminated state after delamination has progressed for temperature loading down to - 65 °C.

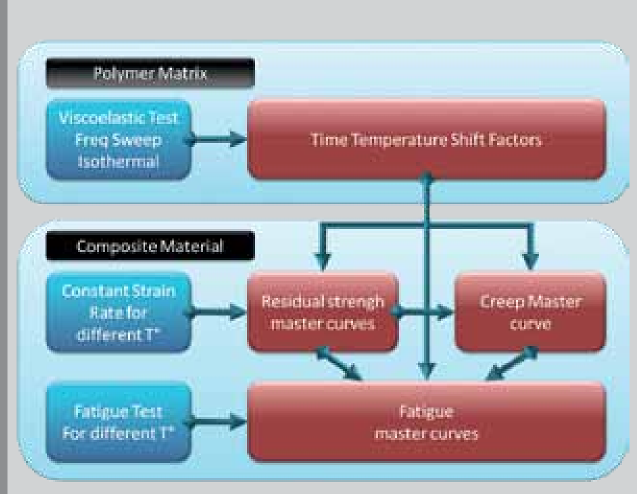


Fig. 1: Methodology for accelerated lifetime evaluation of FRP materials

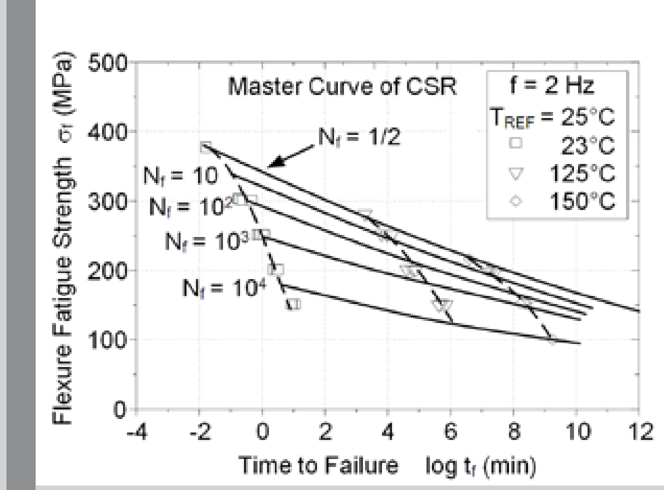


Fig. 2: Fatigue master curve for PCB IS400

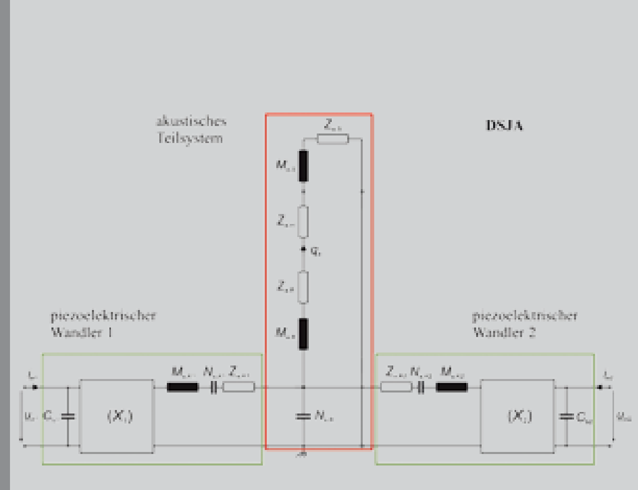


Fig. 3: LE-Model for DWSJAs

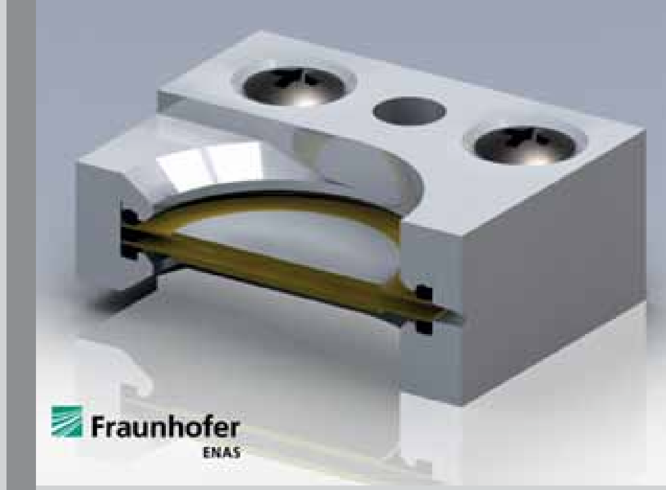


Fig. 4: First design of DWSJAs

FRAUNHOFER ENAS CONTRIBUTES TO THE EU JOINT TECHNOLOGY INITIATIVE "CLEAN SKY"

Eberhard Kaulfersch, Martin Schüller, Thomas Otto, Sven Rzepka, Bernd Michel

Air transport is a key factor to further economic growth in the world. At the same time, it is facing all the global economic and ecological challenges. Consequently, the joint technology initiative (JTI) 'Clean Sky' has been launched in 2008 to run for seven years. It aims at strengthening the competitiveness of Europe's aeronautics industry by massively lowering the impact of air transport on the environment. The ambitious goal is to reduce the fuel consumption of the aircraft so that CO_2 emission is decreased by 50 %, NO_2 emission by 80 %, and noise generation by 50 % till the year of 2020. With 86 partners from 16 countries and a total budget of 1.6 billion Euros, JTI Clean Sky is one of the largest European research projects ever. It comprises six integrated technology demonstrator (ITD) projects dedicated to smart fixed wing aircraft (SFWA), green regional aircraft (GRA), ecological design (ED), systems for green operation (SGO), sustainable and green engines (SAGE), and green rotorcraft (GRC), respectively. Fraunhofer ENAS is participating in four of the six ITDs and is member of the SGO steering committee. This paper highlights major research activities of Fraunhofer ENAS in the ITDs ED and GRA in 2011.

Clean Sky ITD "Eco Design": Methodology for Accelerated Lifetime Testing of FRP Structures

The substitution of metal structures by fiber reinforced polymers (FRP) allows reducing the weight and, hence, increases the energy efficiency of dynamic systems. However, it also raises new reliability concerns. The structural degradation of FRP is well-known to be hardly visible until very short before the full fracture and to be highly dependent on the stress conditions like loading ratio, loading directions, temperature, moisture, and UV radiation. Unfortunately, the current test procedures for these effects are time-consuming and require already well qualified engineering samples of the particular structure. Therefore, it would be beneficial to have decent data for predicting the composite lifetime under various configurations, loads, and environmental conditions during the design of the structures already. Fraunhofer ENAS contributes to the development of accelerated testing and lifetime prediction methodologies for aeronautic FRP as well as for other kinds of dynamic systems. The study has started with HexPly 913, a composite material used in structural part of airplanes. The modified epoxy matrix allows low temperature curing yet exhibits excellent environmental resistance with good hot/wet mechanical performance. The material is reinforced with unidirectional carbon fibers of about 6 µm in diameter. Secondly, IS 400, a typical PCB material, has been included in the study. It allows expanding the methodology to smart systems featuring sensor, electronics, and other functional components into FRP structural parts. IS 400 is an epoxy matrix reinforced by woven E-glass fibers. The accelerated reliability tests for FRP structures have been based on the approach published by Miyano et al. [1]. It comprises three kinds of tests (Fig. 1): visco-elastic dynamic mechanical analysis (DMA), constant strain rate (CSR), and cyclic fatigue tests. The fundamental hypothesis assumes that the visco-elastic behavior of FRP materials is fully determined by the polymer resin and not affected qualitatively by the reinforcing fibers. Furthermore, the function of time-temperature superposition (TTS), which can be determined by visco-elastic material characterization, is assumed to also control the response to fatigue loads and, therefore, the time to failure of complete and complex FRP structures. The Micro Materials Center at Fraunhofer ENAS has demonstrated this methodology of accelerated fatigue testing to be applicable to both materials, HexPly 913 and IS 400, in the same way. Fig. 2 shows the fatigue master curve of the material IS 400. It has been created from a limited number of tests (4…5 load levels at 3 different temperatures) but may now be used for estimating the structural fatigue lifetime at any temperature and under various types of loads (static / constant strain rates … dynamic cycles) [2].

Clean Sky ITD "Green Regoinal Aircraft": Design of Dual Transducer Synthetic Jet Actuators

Active flow control on aircraft wings is proven to be capable of enhancing lift and delaying separation. Suction or continuous blowing can be applied as well as pulsed blowing feeding rapidly switching valves with pressurized air. Synthetic jet actuators (SJA) have the advantage of not requiring pressurized air. They generate a momentum flux greater than zero locally while the global net-mass-flux remains zero [3]. Initial studies by Smith and Glezer [4] in 1994 have already shown synthetic jets to influence or to interact with the boundary layer, which allows SJA to be used for flow control. SJA consists of a cavity bordered by the converter on one side and by an orifice on the other side (a canal/conduit or a duct/nozzle). During the phase of suction, the oscillating fluid is drawn from the environment/ambience into the chamber while it is pushed out during the phase of expulsion. An application specific design of SJA requires high quality models. Equivalent electric circuit models are insufficient. Instead, the electro-mechanical transducer and the acoustic/fluidic subsystems need to be modelled separately. Combining network analysis and finite element methods accordingly [5], Fraunhofer ENAS has developed a new SJA concept of increased performance. A Helmholtz resonator is equipped with two transducers. The piezoelectric membranes generate the volumetric flow symmetrically from both sides of the chamber. A common outlet connects them to the acoustic far field. Fig. 3 shows the network model [6] used for designing and optimizing the SJA. The comparison of the analytical model and the LEM, discussed in previous publications [6], showed a high level of compliance of the results [5]. Based on this, a double-wall actuator (DWSJA) was developed (Fig. 4). Although using two transducers does not fully double the exit velocity [7], it still shows major improvement over conventional SJA with single transducers.

References

[1] Y. Miyano, M. Nakada, and K. Nishigaki: Prediction of long-term fatigue life of quasi-isotropic CFRP laminates for aircraft use. Intl. Journal of Fatigue, Vol. 28, No.10 (2006), pp. 1217 – 25.

[2] S. Rzepka et al.: Accelerated fatigue testing methodology. EuroSimE 2011, 058.pdf on Conf-CD.

[3] C. Lee et al., Sensors and Actuators. A 108 (2003) pp 168 – 174.

[4] C. Hilton et al., J. of the Braz. Soc. of Mech. Sci. & Eng., Vol. XXIX, No. 1 (2007), pp 34 – 41.

[5] M. Schueller et al., Smart System Integration, 2011, Paper 97.

[6] R. Ballas et al., Springer-Verlag, Berlin [u. a.], 2009, ISBN 978-3-540-89317-2.

[7] M. Schueller et al., DGLR 2011, pp 1185 – 1194.

PROF. DR. REINHARD R. BAUMANN

HEAD PRINTED FUNCTIONALITIES

PHONE: +49 371 45001-234
FAX: +49 371 45001-334
EMAIL: REINHARD.BAUMANN@ENAS.FRAUNHOFER.DE

DEPARTMENT PRINTED FUNCTIONALITIES

Head of the Department: Prof. Dr. Reinhard R. Baumann

The department Printed Functionalities focuses on printing technologies for the manufacturing of printed products which do not solely address the human visual sense but employ these deposition technologies for the application of functional materials. These printed functionalities range from simple conductivity, semi conductivity and isolation up to chemical activity e.g. in batteries or catalysis. These functionalities can improve and enhance the performance and the architecture of smart systems e.g. by printed interconnections or printed power modules. In future thus equipped products will have functionalities beyond color enabling them to perceive their neighborhood and their own state, allow the interaction with a user and the communication with computer networks, in short: convey them to an intelligent item of the internet of things.

Since 2009, the publication of a printed battery is raising worldwide attention. The highlight in 2011 has been the pilot manufacturing of greeting cards. Also new demonstrators have been developed and manufactured to underline the flexibility of usage of this battery. New investigations in this area are done in a close cooperation between Fraunhofer ENAS, Chemnitz University of Technology and the company Printechnologics.

The Fraunhofer ENAS thin film batteries are a convincing example of employing printing technologies for the deposition of functional materials in patterns required in subsequent technological steps. Today's printers are equipped with highly advanced press and post-press technologies to produce high-quality print products. These products are solely made to be recognized by the human senses. Most commonly known is the visual reception of color and sharpness, sometimes even glossiness. Special varnishing techniques enable the printer to apply haptic elements to his products. Using special inks containing micro-encapsulated odorous substances even the human scent can be addressed. These printed functionalities are state-of-the-art and they are based on the traditional printing processes gravure, offset, flexo and screen printing as well as the digital printing processes electro photography and inkjet. The today's printing technologies are well developed processes to transfer colored ink dots onto fiber based substrates, plastic foils or sheet metal. The printout is rated of good quality when the human eye sizes the well defined ensemble of screen dots as a halftone image or even a full tone area. In case of haptic or odor elements similar human sense based quality characteristics can be defined. Printing haptic or odor elements is going beyond traditional color printing, facilitating besides the regular functionality "color" further functionalities manufactured by printing.

On this note the term "Printed Functionality" goes far beyond color and we envision that the functionalities Electrical Conductivity, Adapted Dielectric Properties, Electrical Semi-Conductivity, Electric Power, Electro-Luminescence / Light Emission, Sensing Environment, Surface Protection, Intelligence via Chip or even Catalysis will be manufactured by employing press and post-press technologies. And we expect that the digital printing technology inkjet will contribute substantially by enabling the deposition of very small amounts of expensive functional materials.

Under more general aspects printing is a highly efficient image wise coating technology to deposit functional materials in a predefined thickness only at the right position on an appropriate substrate. Which means printing is an additive technology in contrast to subtractive technologies like photo lithography or etching, characterized by coating the substrate with a continuous material film initially and removing the material image wise from the substrate in expensive additional subsequent steps.

Given the today's high accuracy and reproducibility of printing based material deposition in conjunction with the remarkable potential for further developments, printing is expected to be the dominating technology for the fabrication of smart printed matter in high quantities. However, no single printing method is capable to offer an all-encompassing performance. Therefore, instead of using a single printing technology, hybrid machine combinations of contact printing methods (gravure, screen, flexo), inkjet printing, laser processing and further high-volume production technologies need to be utilized. New modular machine concepts shall warrant a flexible design of manufacturing processes at reduced investment costs for smart packaging production.

The evolution in the field of "printed smart objects" depends on the accomplishment of the challenges in the interdisciplinary development of complex functional inks, flexible manufacturing processes and modular machine systems with integrated analogue or digital manufacturing technologies.

If these printed smart objects shall be enabled to exchange data with computer networks they need to be stuffed with wireless Radio Frequency (RF) communication technology, typically consisting of a Silicon chip and an antenna. The efficiency of RF communication strongly depends on the dielectric environment in which the antenna transmits the data. And in reality it is found that more or less every object needs an optimized antenna design for a reliable data communication. In case of printed objects it is obvious that the optimized antenna could be manufactured by printing it directly onto the object together with all the colors. The Fraunhofer ENAS department of Printed Functionalities follows these ideas and hence focuses currently, besides further challenges, on the design, printing and characterization of appropriate antennas.

For all these developments mentioned above we employ traditional and digital printing technologies to manufacture new printed products, taking advantage of the additive character of the printing technologies and their high productivity. We focus on drop-on-demand inkjet, screen, and gravure printing and we develop technologies for the integration of Silicon electronics into printed smart objects. An important factor for success will be our close cooperation with the Chemnitz University of Technology and further local and global industrial and academic partners.

Our Competences:

- Printed functionalities: conductivity, semi-conductivity, insulation, energy accumulation, catalysis, light based energy conversion
- Printed thin film batteries
- Research and Development on antennas to match specific applications and there manufacturing employing printing technologies
- Printed smart objects with integrated micro and nano systems
- Device prototyping and industrialization of their manufacturing
- Characterization of inks, functional layers, components and systems

We offer the following services:

- Precise deposition of liquid processible materials to form patterned layers with defined properties, utilizing printing technologies,
- Specific employment of inkjet techniques for resources-saving, additive material deposition,
- Printing-workflow development to optimize the manufacture of new functionalities,
- Material and layer characterization: viscosity, surface tension, morphology, electronic properties, layer zoning, layer interaction,
- Development of innovative components for specific applications based on printing technologies, e.g. flexible energy/battery systems,
- Printing of conducting patterns, e.g. antennas or electrodes.

Fig. 1: Custom designed battery.

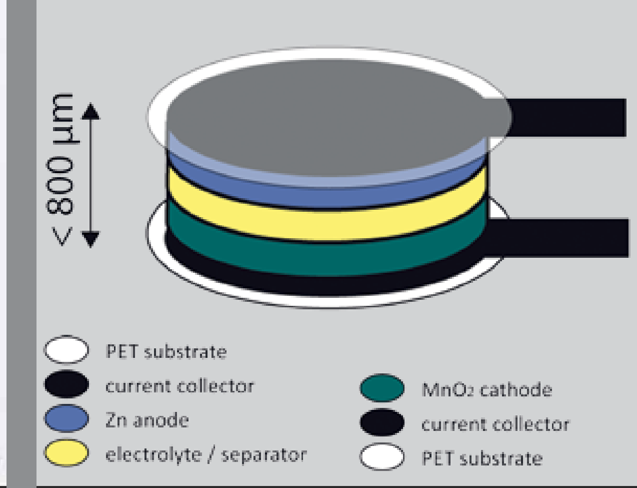


Fig. 2: Assembling scheme of printed batteries.

Fig. 3: Luminescent greeting card.

CUSTOMIZED APPLICATION OF PRINTED BATTERIES IN GREETING CARDS

Michael Espig*, Andreas Willert, Reinhard R. Baumann
*Chemnitz University of Technology, Department Digital Printing and Imaging Technology

Scope

In the field of conventional greeting cards the most important challenge is to draw the addressee's attention. To highlight the issue of thin and flexible power supplies, a special type of power source – a printed battery – was integrated. The ambition was to create a fully integrated device that represents the potential of printing technologies.

Printing of electrical energy sources as part of the manufacturing process offers numerous advantages. So is printing itself considered to be a technology with extraordinary throughput, reproducebility and the applicability for highly efficient mass production associated with low costs. Therefore the use of these technologies opens a high flexibility.

This is not only related to the applied substrates, which can be paper, plastic foil or textiles as well. But also shape, size and layout of printed structures are variable likewise and may be exchanged very quickly. Hence the promising connection of printing and manufacturing of electrical energy sources identifies many opportunities to optimize production technology, reduce production costs and avoid special waste. The highest potential is most likely the development of new applications, e.g. smart cards and tags, lab-on-chip systems or even 3D smart objects that are powered with printed energy sources [1].

Basic Concept

Printed batteries are commercially available in the market. They are sold as a single device that has to be assembled to the application by the customer. In contrast to this traditional business model we demonstrate a fully integrated product consisting of a shape-adapted battery powering a circuitry. The devices are sequentially manufactured on the same substrate and finished by lamination; giving an autonomic flexible, 1 mm thin product that can easily be integrated in an otherwise produced greeting card.

To achieve such a printed smart system the central idea was to join the adaptable power source with the card theme by using a LED-array, representing the headlights of the E-Mobile on top. In order to seamlessly fit into the final product an electrical circuitry was conceived for the LED alignment and the eco-friendly battery. Due to the use of printing technologies it was possible to customize its size and shape just to the requirements in terms of voltage and capacity. In this way the battery is merging into the circuitry, which can be seen in Fig. 1.

Manufacturing

The manufacturing of the custom design was accomplished by using semi-automatic, sheet-to-sheet screen-printing and blading processes. Among others this technology enables coating application of highest layer thicknesses and makes the imprint of almost every material with special inks possible [2]. Thus, the application of screen-printing for processing electrode materials appears to be reasonable. The different battery components were applied layer by layer as shown in the second figure. As a first step current collectors were printed onto PET foil of 100 µm thickness.

After drying the first layer, positive and negative electrode materials need to be deposited. For the appliance within the staple articles like greeting cards an environmentally friendly chemical system was utilized. The use of zinc and manganese dioxide prevents the final smart system from being classified as special waste. The chemicals, formulated with high amounts of solid matter, were printed by the same technology and dried afterwards comparably. Subsequently all remaining parts for the LED array were added to the so-called half-cells. Consisting of two yellow and green SMD LEDs, respectively, and one resistor all pieces were positioned in the circuitry, applied to electrical contact and glued to the substrate. Afterwards the electrolyte, which is based on zinc chloride, was added to both electrodes (positive and negative) using the doctor blade process. The batteries were sealed afterwards by using a proprietary assembling technique and high performance adhesive tape.

Results

The printed and fully integrated devices are very thin and lightweight, including a battery with nominal voltage of 4.5 V and weighting in total less than 5 g. Since the inlays are printed onto a plastic foil substrate, the advantage of being flexible leads to diverse scopes. Due to its design, the manufacturing of series connections of printed batteries is possible as well. Thus, integer multiples of the nominal voltage of 1.5 V are realizable and batteries up to 6 V were already produced. The nominal capacity of the manufactured zinc manganese batteries is 2 mAh/cm².

References

[1] Willert, A.; Kreutzer, A.; Geyer, U.; Baumann, R. R.: Lab-manufacturing of batteries for smart systems based on printing technologies. Smart Systems Integration 2009 – 3rd European Conference & Exhibition on Integration Issues of Miniaturized Systems, March 10-11, 2009, Brussels, Heidelberg: AKA Verlag, 2009, pp. 556 – 559.

[2] Kipphan, H.: Handbuch der Printmedien - Technologien und Produktionsverfahren. Springer Verlag Berlin, 2000, p. 401 et seq.

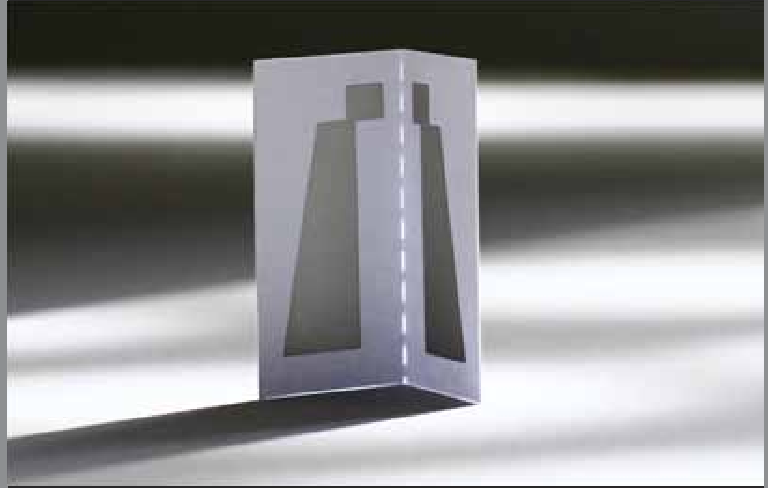


Fig. 1: 3D dipole antenna design.

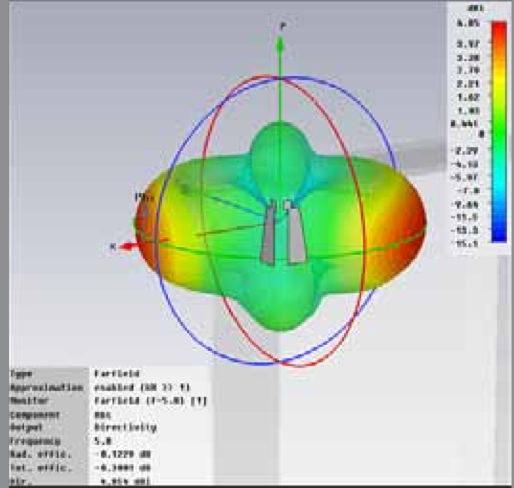


Fig. 2: Radiation characteristic of the 3D antenna, carried out with CST studio suite – Microwave Studio.

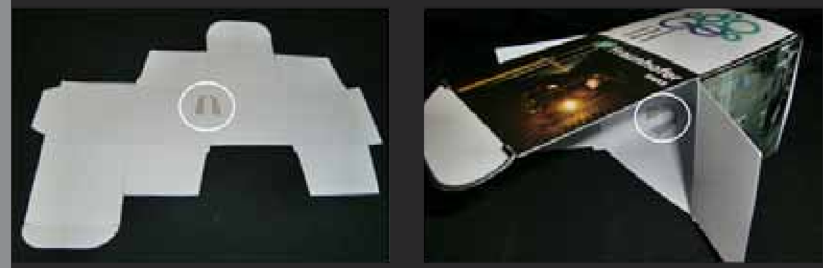


Fig. 3: Screen printed 3D antenna, unfolded and folded of a cardboard box.

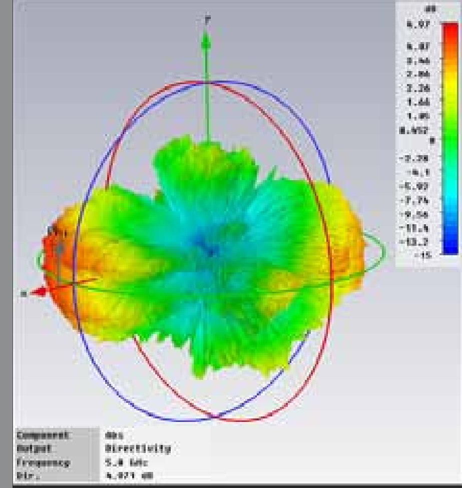


Fig. 4: Experimentally determined 3D antenna radiation characteristic.

PRINTED 5.8 GHZ ANTENNAS FOR SMART PACKAGING APPLICATIONS

Ralf Zichner, Reinhard R. Baumann

Abstract

During the recent years we observe a growing number of smart packaging applications. Within this field radio frequency identification (RFID) technology contributes remarkably to the progress by providing the matching communication / data transmission opportunities. In order to employ RFID technology for packaging applications the availability of highly functional RFID transponders (antenna + silicon chip) is necessary, which satisfy a maximum of communication reliability and reading distance. We report on the introduction of three dimensional (3D) antennas which can be printed cost efficient directly on the planar packaging material and become three dimensional in the folding step of erecting a cardboard box. These 5.8 GHz 3D antennas are designed regarding layout and dimensions of the package as well as the dielectric material of the package. These new 3D antennas open a wide range of reliable packaging applications and therefore contribute remarkably to the development of the "internet of things".

Basics

Radio Frequency Identification Systems allow wireless transmission of data / signals utilizing two different RF coupling technologies in different frequency bands. Most of the state of the art applications are based on alternating magnetic fields @ 125 kHz and 13.56 MHz [1]. A gain in communication quality is achieved by electromagnetic wave coupling @ 868 – 928 MHz [2], 2.45 GHz and 5.8 GHz. Both techniques have advantages and disadvantages and therefore they are handpicked depending on the application. The approach on which we report here focuses on RFID transponder antennas for passive future tags working at 5.8 GHz, a legally attested communication frequency with promising prospects of success. This frequency was chosen to extend the reading range remarkably and to improve the communication reliability and communication quality simultaneously.

For the signal transmission via electromagnetic waves, generally dipole antenna structures are employed. These antenna structures show omnidirectional radiation characteristics with the consequence that significant parts of the antenna radiation is emitted in the direction of the inner cardboard box which might be filled with challenging dielectric material. This results in absorption, reflection and diffraction effects of the emitted electromagnetic waves which are fed back into the antenna and so negatively influence the functionality and communication reliability of the transponder [3].

In order to improve the communication reliability and communication quality, it is necessary to develop transponder antennas which have a directional radiation characteristic without signal emission into the interior of tagged cardboard box.

Results

To implement a radiation directionality which does not cover the interior of a packaging box a three dimensional antenna structure was designed (see Fig. 1). Furthermore this dipole antenna was designed to fit in the corner of a rectangular package (see Fig. 3).

The radiation behavior of the 3D antenna arrangement was calculated with the simulation software CST Studio Suite – Microwave Studio (compare Fig. 2). It is shown that the radiation behavior is focused into two directions left and right (red areas in Fig. 2).

Accordingly, only a very small portion of the electromagnetic waves are emitted into the interior of the package. Consequently, reflection and diffraction effects of the electromagnetic waves are minimized and communication reliability and communication quality is remarkably increased. In addition to the advanced functionality of the new 3D antennas we intend to optimize the manufacturing costs. The application of conducting material on 3D objects was reported recently [4] but this technology requires rather complex manufacturing processes and equipment. Therefore we propose to print an appropriate conducting ink (e.g. Ag based) on the backside of the planar signature of a package and transform it into a 3D object / antenna in the step when the printed sheet becomes a box by folding the signature.

The antenna shown in Fig. 3 was manufactured on cardboard by screen printing a silver paste (Sun Chemical CRSN2442) and using a polyester screen (195 meshes). The silver layer was dried for 15 minutes at 110 °C. These printed and folded 3D antennas were analyzed in an anechoic chamber. To visualize the calculated directivity, out of the measured data, we employed again CST Studio Suite. The result is presented in Fig. 4, demonstrating a rather clear agreement of simulation and experiment.

Summary

We have shown that 5.8 GHz 3D RFID transponder antennas for packaging applications can be designed and adapted in terms of the highest standards of communication reliability and communication quality. Moreover, the printing-based manufacturing process of the 3D RFID transponder antennas is extremely cost-effective since planar printing techniques were employed and the 3D object / antenna is generated by folding the printed sheet to a three dimensional cardboard box .

References

[1] L. Yang, A. Rida, R. Vyas, and M. M. Tentzeris: RFID Tag and RF Structures on a Paper Substrate Using Inkjet-Printing Technology. IEEE Transactions on Microwave Theory and Techniques, Vol. 55, No. 12, (2007).

[2] R. Zichner, F. Siegel, and R. R. Baumann: Communication Quality of printed UHF RFID Transponder Antennas. Proc. LOPE-C, pp. 361 – 363. (2011).

[3] R. Zichner and R. R. Baumann: Customized Printed RFID Antennas for Various Environments. Proc. LOPE-C, pp. 09•1 – 09•4, (2009).

[4] J. J. Adams et al.: Conformal Printing of Electrically Small Antennas on Three-Dimensional Surfaces. Advanced Materials, (2011).

PROF. DR. STEFAN E. SCHULZ

HEAD BACK-END OF LINE

PHONE: +49 371 45001-232
FAX: +49 371 45001-332
EMAIL: STEFAN.SCHULZ
@ENAS.FRAUNHOFER.DE

DEPARTMENT BACK-END OF LINE

Head of the Department: Prof. Dr. Stefan E. Schulz

The department Back-end of Line focuses on

- Materials and process development
- Process integration
- Modelling and simulation

for interconnect systems in ultra large-scale integrated CMOS devices (ULSI) as well as MEMS and NEMS components.

Competences & Research Fields

The main competences and research fields of the department BEOL are in the fields of:

- Low-k and ultra-low-k (ULK) dielectrics
- Metallization for micro and nanoelectronics as well as for 3D and system integration
- Airgaps for low parasitic capacitances in nanoelectronic interconnect systems
- Process and equipment modelling and simulation
- Modelling and simulation of interconnect materials and systems
- Planarization and surface modification for BEOL and MEMS/NEMS fabrication
- Wafer-level integration of carbon nanotubes for interconnects and sensors
- Magnetoresistive sensors based on spin-valve systems

Special emphasis is placed on integrating low-k and porous ultra low-k materials into copper damascene interconnect systems. The specific properties of those materials require a modified integration pattern adapted to the respective material. For their successful integration especially etching and cleaning techniques, k-restore processes after patterning, diffusion barrier compatibility and low down force barrier and copper CMP are investigated. For this and to evaluate porous low-k dielectrics properties, several optical, mechanical, thermal and electrical characterization techniques are applied.

New interconnect architectures are under investigation for example with respect to the integration of carbon nanotubes and airgaps. Here, not only the potential for manufacturing airgap structures is studied, but also their electrical, thermal and mechanical impact on the interconnect system. Development and optimization of the single process steps as well as the complete technology are accompanied by electrical, mechanical and thermal modelling and simulation of airgap-containing interconnect systems.

3D and system integration require metallization solutions for flip chip techniques, chip scale packages and, of course, for high aspect ratio "through silicon vias" (TSVs). By providing several process solutions, like PVD and CVD barrier and seed layers, copper CVD and electroplating (ECD) these fields can be addressed for different feature geometries and various applications.

Developing new technologies requires new or optimized processes and equipment. To realize this, Fraunhofer ENAS is developing advanced models and simulation tools e.g. for PVD, CVD and CMP. They support the development of improved deposition and polishing techniques by optimizing process conditions, reactor configuration, and feature topography. By means of appropriate simulations is it possible to estimate chances and risks of new technologies and to determine convenient process windows while minimizing costs of processing test runs with large scaled wafer diameters and batches. The knowledge and experience gained from the simulations are made available to our customers and partners to optimize process parameters and equipment.

The department closely collaborates with the Center for Microtechnologies (ZfM) at Chemnitz University of Technology. This is not only expressed by shared cleanroom facilities and equipment. Many results of the basic research work carried out at the ZfM have been successfully transferred to application by the Back-end of Line Department at Fraunhofer ENAS. For example, the integration of low-k materials and the development of novel processes such as for the atomic layer deposition (ALD) of metals and growth of carbon nanotubes continue to be important areas of work at both institutions.

Services

We offer the following services related to the fields described above:

- Wafer processing (deposition, patterning, thinning, planarization)
- Thin film measurement and characterization, incl. SEM, FIB, STEM, EDX, XPS, FTIR, Raman spectroscopy
- R&D services for processes and technology development
- In-situ process diagnostics
- Modelling and simulation of processes and equipment
- Modelling and simulation of interconnect materials and systems

Results of R&D Projects in Brief

Metallization for 3D interconnects

Within the "ENIAC" European project JEMSiP-3D a CVD based barrier / Cu seed layer deposition technology for TSV metallization is developed and evaluated. To overcome limitations of existing Cu CVD process solutions a new Cu CVD chamber with a direct liquid injection system from Kemstream has been installed. This injection system enables a very efficient flash vaporization with almost no condensation at internal chamber and pipeline walls. In that way it becomes possible to efficiently vaporize thermally unstable compounds without the risk of clogging.

Using this system, new copper precursors have been tested on 200 mm wafers.

Stressor Films for Carrier Mobility Enhancement

Within the project COOLTRANS, technological and simulation efforts for the improvement of stressor films have been continued in close cooperation with GLOBALFOUNDRIES. The existing simulation model for the prediction of stress transfer from the stressor films to the transistor channel has been extended and covers now also the technology nodes 28 nm and 22 nm. Based on this model, the scaling behaviour of the stressor performance has been studied by simulations. Further, the simulation model was used to study the interplay between stressor performance and contact metallization. In parallel, new processes and materials involving UV treatments are developed and evaluated in order to achieve higher stress levels in the films.

Modeling and Simulation

Deposition equipment simulation using computational fluid dynamics (CFD) has been performed for several customers to optimize their CVD and PECVD chambers and processes.

A new research topic has been set up concerning the simulation of silicon-based solar cells. In cooperation with Roth & Rau AG the cell efficiency improvement was targeted by applying advanced concepts and developing optimized designs.

Atomic Layer Deposition for Spintronics

Within the research consortium nanett "nano system integration network of excellence", the department Back-end of Line is working on the development of novel atomic layer deposition (ALD) processes for the application in magnetic sensor systems, such as giant magnetoresistance (GMR) spin-valve sensors. In combination with the already developed copper ALD process for the non-magnetic film in such devices, a nickel ALD process for the ferromagnetic layer is under development.

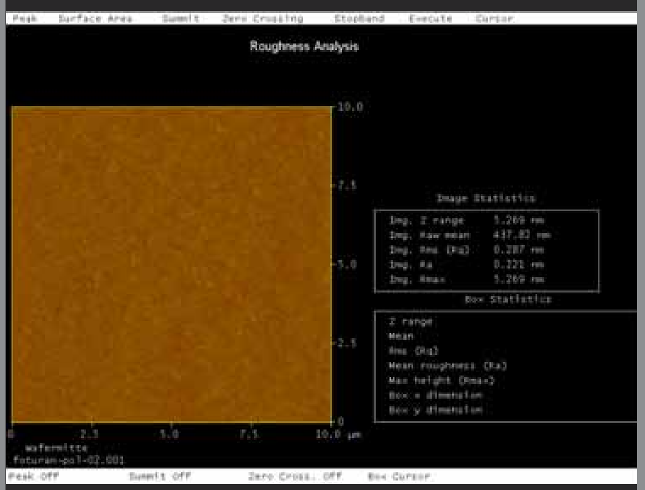


Fig. 1: Foturan® surface after surface finishing by CMP

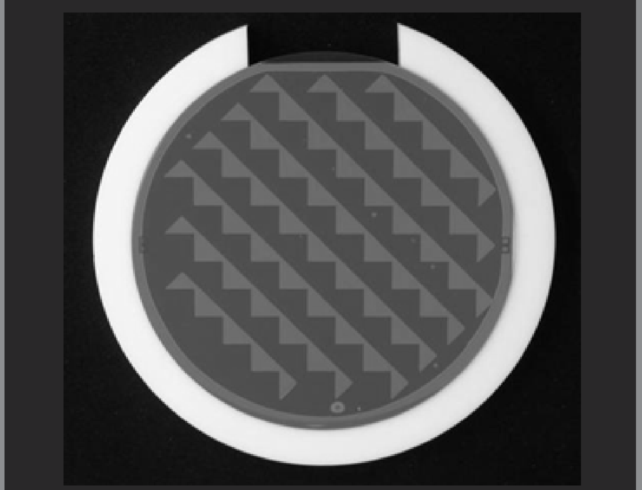


Fig. 2: Bonded Foturan®/silicon compound with chevron patterns

CMP SURFACE PREPARATION AS ENABLER FOR FOTURAN® GLASS WAFER BONDING

Ina Schubert[1], Dirk Wünsch[2], Mario Baum[2], Knut Gottfried[1]
[1] Fraunhofer ENAS, Department BEOL
[2] Fraunhofer ENAS, Department SP

Foturan® glass is an attractive material for MEMS fabrication. Because of its photosensitivity it can be directly exposed using a 310 nm light source. Subsequent pattern generation can be done by simple wet etching without any additional mask layers. In contrast to that, Foturan® wafer bonding is a more complex issue. Foturan® wafers as fabricated are not bondable, neither to Foturan® itself nor to other materials like Si and SiO_2, respectively. Possible reasons are a poor surface quality and an insufficient number of dangling bonds. Thus, surface modification, i.e. by chemical mechanical polishing (CMP), is a promising way to solve that issue. The chemical nature of glasses requires SiO_2-CMP. Table 1 gives the finally used process setup, carried out on an IPEC 472 polisher. Applying this process improves the roughness approx. by 4, compared to the initial state. A typical mean roughness of 0.2 nm was found after CMP, see Fig. 1.

Foturan® wafers polished as described have been successfully bonded to each other as well as to plain and oxidized silicon wafers. Finally, Foturan®/silicon compounds containing chevron test patterns have been prepared. Fig. 2 exemplarily shows a prepared compound. Chevron structures are used to evaluate the bond strength by applying a continuously increasing tensile force until the interface cracks. A maximum tensile force of about 10 N was obtained for all tested samples. In consideration of the sample geometries this force is corresponding to a bond strength close to the bulk material's strength. Furthermore, within these experiments we observed a dependency on the time between polishing and bonding. Wafers bonded immediately after CMP showed a very fast bond spreading. For wafers bonded after several hours bond spreading was significantly slower. This can be explained by the removal of physically or chemically adsorbed layers during CMP. As a result of that, dangling bonds are generated which naturally endeavors to get saturated, e.g. by atoms and molecules coming from the surrounding atmosphere. For that reason a short time between CMP and bonding is required to ensure the desired high bond strength. In summary, Foturan®-Foturan® as well Foturan®-silicon wafer bonding could be realized for the first time. Surface finishing by CMP was found to be an enabler for that.

	Platen 1	Platen 2
Polish pad	Hard pad	Soft pad
Slurry	Klebosol series	DI water
Down force	2 psi	1 psi
Polish time	up to 90 s	up to 60 s
Head / platen speed	64 rpm / 60 rpm	20 rpm / 20 rpm

Tab. 1: Process parameters for Foturan® surface finishing

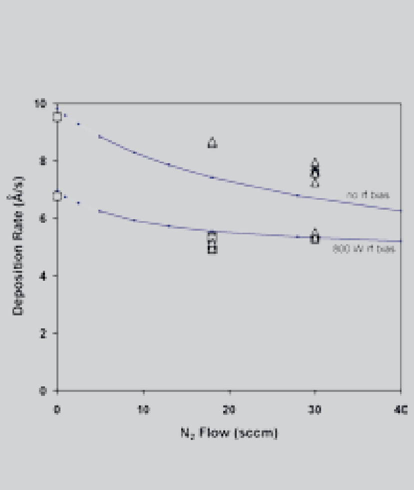


FIG. 1

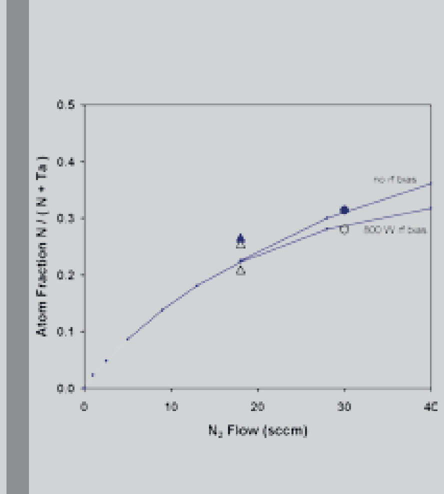


FIG. 2

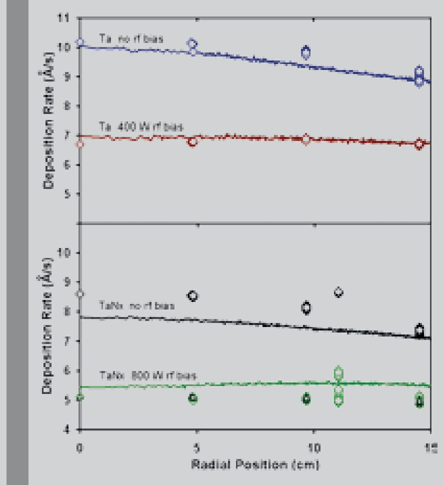


FIG. 3

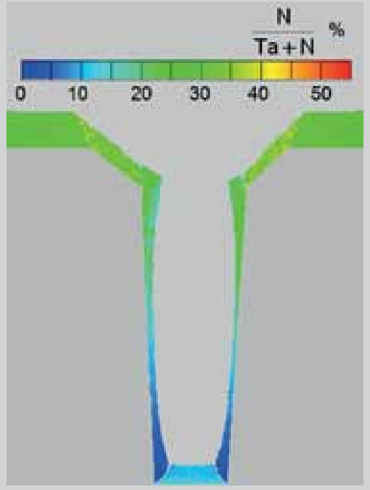


FIG. 4

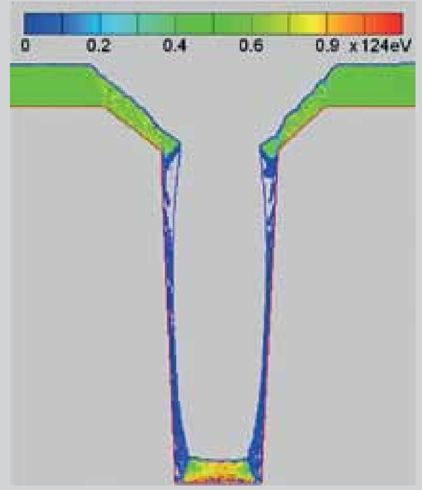


FIG. 5

SIMULATION OF REACTIVE PVD FOR THE DEPOSITION OF TAN$_X$

Hermann Wolf , Reinhard Streiter, Michael Friedemann[1], Petr Belsky[2], Tobias Letz[1]

[1] GLOBALFOUNDRIES Dresden, Germany

[2] Center of Microtechnologies ZfM, Chemnitz University of Technology, Chemnitz, Germany

Introduction

PVD is still the method of choice for the barrier and seed layer formation within the copper metallization process of integrated circuits. Particularly the deposition of Ta/TaN$_x$ barriers by reactive sputtering is applied at the 32 nm node. The use of process and equipment simulation is helpful for further optimizations of processes, equipment, and structures, but the simulation tools have to be qualified for the application to reactive PVD.

Our simulation tool T2 has therefore been further developed for the application to TaN$_x$ deposition [1].

Model extensions for RPVD

Calculating the composition of the plasma and of the ion flux to the target requires the knowledge of the degree of ionization of each species and of the degree of decomposition of diatomic molecules. Neglecting local resolution and confining ourselves to only the few most important ionization reactions, we apply the zero-dimensional analytical plasma model of Möller and Güttler [2] for calculating the ion and radical fluxes to the target surface.

The emission from a partially nitrided target depends on the fraction of TaN coverage. According to the target nitridation model of Da Zhang and Schaeffer [3] the TaN coverage can be estimated by balancing the TaN formation caused by the chemical reaction of the target surface with atomic N (radicals) on the one hand and the decomposition and removal of the nitride due to the bombardment with ions on the other hand.

The interactions of Ar, N, and Ta projectiles hitting on TaN are calculated and tabulated applying the static BCA code SRIM 2008 [4]. Corresponding tables for the interaction of Ar and Ta with clean Ta surfaces have been calculated for bcc-Ta(110) using the molecular dynamics code Kalypso written by M. Karolewski [5].

To calculate the deposition rate from the particle fluxes arriving at the wafer surface the composition-dependent atomic density must be known. Experimental investigations [6] applying RBS and XRD show that the atomic density increases roughly linear with increasing N content from 5.52e22 cm^{-3} for Ta to 9.39e22 cm^{-3} for Ta_5N_6, which is the most stable phase in the Ta-N system.

The influence of the electric field on the motion of ions throughout the presheath is considered if rf bias is applied to the wafer. For the determination of the energy dispersion (peak separation) and of the energy distribution function, analytical solutions are used.

Results

The simulations were performed using a common set of models and parameters. Close agreement with experimental data at reactor scale (Figs. 1 – 3) was achieved in many cases by fitting the parameters of the target nitridation model, the target emission profile, and the sticking coefficients of thermal nitrogen species and by empirical adjustments regarding the N_2^+ density in the plasma and the radial non-uniformity of ioniziation near the biased wafer.

Simulations at feature scale were carried out to optimize the conformality of barrier deposition. Additionaly, the variation of film composition (Fig. 4) and energy deposition (Fig. 5) inside the features have been investigated as well as the influence of target ageing on these properties

Conclusions

Even though very simple, the implemented plasma, gas transport, and surface models allow a fast simulation of process-relevant influences on deposition rate, uniformity, and film composition for the RPVD of TaN$_x$ barriers at reactor scale. The simplifications restrict the application to a limited range of process conditions. More experimental data are needed to enhance and to validate the models for a larger range of application. The calculated fluxes and the models for particle-surface interactions and film growth are applied for the simulation at the feature scale. Here, the simulation results represent quite well the essential trends with regard to feature topography, film composition, and energy deposition as well.

References

[1] H. Wolf et al., Microelectron. Eng. 87 (2010) 1907.

[2] W. Möller, D. Güttler, J. Appl. Phys. 102, 094501 (2007).

[3] Da Zhang, J. K. Schaeffer, J. Vac. Sci. Technol. A22, 264 (2004).

[4] J. F. Ziegler, J. P. Biersack, M. D. Ziegler, http://www.srim.org/.

[5] M. A. Karolewski, http://sites.google.com/site/kalypso-simulation/Home.

[6] X. Sun et. al., Thin Solid Films, 236 (1993) 347.

Legend

Fig. 1: Simulated deposition rates as a function of N_2 flow for depositions without rf bias (upper line) and with 800 W rf bias applied to the substrate (lower line). Measured rates from different chambers are denoted with triangles and squares, respectively.

Fig. 2: Simulated film composition as a function of N_2 flow (lines) and measured composition of films deposited in different chambers (triangles, circles). Filled symbols and the upper line refer to depositions without rf bias. Open symbols and the lower line belong to depositions with 800 W rf bias applied to the substrate.

Fig. 3: Radial dependence of simulated (lines) and measured (symbols) deposition rates for the deposition of Ta (upper frame) and TaN$_x$ (lower frame) without and with rf bias applied to the wafer. Diamonds denote experimental deposition rates determined from thickness measurements by x-ray reflectometry and triangles designate deposition rates derived from measurements of the sheet resistance. The deposition rates at 11 cm are wafer-averaged values from different tools. The observed offset is presumably due to different target properties (age).

Fig. 4: Simulated topography and film composition inside a trench.

Fig. 5: Distribution of energy per deposited atom inside a trench.

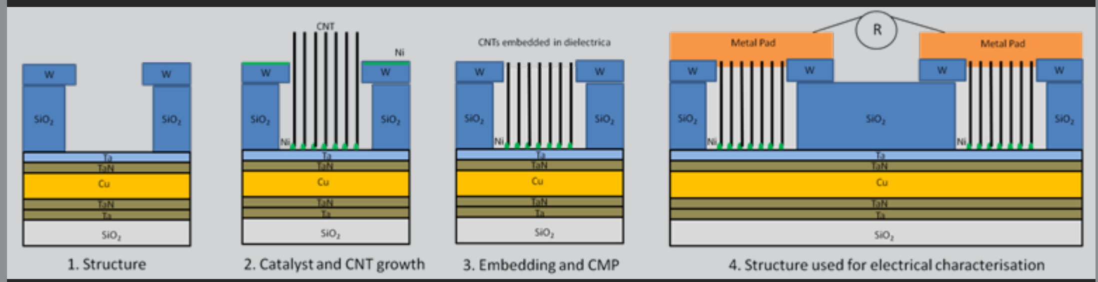


Fig. 1: Scheme of the process flow.

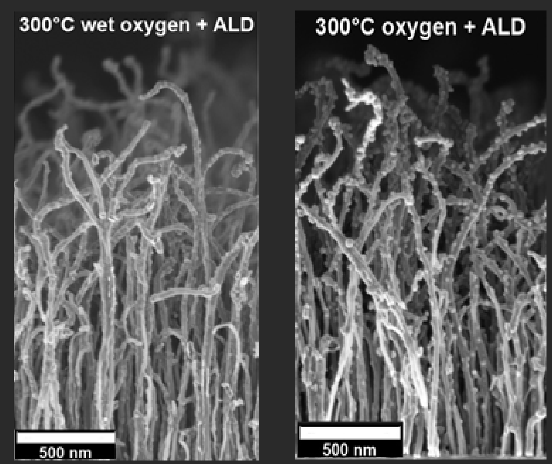


Fig. 3: ALD copper oxide growth on CNTs after pre-treatments with wet oxygen (left) and pure oxygen (right).

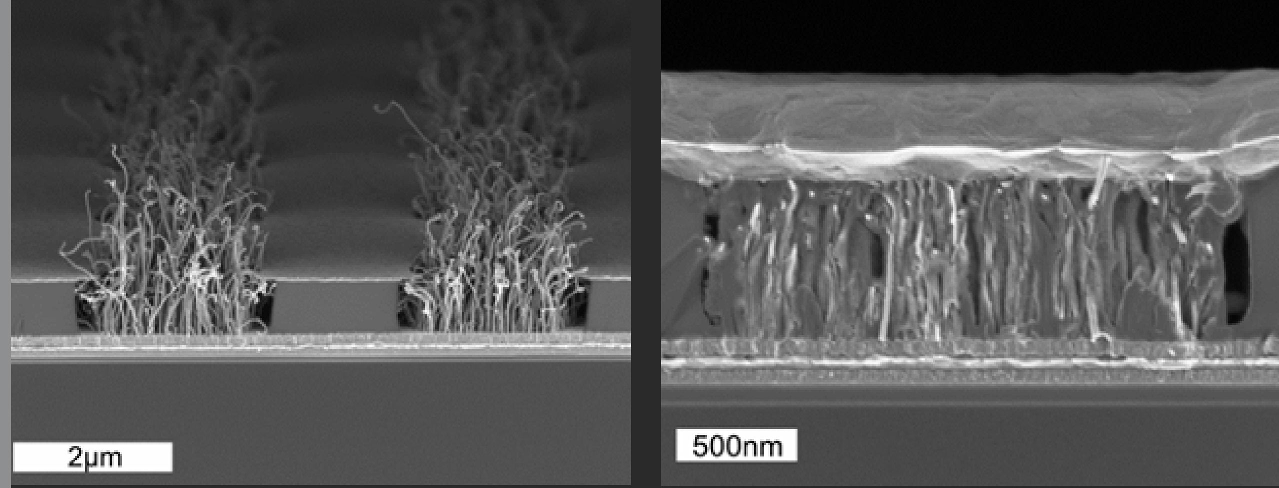


Fig. 4: SEM images after CNT growth (left) and after top contact deposition (right).

INTEGRATION OF CARBON NANOTUBES IN ULSI INTERCONNECT SCHEMES

Holger Fiedler[1], Sascha Hermann[1], Marcel Melzer, Thomas Waechtler, Stefan E. Schulz
Center of Microtechnologies ZfM, Chemnitz University of Technology, Chemnitz, Germany

The ongoing miniaturization in the semiconductor industry faces several challenges. Especially the RC delay, determining the speed of the integrated circuits, is important. To reduce the resistance of the interconnect, copper was introduced as conductive material in the past. Today, carbon nanotubes (CNT) are a potential candidate to replace copper, since CNTs have an extraordinary high electrical conductivity. Further, due to their one-dimensional nature, CNTs show a stronger resistance towards electromigration, which is currently one of the most important reliability challenges. Also the thermal properties of CNTs are superior compared to copper.

For the integration of CNTs into the interconnect system we designed a process flow for a hybrid copper/CNT technology at the Fraunhofer ENAS. Thereby we addressed the following challenges:

1. CNTs have to be grown on a conductive copper line.
2. The maximum possible density of CNTs is required to achieve a high conductivity.
3. The metal-CNT contact resistance should be as low as possible.
4. In the case of multi-walled CNTs (MWCNT) all individual shells should contribute to the via conductance.

The vias were fabricated using a single damascene process. As interlayer dielectric we deposited 800 nm thick silicon dioxide by a plasma enhanced chemical vapor deposition process. The last 50 nm were etched by wet chemistry to minimise damage to the substrates surface. A thin nickel film was deposited by electron beam evaporation. CNT growth was restricted to the vias by selective deactivation of the Ni catalyst. A tungsten layer on top of the PECVD silicon oxide inhibited CVD growth in this region, while CNTs grow vertically aligned on the tantalum substrate. The incorporation of copper beneath the substrate proved feasible as long as TaN was incorporated as a diffusion barrier between the substrate and the copper line. An intermixing between Cu and the Ni would alter the catalytic properties of the Ni and thus inhibit vertically aligned CNT growth. The quality of the CNTs grown at 620 °C is high throughout the 100 mm

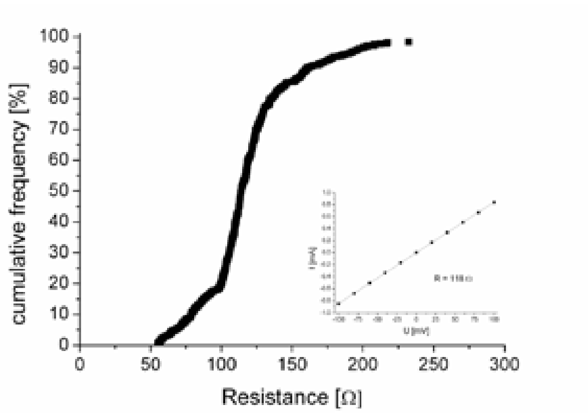


Fig. 2: Electrical characterisation of fabricated 5µm CNT vias.

wafer, as investigated by Raman spectroscopy. Further, TEM investigations revealed that the as-grown multi-wall CNTs are 14 nm ± 3 nm in diameter and have 12 to 16 shells. For achieving an optimal CNT-metal interface and to ensure the contribution of all MWCNT shells to the via conductance, chemical-mechanical polishing (CMP) was applied to the vias. To avoid snapping off the CNTs during this process, they were embedded into a silicon oxide deposited by thermal low pressure CVD using tetraethylorthosilicate (TEOS) and ozone as precursors. CMP successfully planarized the surface and supported the subsequent formation of the top contact required for electrical characterization. Finally the wafer was heat treated at 400 °C in a forming gas atmosphere to induce the formation of a low contact resistance at the metal-CNT interfaces. For electrical measurements, 440 structures were evaluated on the wafer. IV characteristics were obtained on all structures for two 5 µm series connected CNT vias. In the low voltage regime, ohmic behavior was observed. 95 % of the investigated structures had a resistance below 200 Ω. In contrast, non-ohmic behavior was observed for higher voltages, which is most probably due to heating effects during the course of the electrical characterization.

However, a large drawback of the current state of the art of CNT research is the insufficient density of CNTs. In our case, the density as derived from the density of the catalyst nanoparticles is 3 x 10^{11} CNTs/cm^2 (see Fig. 2), which corresponds to a filling of only 30 % of the via with CNTs. Therefore, we emphasize to embed the CNTs in a conductive matrix instead of the silicon dioxide. In this respect, we investigated the potential of a copper filling, since it is expected that copper generates additional bands near the Fermi level resulting in an increased conductivity of the CNTs. Furthermore, copper filling the intermediate spaces between the CNTs s expected to lower the via resistance.. The embedding of the CNTs into copper is designed as a four-step process and based on atomic layer deposition (ALD). At first, the CNTs are pretreated in-situ prior to the ALD. During the next step, a thin copper oxide layer is prepared by a thermal ALD process. Depending on the pre-treatment conditions, the growth mode of the ALD copper oxide can be tuned between particle growth and the growth of continuous films on the CNTs. A subsequent gas phase reduction process by formic acid or hydrogen plasma can be used to reduce this oxide film to metallic copper. This film could afterwards serve as the seed layer for an electrochemical deposition step to finally fill the spaces between the CNTs. So far, the ALD growth of the copper oxide on the CNTs was studied in detail. The ALD process is based on the Cu(I) β-diketonate $[(^nBu_3P)_2Cu(acac)]$ and a mixture of oxygen and water vapor as co-reactant at 135 °C. In contrast to the widely used wet chemistry approaches, which are applied to functionalize the surface of CNTs for subsequent processes, the in-situ gas phase approach used here is highly promising to be integrated straightforward into the production of ULSI integrated circuits. A critical issue is the weak interaction of copper to CNTs, thus forming clusters instead of a closed layer on the CNT surface. In order to reduce the surface tension various thermal oxidation processes prior to the atomic layer deposition of copper oxide were investigated. Oxygen, water vapor and wet oxygen were applied as oxidation agents at temperatures between 100 and 300 °C. The obtained data suggest a layer-like growth of copper only occurs on parts of CNTs which have been functionalized during the oxidation. Partially layer like growth was exclusively observed on CNTs which were oxidized with wet oxygen at 300 °C. On all other samples formation of particles with a diameter between 3 and 20 nm takes place. The largest particles are formed if the CNTs are pretreated with oxygen or water vapor at 300 °C. The challenge is to find a process that functionalizes the outer shell of the MWCNTs in large parts to allow for layer-like ALD growth and leaves the inner shells intact, in order to enable the conformal deposition of copper on the outer shell without reducing the conductivity of the inner shells. Therefore, further oxidation processes at temperatures above 300 °C and with different oxidizing agents will be examined to investigate whether the percentage of areas with layer-like growth can be increased.

DR. MAIK WIEMER

HEAD SYSTEM PACKAGING

PHONE: +49 371 45001-233
FAX: +49 371 45001-333
EMAIL: MAIK.WIEMER
@ENAS.FRAUNHOFER.DE

DEPARTMENT SYSTEM PACKAGING

Head of the Department: Dr. Maik Wiemer

The department System Packaging is working in the fields of packaging technologies for MEMS and NEMS covering topics from zero level packaging up to second level packaging. The potentials and the importance of packaging and system integration are manifold, ranging from hybrid integration of the components on application-specific substrate carriers over monolithic integration of electronic, sensing, and actuating components on a silicon substrate, to the vertical integration, in which 3D stacking takes place on chip and wafer level. In addition to the increasing functionality and reliability, the miniaturization and the smart systems integration are the greatest challenges for "More-than-Moore" development. With the department's research work this trend results in new, customer-specific applications.

Wafer Bonding and Wafer Level Packaging

The term wafer bonding describes all bonding techniques for joining two or more wafers with and without interlayer. Standard methods, such as silicon direct bonding, anodic, eutectic, adhesive and glass frit bonding are used, but also adapted and continuously developed for specific requirements. Actual research focuses on low-temperature bonding, with the process temperature below 200 °C. Another important field of research for these low-temperature procedures is the usage of nano scale effects and new material combinations. Examples for nano scale effects are reactive bonding with nano scaled multilayers, or the reduction of the melting temperature with only a few nanometer thick interlayers. Moreover, new materials were integrated as intermediate layers to reach eutectic combinations or solid liquid interdiffusion (SLID) effects, e. g. Cu, Au, Sn, Si. With these materials based bonding technologies metallic joints could be performed with a process temperature of about 200 °C. Furthermore the laser assisted bonding allows selective bonding without any temperature influence on the functional elements.

Other methods for the technological developments are constituted by the increasing diversity of materials used in microsystems technology. Materials, in particular plastics, metals and ceramics are currently analyzed to respect aspects such as temperature and media resistance and low costs during the product development. One example for this is the polymer bonding, which aims a tight bonding of plastics, covering the whole surface. Moreover, research is done in the fields of thermo compression bonding and the direct integration of functional ceramics.

All wafer bonding techniques are characterized in terms of their bonding quality, strength, and hermiticity. The competence of the department System Packaging involves the dicing and the chip and wire bonding as well as technologies for the integration of complex, miniaturized and even intelligent systems.

Characterization and Measurement

Wafer bond technologies and bonded substrates respectively were in particular characterized in terms of their electrical and mechanical bonding quality, tightness and hermiticity. Here, research methods, such as infrared, ultrasonic and scanning electron microscopy, including FIB and EDX analyses, are applied to detect failures, voids and other critical states in an early process step. Maszara Blade test, Micro-Chevron test and shear test are used to evaluate the bond strength. Here special test samples are necessary to evaluate the mechanical strength at wafer level. Also new materials like described above have to be considered in the test planning. One important point is the standardization of these tests to get a comparable result of mechanical strength. The department works closely together with German standardization institutes but also worldwide with SEMI organization. The hermiticity of bonded wafers or chips is analyzed by combined spectroscopic leakage tests (helium, nitrous oxide) and bow measurements using white light interferometry. Leakage rates up to a resolution of 1×10^{-11} mbarl/s could be measured that way. To reach an even higher resolution the devices could be also electrically characterized with integrated resonant structures. Accompanying to current technological developments the MEMS packaging technologies are characterized and evaluated too. For this reason also other tensile, pressure and shear tests, electrical tests as well as climate, vibration and temperature tests are available in cooperation with other departments of the Fraunhofer ENAS.

Nano Scale Effects and Imprinting

In order to make use of the nano effects in MEMS packaging, the department System Packaging analyzes nano scale intermediate layers and layer systems using PLD, PVD and Aerosol-Jet deposition. Furthermore, surface and material effects are investigated and characterized on the basis of metallic nano structures. These nano structures are applied to new bonding techniques on chip and wafer level. The aim of these investigations is to achieve a permanent and hermetic sealed joint between two wafers, using the lowest process temperature possible. Furthermore new application fields for nano patterns are e. g. optics, electronics, and medical technology.

Molding micro and nano structures by UV nano imprint lithography and hot embossing enables a precise formation of micro optical and micro fluidic structures using nano and micro scaled master tools. Here, the basic distinction is to make between hot and cold embossing processes. In opposition to thermal nano imprinting no temperature is required for UV nano imprint lithography (UV-NIL). The pattern transfer is realized with UV exposure after imprinting the working stamp into the certain resist. This technology enables the patterning of silicon substrates in a range of 50 nm and beyond.

The process temperature for hot embossing of glass, thermoplastics, and not sintered ceramics exceeds the glass transition temperature of the respective material. The research work of the department System Packaging does not only include the development of embossing processes, but also the design and fabrication of silicon master tools, tools with patterned photo resist and electroplated molded nickel tools (UV-LIGA).

MEMS Packaging and 3D Integration

The meaning of MEMS packaging can be deduced from its portion of costs by producing a micro system. Herein, proportional costs ranging from 20 per cent to 95 per cent are likely to arise, whereas this wide margin results from specific application requirements. On the one hand side the MEMS package has to allow access for the desired media to be measured, like liquids, gases or light. But on the other hand it has to shield the MEMS from outer unwanted influences, and thus to guarantee long-term functionality. Current packaging technologies are not only applied to passive elements such as inertial or gas sensors, but also to active elements like micro mirrors and print heads. In view of the further advanced system integration, electronic components can also be implemented into the MEMS packaging.

In addition to the integration on wafer level and hybrid integration on chip level, integration technologies in the third dimension are developed. 3D integration has obvious advantages. For one, it can reduce the size of a chip and for another it can improve the signal quality. In vertical stacks like this it is of highest importance to consider the influence of each bonding technology on materials, but also on the electrical and thermal behavior of the whole system.

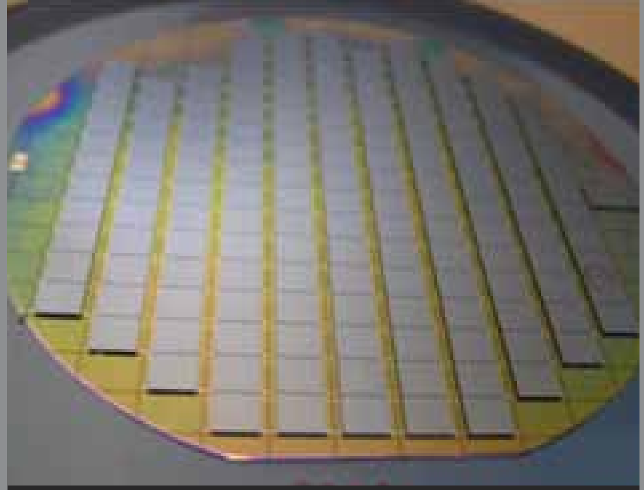


Fig. 1: Yield after dicing, Cu bonded 4”-wafers were treated using a dicing saw.

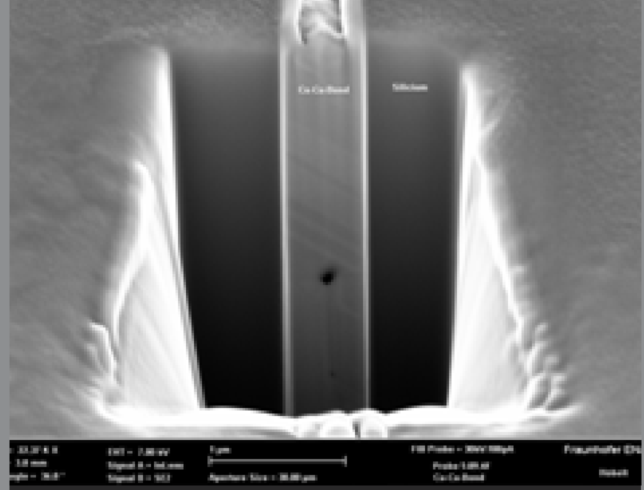


Fig. 2: FIB preparation and SEM image of a Cu-Cu bond interface.

METAL THERMO COMPRESSION WAFER BONDING USING COPPER INTERLAYERS

Mario Baum[1], Frank Roscher[1], Marco Haubold[1], Jörg Frömel[1], Ina Schubert[2], Knut Gottfried[2]
[1] Fraunhofer ENAS, Department SP | [2] Fraunhofer ENAS, Department BEOL

Introduction

Copper as a possible material for MEMS and electronics as well is mainly used as an interconnect material because of its physical properties e. g. conductivity and its technological compatibility. Furthermore there is a parallel development to use copper for wafer bonding itself but also for vertical interconnects, so called through Silicon vias (TSV). Regarding this important fact copper is an interesting material for both and an ideal material for 3D applications because it enables reliable electrical and mechanical interconnections within one process step.

Wafer Bonding Technology and Pre-Treatment

While the deposition of copper for TSV filling is mainly performed with a combined CVD and ECD step the bonding layers can also be deposited by using sputtering. In dependence of the surface conditions special pre-treatment processes like CMP or reducing atmospheres could be applied to enable the bonding process. The bonding process is a thermo compression bonding quite similar to the so called diffusion welding and requires high forces and temperatures as main parameters. Hence the temperature should be around 60 % of the melting temperature; this is one point to be decreased necessarily.

Such high process temperatures are typically not applicable to any electronic or MEMS devices. So some important influences were investigated to reach the goal of lower process temperatures. For that reason PVD-Cu films and structures were performed to investigate the influence of certain process parameters and the pre-treatment directly before the bonding step. Next to wet pretreatment processes like spin coating of reducing acids also chemical mechanical polishing was performed in order to planarize the surface and enhance the atomic contact between the two substrates for bonding.

Results and Characterization

In order to evaluate bond quality and strength, the copper frames and chips have been prepared and shear tested. For a micro hermeticity test special cavities were designed and etched to get a combined post bond result. First the measurement of the bow of the vacuum bonded membrane shows a fast response for tightness. In a second step a leakage rate measurement using a tracer gas and a subsequent FTIR spectroscopy shows the absorption of the tracer gas in case of a non hermetic sealing. Typical frame geometries are 5 by 5 millimeters and a frame width between 15 µm and 300 µm.

Within the experiments the parameter set could be optimized reaching a high yield after dicing at wafer level (Fig. 1). A mechanical strength of about 160 N maximum force could be measured while shear testing. This is a reasonable value regarding the geometrical dimensions of the bonding frame. About 75 per cent of the vacuum bonded chips were characterized as tight with a leakage rate below $1 \times 10 \exp^{-13}$ mbar l / s. At least micro structural analysis (SEM incl. FIB) showed a good interdiffusion of the copper and a disappeared bonding interface after bonding (Fig. 2).

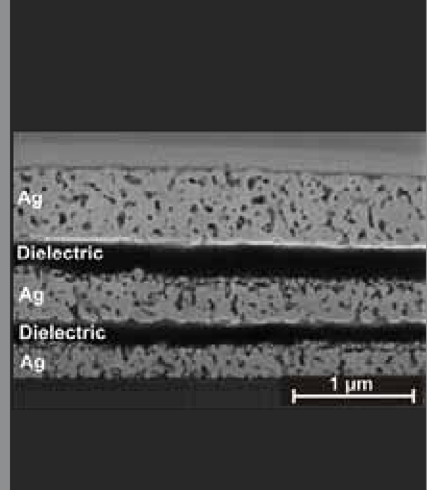


Fig. 1: SEM picture (prepared by FIB) of printed multilayer.


Fig. 2: Electrical characterization of sintered silver interconnects.


Fig. 3: Printed Ag ink on top of 3-D substrate

AEROSOL-JET DEPOSITION OF FUNCTIONAL MATERIALS

Frank Roscher, Tobias Seifert

Introduction

Today’s conventional thin film technologies (evaporation, sputtering, and electro chemical deposition) are leading methods for metallization and layer deposition to fabricate semiconductors, micro electro mechanical systems, biological sensors and electronic sensor devices. This metallization processes include steps like pattern and material transfer involving material addition, mask fabrication and material removal. Technologies capable of transferring pattern and material to the substrate in one single process step are so called direct writing technologies [DWT].

Aerosol-Jet Technology

Among others, Aerosol-Jet deposition is defined as an additive DWT and is now attracting more and more attention due to its manifold fields of applications. The capability of this method for the fabrication of conductive metal layers, dielectric layers and other functional materials is intensively researched at the Fraunhofer ENAS since the beginning of 2011 by using an Optomec AJ300 system.

Specifications

- Minimum printable line width: 10 µm, 20 µm pitch
- Print speed: 200 mm/s max.
- Ink viscosity range: 1 cP to 1000 cP

Post-Treatment

Beside inks that are containing silver nano particles also dielectrics and UV curable inks were deposited using Aerosol-Jet technology. Post-treatments like temperature, laser and UV light curing can be used to stabilize the materials after deposition or to enhance the conductivity of the Ag particle solution due to the removal of additives and sintering of the metal nano particles. Fig. 1 shows the profile of a printed multilayer structure consisting of three layers of silver and two layers of a dielectric material on top of an oxidized silicon surface. For post-treatment UV light was used to stabilize the dielectric at room temperature and a 250 °C temperature treatment for 30 minutes leads to sintered and conductive Ag layers. The conductivity of metal nano particles is strongly dependent on the applied post-treatment. The interrelation of the post-treatment and the conductivity was investigated for a silver nano particle ink comparing conventional oven sintering and laser curing (Fig. 2).

3D Packaging

A main advantage of the Aerosol-Jet technology is the high standoff between substrate and print nozzle. This allows printing on top of patterned surfaces without any changes in the print results (Fig. 3) to realize three dimensional sensor structures. The high potential of this feature could be found in 3D integration when replacing conventional wire bonds with printed interconnections.

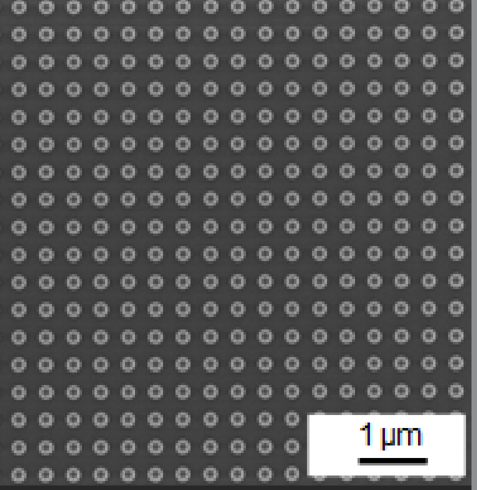


Fig. 1: SEM top view of a silicon master – courtesy of AMO GmbH, Germany.

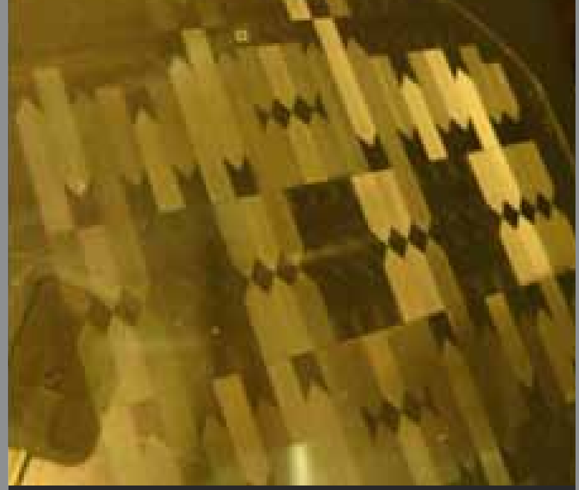


Fig. 2: Photograph of a PFPE working stamp.

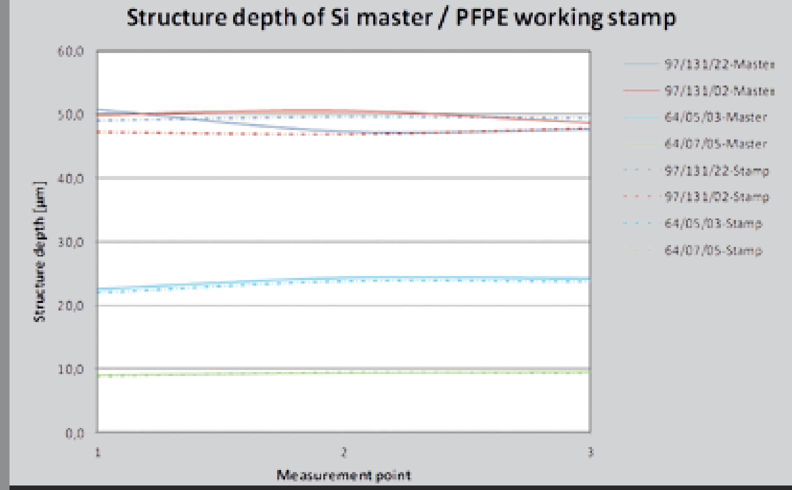


Fig. 3: Dimensional accuracy of polymer working stamps.

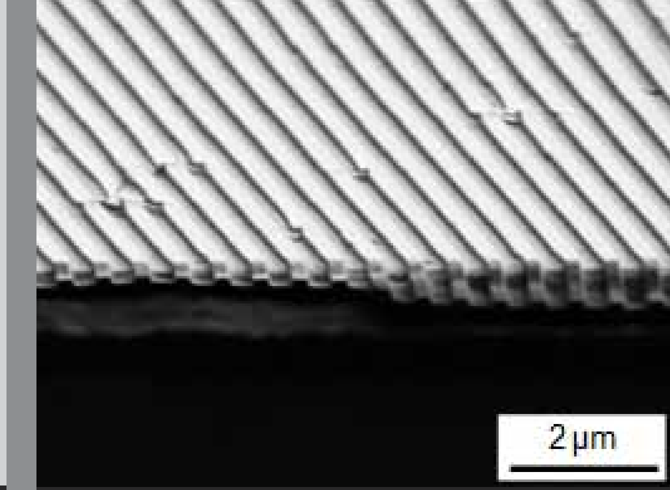


Fig. 4: 200 nm lines structure as printed onto aluminum layer; SEM top view with an angle of 5°.

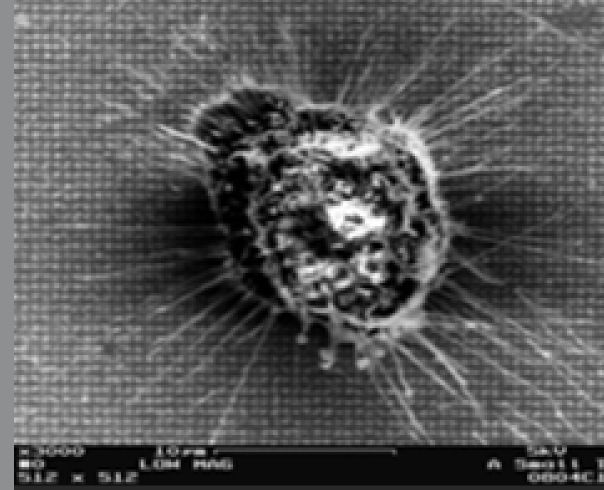


Fig. 5: SEM image of a cell on a nano patterned Si/Au surface – courtesy of Leibniz IFW, Germany.

NANOIMPRINT LITHOGRAPHY (NIL)

Jan Besser, Thomas Werner, Mario Baum

Introduction

"The future of integrated electronics is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas." [1] With these lines starts the famous article "Cramming more components onto integrated circuits" by Gordon Moore in 1965. Nowadays, integrated electronics or better integrated systems are to find in nearly every high-tech product. Smart micro and nano systems are on the way to be state of the art and Moore`s Law was once the beginning of the exponential reduction of geometric dimensions in microelectronics but it is still up to date!

The nanoimprint lithography (NIL) is a quite young process which is used for the precise patterning in the nanometer scale. For high production volume the nanoimprint lithography is characterized to be economical. Richard Feynman is considered as founder of nanotechnology. In 1959 his speech [2] "There´s Plenty of Room at the Bottom: An Investigation to Enter a New Field of Physics" was the beginning of technological development with much smaller dimensions. So Feynman anticipated the nanoimprint process which was developed and described as such in 1995 [3].

The main advantages of the NIL process are [4]:

- High resolution of 2 – 5 nm,
- Fast process (parallel), high throughput,
- Processing of functional materials possible,
- Multiplication factor of using soft stamps instead of master stamps for molding,
- Low cost of ownership,
- No heating involved (room temperature process),
- Simple fabrication process,
- Available for wafer level and R to R applications.

Especially in the field of the patterning of surfaces there exist a wide range of applications in the medical and biological sector. One example is the well-directed structuring of implant surfaces to enhance and/or worsen the cell growth [5].
The main applications of NIL are listed below [6]:

- Nanophotonics and -optics,
- Medical implants,
- Micro and nanoelectronics,
- Biosensors,
- Photovoltaics,
- Building materials.

Master tools and polymer working stamps

In general a high precision nano patterned master tool substrate is necessary for imprinting. Depending on the feature size and the area of nano structures this could be a significant cost factor for the development. Therefore a further copy of the structures can be realized using a polymer based working stamp. For instance, it is possible to fabricate perfluoropolyether (PFPE) working stamps over a wide dimensional range from several µm down to some nm. For the stamp fabrication 6 inch, 500 µm thick borosilicate glass wafers were used as UV transparent back plane. A special adhesion promoter delivered by Shin-Etsu is deposited onto the glass using a spin coater RC8 from SUESS MicroTec. This step is followed by a hard bake at 180 °C for 5 minutes on a hot plate. Parallel to that the silicon master wafer (see Fig. 1) must be pretreated with a anti-sticking layer to ensure the demoulding of the silicon master - polymer stamp stack. The used forming polymer consists of the perfluoroalkylpolyether (PFPE) Fluorolink® MD500 by Solvay Solexis and 1 – 2 % of the photo initiator DURACOUR. This photo sensitive forming polymer is coated onto the pretreated silicon master and the glass backplane. Then, the stack is cured with UV light for 20 minutes and manually demoulded. Fig. 2 shows a finalized PFPE working stamp. For verification of the working stamp fabrication some silicon masters and polymer working stamps with structures in the µm range were characterized by profilometry. Until 25 µm structure depth the dimensional accuracy is about 100 % between the master and the stamp. For silicon masters with deeper structures the manual demoulding is more difficult, so that the dimensional accuracy is lower. Herein a mismatch of ±7 % could be determined (compare Fig. 3).

UV-NIL Technology

For ultraviolet (UV)-NIL 6 inch silicon wafers coated with different materials like silicon oxide, silicon nitride or aluminum were used as substrates to be patterned. After thermal pre-treatment at 200 °C for 30 minutes the substrates were coated by adhesion promoter mr-APS1 and UV resist mr-UVCur21 (micro resist technology GmbH) followed by a thermal bake for 60 seconds on a hot plate. The primer was baked at 150 °C and the resist at 80 °C. To determine the resist thickness a working model for ellipsometry was developed and used too. After spin coating, the adhesion promoter is around 10 nm thick and the resist thickness is about 185 nm. Finally the substrate and the working stamp were pressed together, imprinted and exposed for 200 seconds using an EVG 6200 Aligner System. After manual demoulding the substrates were dry etched in two steps. First step was to remove the residual resist and in a second step the patterns were transferred into the substrate.

After dry etching, the dimensional accuracy is quite high but the structure depth is only around 30 – 50 nm. This depends on the low etching selectivity between the resist and the layer to be patterned. Fig. 4 shows an aluminum surface with an imprinted structure and some particles. After the NIL process using a soft working stamp the particles are overprinted and buried under the resist. So, little remains do not cause large defects.

Selected Applications

Optics: For the fabrication of functional layers 100 nm aluminum were deposited onto 6 inch silicon wafers via sputtering. These wafers were imprinted using lines and pillars structures. The silicon masters were fabricated via laser holography. After the NIL the aluminum layer was dry etched using an Oxford System (see Fig. 4).

Cell Growth Investigation: For cell growth investigation different geometries like chessboard, gratings, lines, pillars and meanders with lateral dimensions ranging from 50 nm to 300 nm were used to pattern the surface. After dry etching some of the wafers were deposited with 20 nm gold or titanium, respectively. The surfaces were modified with Fibronectin, a protein from the extracellular matrix, so the cells can bind. Last but not least, the structured samples were placed in a usual cell culture and the behavior of the cells was explored via SEM. The SEM image shown in Fig. 5 was taken after 24 hours of culturing, so the cells perfectly survive on the gold functionalized surfaces but show also a different behavior depending on the patterns itself. For a non-continuous pattern like the meander the cells do not spread so much and long filopodia are shown. However, in some case one can see extension of lamellipodia [7].

Microfluidics: Regarding the thermal NIL steps and a test layout with smallest structures around 5 µm was designed and manufactured. Additionally a second level of structures was integrated. That means a first structure was used for fluidic channels and the second step was used for supporting the laser welding process. Thermal NIL that was performed in a 540 HE substrate bonder (EVG) under defined vacuum and temperature conditions. The successful process results in structured PMMA material and shows a high accuracy regarding duplication precision. The range of tolerance was between 3 % and 5 %.

References

[1] G. E. Moore. Electronics, Vol. 38, 1965.
[2] R. P. Feynman. Speech, 1959.
[3] S. Y. Chouet al. Applied Physics Letters, Vol. 67 (Issue 21), pp. 3114 – 3116, 1995.
[4] Proceedings, NaPANIL Industrial Day, Berlin, Germany, April 2011.
[5] K. Anselme et al. Acta Biomaterialia, 6 (10), pp. 3824 – 3846, 2010.
[6] Micro resists technology, Processing guidelines mr-UVCur21 series – UV-curable Polymer for UV-based Nanoimprint Lithography.
[7] M. Baum et al. BMT 2011, Proceedings, Freiburg, Germany, 09/2011.

PROF. DR. ULRICH HILLERINGMANN

CHAIR SENSOR TECHNOLOGY
UNIVERSITY OF PADERBORN

PHONE: +49 5251 60-2225
FAX: +49 5251 60-5913
EMAIL: HILLERINGMANN
@SENSORIK.UPB.DE

DR. CHRISTIAN HEDAYAT

HEAD ADVANCED SYSTEM ENGINEERING

PHONE: +49 5251 60-5630
FAX: +49 5251 60-5621
EMAIL: CHRISTIAN.HEDAYAT
@ENAS-PB.FRAUNHOFER.DE

DEPARTMENT ADVANCED SYSTEM ENGINEERING

Head of the Department: Dr. Christian Hedayat
in cooperation with Prof. Dr. Ulrich Hilleringmann

Short Portrait

The department Advanced System Engineering (ASE) focuses its research and development activities on the topics design, simulation and characterization of micro and nano electronic systems. In this context all design stages – starting from circuit design over system integration up to the investigation of electromagnetic reliability – are considered.

The department works in close collaboration with the University of Paderborn on developing simulation methods for heterogeneous micro and nano electronic systems as well as for specific wireless devices such as RFID systems. The goal of all this activities is the characterization and optimization of complex electronic systems in order to assess their electromagnetic reliability as well as the signal and clock integrity at high frequencies. This is done not only at the IC level but also for packages, modules and PCB. This research provides a crucial contribution to the development of reliable miniaturized systems.

The main competences and long-term experiences of the department ASE are in the fields of:

- RFID antennas and circuits,
- Advanced 3D Near-EM-Field scanning system,
- Advanced modeling and analysis of EMC and SI-effects,
- Mobile wireless smart sensor systems,
- EMC/EMR of micro and nanoelectronic systems,
- Design methodologies for device integration,
- Efficient modeling and simulation methodologies for Mixed-Signal Devices,
- Model-based development methods for heterogeneous systems in package.

Today's electronic development is much more complicate than just some years ago. While electronic components become smaller, the signal to noise ratio as well as the absolute signal level decreases. This necessitates methods for the precise measurement and calculation of electromagnetic effects of analogue and mixed signal systems. In this context the competences of the department ASE concerning Electromagnetic Reliability and model driven design can support the system designer with efficient fast simulation methodologies (like black box modeling and event-driven modeling).

Unfortunately not all parasitic and coupling effects of complex high density systems can be predicted with the help of such EDA tools and the associated simulation approaches during the design phase. Therefore it is very helpful for the system designer to have the possibility to visualize the EM-field of first prototypes with the help of the new 3D near-field scanning technology developed by Fraunhofer ENAS department ASE. This technology provides a powerful methodology allowing the precise detection of coupling paths and the characterization of antenna patterns (e.g. RFID design). Necessary redesigns can be efficiently realized and its validity can be evaluated.

These areas have been systematically developed and their success is reflected in numerous R&D projects in collaboration with industry partners, specifically MESDIE (MEDEA+), PARACHUTE (MEDEA+), EMCpack (PIDEA+), JTI-Clean Sky (EU), PARIFLEX (BMBF) and A3NFM (BMWI/AiF).

The Fraunhofer ENAS department ASE closely cooperates with the University of Paderborn (Faculty of Electrical Engineering, Computer Science and Mathematics) within the competence network future EMC/RF modeling and simulation methodologies. A very close cooperation exists especially with Prof. Dr. Ulrich Hilleringmann, Chair for Sensor Technology at the Department of Electrical Engineering and Information Technology of the University of Paderborn.

Trends

The design of complex modern electronic devices requires the usage of adequate system level modeling technologies. The ASE supports these requirements by the development of black box modeling approaches, analogue circuit and mixed-signal simulation concepts as well as event-driven simulation methods. Electromagnetic and thermal aspects of such systems can be analyzed by state of the art measurement and accompanying 3D field simulation. Such methodology is necessary to predict and guarantee the reliability of power and high-speed systems.

The developed modeling and simulation concepts have been enclosed within an object-oriented library that has been implemented within the EDA tools of our industrial partners. Based on high-performance measurement equipment – including the innovative self-developed Near-Field Scanning System – various microelectronic systems and integrated components can be optimally characterized with respect to physical and EMC/SI/RF constraints. Besides the efficient simulation and design of advanced micro-packaged systems, a solid know-how is developed in the area of mixed-signal IC modeling and design methodologies for reliable clock synthesizing systems (such as Phase Locked Loops).

The design activities concentrate not only on electronic systems for telecommunications, radar and automotive applications, but also on the challenging new area of energy harvesting and smart wireless sensor systems. The department focuses here in particular on the design of optimized antenna and energy management strategies.

The Fraunhofer ENAS department ASE is ready to tackle all these challenges.

Competences

The main competences of the ASE department are:

- Mobile wireless smart sensor systems,
- RFID antennas and circuits,
- Advanced modeling and analysis of EMC and SI-effects,
- EMC/EMR of micro and nanoelectronic systems,
- Design methodologies for multiple device integration,
- System modeling and simulation,
- Model-based development methods for heterogeneous systems in package,
- Advanced 3D Near-EM-Field scanning system.

Services

We offer the following services:

- RF and EMC Characterization and Modeling,
- Vector Network Analysers for 4 Port Measurement (300 KHz – 20 GHz),
- RF-Probing Station for On Wafer measurements (300 µm Pitch Size, 40 GHz),
- 3D Near-Field Scanner (high resolution, 9 kHz – 6.0 Hz),
- Spectrum Analyzer (9 kHz – 26.5 GHz),
- Power Meter (-30 dBm to +20 dBm),
- Digital Oscilloscope,
- Communication Signal Analyzer with 20 GHz TDR/Sampling Heads,
- RF Signal Generator (up to 3.2 GHz, analogue modulations),
- Modeling and Simulation Competences:
  - » CST µWave Studio
  - » AnSys (HFSS)
  - » Cadence (HSPICE and Spectra
  - » Custom-specific solutions.

SUPA – THE INVISIBLE REVOLUTION

Christian Hedayat

The conference table of the future will show no more cables: Notebooks will be supplied directly via the desk top with power and are connected by wireless USB or WiFi to the local network and with the beamer.

To let this vision become reality, the department ASE develops the base of this innovative technology together with a consortium of industrial companies within the scope of the project SUPA (Smart Universal Power Antenna) promoted by the Federal Ministry of Economy and Technology (BMWi).

SUPA is the wireless infrastructure of the future for the data transfer and energy supply of mobile devices. The inductive power supply system consists of a transmitter and a receiver unit. The transmitter unit is invisibly integrated inside or below surfaces and transfers the power, as well as the data to the SUPA compatible user device (e.g. a smart phone or a notebook). The challenge of this development is it, to realize that really the complete furniture surface can be used for the power transfer and that a maximum power up 50 W can be supplied to each single device. Due to the effect that the power antenna serves also as data antenna, various can be wirelessly connected by this technology. Besides, the working range for data and energy transference is consciously minimized (approx. 5 cm to 10 cm). This leads to a low radiation level and optimizes safety of interception of the data networks.

It is planned to obstruct SUPA transmitter modules in all office and public areas to achieve a wide cover of supply points. To reach this goal a huge number by contacts with famous manufacturers from the areas IT, tool machines and furniture branch were built up in the course of the last year.

Furthermore it is planned to create a spin-off, in order to bring this innovative power and data transmission solution toward the market.

This work washonored by numerous awards:

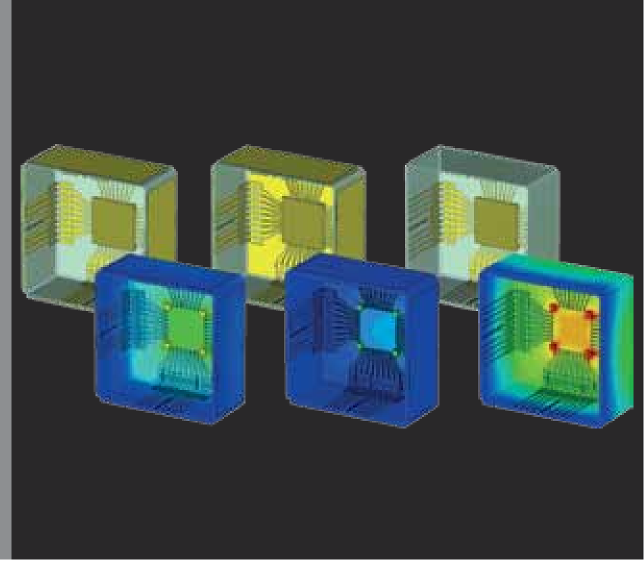
Zukunftspreis Handwerk 2011
Universal Design Award 2011
Consumer Favorit 2011
1st prize: Fraunhofer Ideenwelten 2011
1st prize: Ideenwettbewerb
Fraunhofer-Symposium 2011 »Netzwert«
Nominierung Designpreis
Deutschland 2012

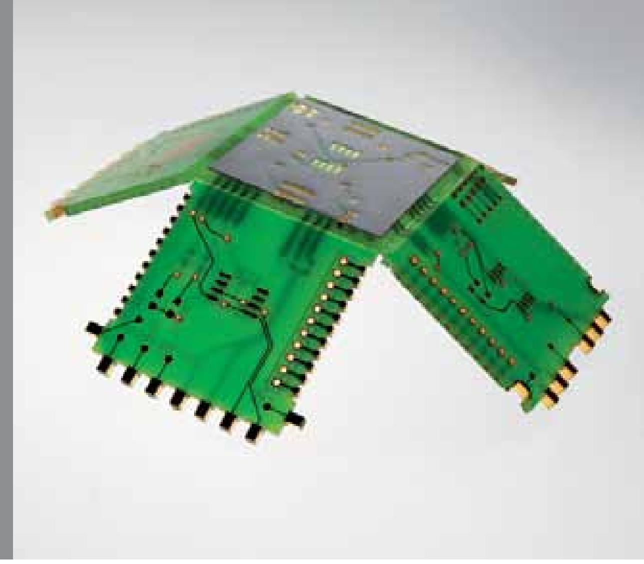
Following enterprises and universities take part to the project SUPA beside Fraunhofer ENAS:

Universität Paderborn – Die Universität der Informationsgesellschaft
Christmann Informationstechnik + Medien
Euskirchen Manufaktur
Hotoprint

The project is promoted by

Bundesministerium für Wirtschaft und Technologie
ZIM – impulse für wachstum – Zentrales Innovationsprogramm Mittelstand





DESIGN FOR FOLDED PRINTED CIRCUIT BOARDS EMC-CUBUSLAY

Christian Hedayat

The design of control electronics in the automotive and consumer area require increasingly the highest efforts in space optimization as well as in saving material and production costs. One original idea is to develop the systems using the third space dimension by folding the printed circuit boards (PCB). For this purpose wires are embedded in the inner layers of the printed circuit boards. These wires ensure the electric connection between the different folded planes of the system as well as the mechanical stability of the bended corner. Beside the mechanical reliability also the aspects of electromagnetic and thermal emission must be considered during the design process.

Current procedures and tools are laid out for the design and the fabrication of flat printed circuit boards. Hence, the design and the validation of folded PCB is very complex and cost intensive using the usual design tools.

The aim of this research purpose, carried out by Fraunhofer ENAS together with the Society for the Promotion of Applied Computer Sciences GFaI, consists in the development of a procedure for a software-supported design methodology of cost effective three dimensional PCBs taking into account EMC and thermal compliant design rules.

Besides, the main focus of the work of the department ASE consists in the investigation of specific electromagnetic and thermal properties of this new connection technology. Critical effects are, for example, disturbances of the electric properties based on discontinuities at the bending edges, as well as the altered thermal conductivity properties along the innovative PCB structure. These investigations are done by simulation with suitable tools (CST Studio Suite, ANSYS), as well as through measurement of suitable hardware test structures.

Within this project, the partner GFaI is responsible for the development of a layout tool which solves the new challenging placement problems which appear by folding the PCB.

The development of the folded PCB technology addresses the high interest of the automotive sector for both space optimization and cost reduction.

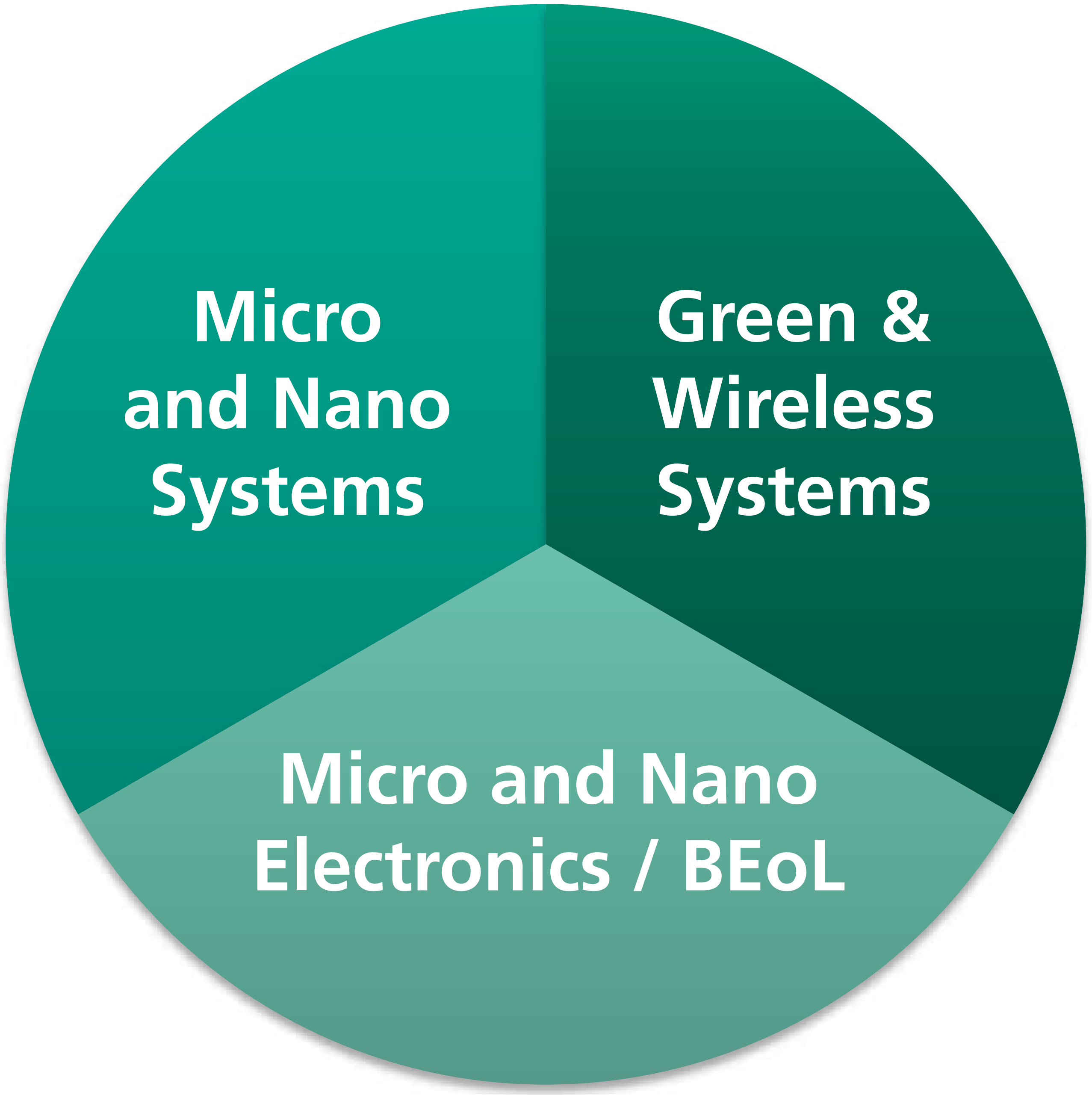
The new folding technology avoids the employment of cost-intensive connectors, because the folded PCB-cube can be reliably fixed on the motherboard by a cost-effective soldering method.

The following research institutions take part to the project beside Fraunhofer ENAS:

Universität Paderborn – Die Universität der Informationsgesellschaft
GFaI – Gesellschaft zur Förderung angewandter Informatik e.V.

The project is promoted by

Federal Ministry of Economics and Technology
AiF – Allianz Industrie Forschung



BUSINESS UNITS

BUSINESS UNITS OF FRAUNHOFER ENAS

The Fraunhofer-Gesellschaft is one of the leading organizations for applied research in Germany, Europe and worldwide. The main task is to bring research and innovation into products. The successful implementation of research results requires a successful bridging.

The Fraunhofer ENAS works in the field of smart systems integration. The product and service portfolio of Fraunhofer ENAS covers high-precision sensors for industrial applications, sensor and actuator systems with control units and evaluation electronics, printed functionalities like antennas and batteries as well as material and reliability research for micro electronics and micro system technology. The development, the design and the test of silicon-based and polymer-based MEMS/NEMS, methods and technologies for their encapsulation and integration with electronics as well as metallization and interconnect systems for micro and nanoelectronics and 3D integration are especially in the focus of the work. Special attention is paid to security and reliability of components and systems. Application areas are semiconductor industry, medical engineering, mechanical engineering, automotive industry, logistics as well as aeronautics.

In order to ensure a longterm scientific and economic success Fraunhofer ENAS has defined three business units:

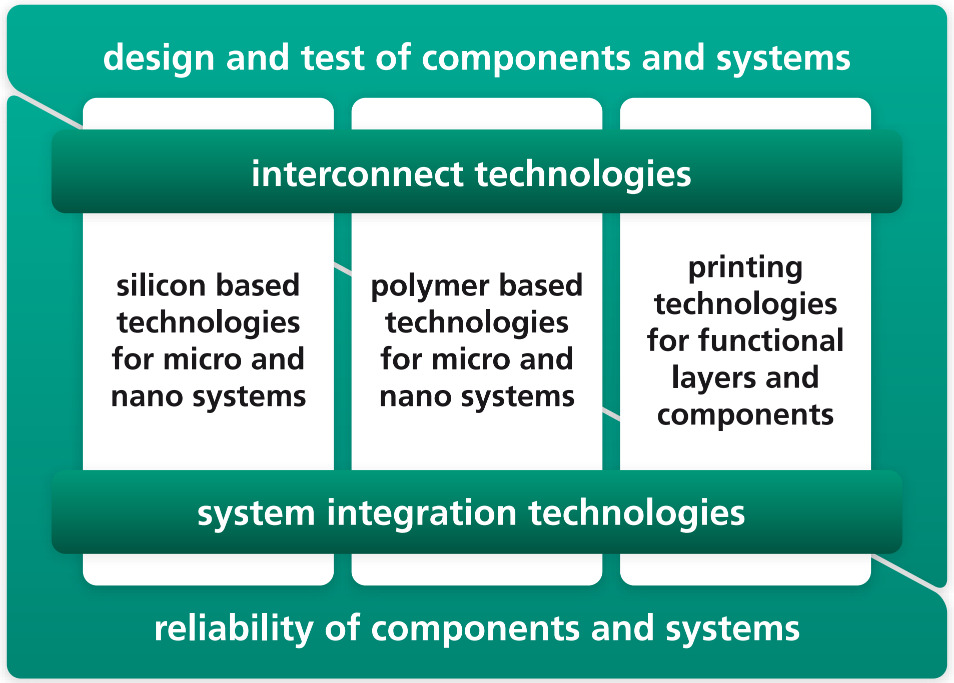
- Micro and Nano Systems,
- Micro and Nanoelectronics / Back-end of Line as well as
- Green and Wireless Systems.

They address different markets and different customers and will be described in more detail in the following pages.

The core competences are an indicator for the specific technological know-how of the Fraunhofer Institute for Electronic Nano Systems. Fraunhofer ENAS accesses on a broad variety of technologies and methods for smart systems integration. There have been defined seven core competences, which are the inner structure of the technology portfolio of Fraunhofer ENAS. These are:

- Design and Test of Components and Systems,
- Silicon Based Technologies for Micro and Nano Systems,
- Polymer Based Technologies for Micro and Nano Systems,
- Printing Technologies for Functional Layers and Component,
- Interconnect Technologies,
- System Integration Technologies,
- Reliability of Components and Systems.

The core competences "Silicon Based Technologies for Micro and Nano Systems", "Polymer Based Technologies for Micro and Nano Systems" as well as "Printing Technologies for Functional Layers and Components" are the technological basis for the development of components of micro and nano systems. "Interconnect Technologies" and "System Integration Technologies" are so-called cross-sectional technologies. They have a strong interaction with the other core competences via common projects. "Design and Test of Components and Systems" as well as "Reliability of Components and Systems" are supporting fields for the other technologies. They have a lot of interfaces to all other core competences. Moreover, they also interact as e.g. reliability issues have to be considered just in the design phase and vice versa simulations and life time predictions need to be supported and calibrated by measured data.



Based on these basic technologies, the cross-sectional technologies and methods for design, test and reliability Fraunhofer ENAS is able to process complete MEMS/NEMS and to integrate them into challenging smart systems.

The core competences are based on the know-how of the employees of the six departments of Fraunhofer ENAS. It needs to be mentioned that departments contribute to different core competences. Moreover the core competences are supported by the cooperation with our partners:

- Center for Microtechnologies ZfM of Chemnitz University of Technology,
- Chair Digital Printing and Imaging Technology of the faculty of mechanical engineering of Chemnitz University of Technology,
- Chair Sensor Systems of the faculty of electrical engineering of University Paderborn.

On the following pages the three business units will be described in more detail. The description will be supported by examples, that means by projects which belong to the business units.

MICRO AND NANO SYSTEMS

The business unit "Micro and Nano Systems" includes all silicon based and polymer based micro and nano systems. According to markets and customers it is divided into the three parts "High Precision MEMS/NEMS", "Polymer Based Low-Cost Systems" and "RF-MEMS". The business unit bases on the core competences "Design and Test of Components and Systems", "Silicon Based Micro and Nano Technologies", "Polymer Based Micro and Nano Technologies", "System Integration Technologies" as well as "Reliability of Components and Systems".

High Precision MEMS/NEMS

"High Precision MEMS/NEMS" includes the development of prototypes and system solutions of high precision micro electro mechanical systems (MEMS) and nano electro mechanical systems (NEMS). The focus is on high precision actuators for optical MEMS as well as on high precision inertial sensors for industrial applications, navigation and medical application. MEMS/NEMS design and modeling.

Fraunhofer ENAS provides services in:

- System design and modeling,
- Technology development,
- Prototypes manufactured by basic and special technologies,
- MEMS/NEMS test,
- System test.

Polymer Based Low-Cost MEMS/NEMS

"Polymer Based Low-Cost MEMS/NEMS" addresses the integration of micro and nano sensoric as well as actuatoric functionalities as integrative components of smart systems. Focus is on nano composite based sensors as well as material integrated actuators for polymeric micro systems. Thereby two different markets are addressed. The first one is industrial process monitoring and the second one medical and life science. Related to nano composite based sensors industrial process monitoring is especially of interest. Thereby the sensors need to fulfill the following requirements:

- Cost-effective, large area, high sensitive sensors,
- Integration of sensor principles which could not be integrated up to now (integrated condition monitoring),
- Components and systems for precise reliability monitoring,
- Cost reduction based on mass production.

Fraunhofer ENAS provides services in:

- Development of system integrated functionalities based on nano composites,
- Customer specific configuration of the nano composites for specific applications, e.g. in lightweight structures engineering,
- Condition monitoring based on cost-effective nano composite based sensors,
- Development of customer specific fully integrated sensor and actuator solutions,
- Common developments with SMEs in the field of molecular diagnostics and cell biology.

RF-MEMS

"RF-MEMS" comprises manufacturing of components for radio frequency applications, which electrical properties may vary based on implementation of micromechanical components or which functionality is mainly determined by mechanical components. RF-MEMS include RF-MEMS switches and varactors, which will be able to substitute existing conventional products or enable new applications due to better electrical performance. The market of RF-MEMS can be divided into two parts. Aeronautic applications, security and defence applications as well as measuring technique belong to the first category. Therefore components are required with extremely high demands on performance (at the threshold of the physical possibilities). This is the main market.

The second category is communication technique (stationary and mobile). Thereby the improvement of main properties is in the focus. These are power requirements, configuration as well as functionality. RF-MEMS can be applied for instance as tunable filters. Using tunable components it is possible to ensure their functionality at different frequencies and standards without constructing parallel signal paths.

The following topics are in the focus:

- Concepts and developments of RF-MEMS,
- Development of technologies for manufacturing and integration of RF-MEMS,
- Prototypes and small series.

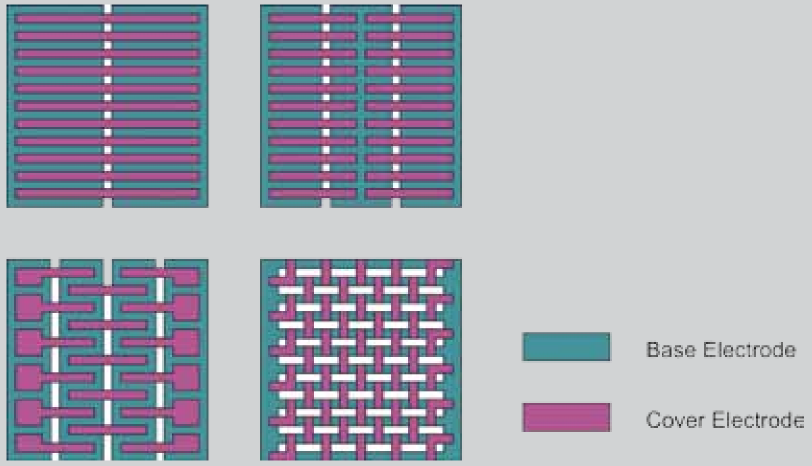


Fig. 1: Different humidity sensor layouts.

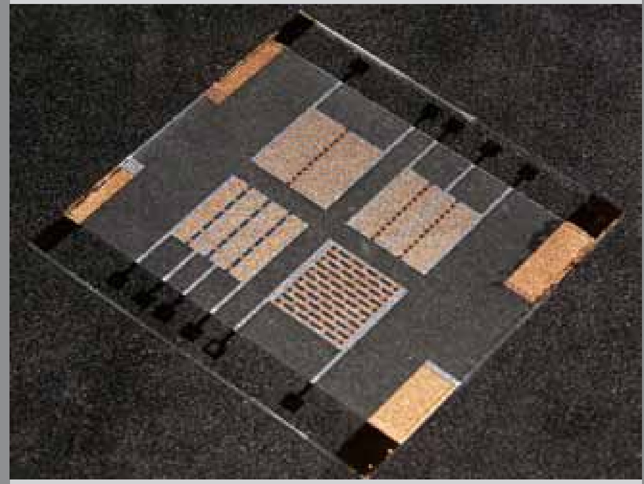


Fig. 2: Photograph of fabricated humidity sensor prototypes.

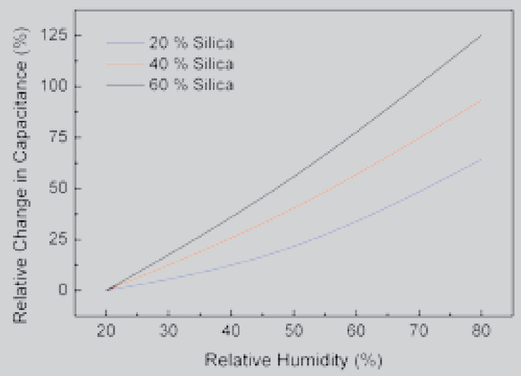


Fig. 3: Sensor response on relative humidity.

HIGH SENSITIVE HUMIDITY SENSORS BASED ON NANOCOMPOSITES

Jörg Martin[1], Doreen Piasta[1], Michael Wegener[2], Jens Hammacher[3], Thomas Otto[1]

[1] Fraunhofer-Institute for Electronic Nano Systems, Chemnitz, Germany
[2] Fraunhofer-Institute for Applied Polymer Research, Potsdam-Golm, Germany
[3] Chemnitzer Werkstoffmechanik GmbH, Chemnitz, Germany

Nanotechnology is already used in many areas of science, technology and medicine. So it is not surprising that even for micro systems engineering a large number of materials are available for the development of sensors and actuators. Thereby the substances appear frequently in form of composites, which are comprised of micro- or nanoparticles embedded in a polymer matrix. Thus composites are the connection between the nanoworld and macroscopic components.

Today many humidity sensors are based on ceramic dielectrics as part of a capacitor assembly. While using this material some disadvantages and limitations arise for these measurement systems, such as time and cost consuming manufacturing procedures as well as brittle mechanical properties [1, 2]. In contrast, nanocomposites are easily processable at room temperature and under normal atmosphere. Rigid or flexible substrates can act as basis for one or more moisture-sensitive nanocomposite layers.

In cooperation with the Fraunhofer-Institute for Applied Polymer Research IAP and the companies Chemnitzer Werkstoffmechanik GmbH (CWM) and Gesellschaft für Mikroelektronikanwendung Chemnitz mbH (GEMAC) we developed and characterized composite based humidity sensors.

The produced new sensors operate on the capacitive principle. The moisture-sensitive capacitor dielectric consists of nanoporous silica particles, which are embedded in poly(methyl methacrylate) (PMMA). A special preparation technique ensures that the humidity sensitive particles have good contact to the environment, despite the surrounding matrix.

Water within the ambient air diffuses into the pores of the silica particles and leads to a variation of the dielectric constant of the composite material corresponding to the air's water vapor content. Therefore a change in relative humidity results in a change of the dielectric constant and hence the capacity of the setup.

Sensor prototypes with different layouts and particle concentrations have been fabricated and verified according to their functionality and signal stability. Fig. 1 shows different electrode layouts for the sensor preparation on glass substrates. Each sensor has a size of 11 x 11 mm².

Base electrodes have been created by evaporation of aluminum or gold. Across these electrodes the composite layer has been applied. Finally, a thin structured gold layer has been evaporated on top of the assembly. In Fig. 2 a test pattern with different electrode designs on a glass substrate is depicted.

Test patterns have been characterized concerning sensitivity and temperature behavior. In addition, response times for an abrupt humidity change have been measured. By increasing the relative humidity from 20 up to 80 % r. h., capacitance changes of more than 100 % have been achieved, as can be seen in Fig. 3. This result reflects the very high sensitivity of the created new nanocomposite sensors. The sensitivity is dependent on the silica content of the dielectrics and rises with increasing silica concentration.

The response times of the samples have been determined for an abrupt humidity change from 33 to 95 % r. h. It appears that higher particle concentrations lead to shorter response times. Measured response times of approx. 20 seconds are similar to parameters of commercially available capacitive humidity sensors [3].

Acknowledgements

Financial support of the project "Entwicklung nanokomposit-basierter Magnetfeld- und Feuchtesensoren" by Sächsische Aufbaubank via the European Regional Development Fund (EFRE) is gratefully acknowledged.

References

[1] G. Schanz, Sensoren – Fühler der Meßtechnik, Dr. Alfred Hüthig Verlag GmbH, Heidelberg (1988).
[2] C. Leondes, MEMS/NEMS Handbook – Techniques and Applications, Springer Verlag, New York (2006).
[3] Hygrosens Instruments GmbH, Data Sheet Humidity Sensor KFS 33 LC.

MICRO AND NANOELECTRONICS / BACK-END OF LINE

The business unit "Micro and Nanoelectronics / Back-end of Line" focuses on three main fields of activity:

- Materials, processes, and technologies for micro and nanoelectronics with emphasis on back-end of line,
- Modeling and simulation of processes, equipments, as well as complete interconnect systems,
- Characterization and reliability assessment, starting from BEOL components towards complete chip-package interactions.

The Back-end of Line (BEOL) comprises all process steps starting from contact level till complete wafer processing prior to electrical testing. In other words, the entire interconnect system including passivation. Depending on the specific product (high performance / low power / generic), significant changes in the Back-end of Line have been implemented within the past years due to ongoing downscaling. While transistors become faster as their dimension shrink, the interconnect system is limiting this gain in speed, because its RC-product rises. Thus, signal delay time increases. Appropriate materials can reduce resistance and capacitance of the interconnect system and consequently compensate for the losses. While the past decade was characterized by the introduction of copper and low-k dielectrics, future challenges require a more holistic approach. Strong interactions between technology, material science, as well as modeling and simulation are necessary to face these challenges. At Fraunhofer ENAS close meshed interrelations have been established between the specific fields of activity within the past years.

The business unit "Micro and Nanoelectronics / Back-end of Line" is mainly driven by the core competences "Interconnect Technologies" and "Reliability of Components and Systems". Moreover, additional input comes from the core competences "System Integration Technologies", "Silicon Based Technologies for Micro and Nano Systems", and "Design and Test of Components and Systems ".

Markets and branches – relevant to this business field – can be derived from the value chain of integrated electronic devices:

- Materials, chemicals and consumables,
- Device fabrication and testing / equipment manufacturing,
- Integrated devices (ICs) and systems (SiPs).

Sorting the final products (ICs & SiPs) by application fields, the following further classification can be conducted:

- Consumer electronics and communication,
- Medical,
- Automotive,
- Aerospace and defense,
- Industrial and instrumentation.

Within the working fields materials, processes, technologies, and simulation, research and development are dedicated mainly to consumer electronics and communication. Thereby, emphasis is on leading edge CMOS-technologies with highly efficient and low parasitic interconnects. Within the working field reliability, almost all application areas are addressed.

Fraunhofer ENAS offers services in research, development, and wafer processing specific to markets and branches.

Device manufacturers:

- Process development, process control methodology and methods,
- Process integration issues,
- Analytics and reliability assessment,
- Simulation and modeling.

Equipment manufacturers:

- Process development and optimization dedicated to specific equipment ,
- Process and equipment simulation and modeling.

Chemical and material manufacturers:

- Evaluation, screening and development of chemicals and precursors,
- Analytics and characterization,
- Wafer processing and process optimization.

Further activities within the business unit are determined by the international semiconductor roadmap (ITRS) as well as by the global trends "Beyond CMOS" and "More than Moore".

Within leading edge micro and nanoelectronics, emphasis will be on dielectrics as well as metallization and barriers, e.g.:

- Ultra-low-k materials ($k = 2.0 – 2.3$), deposited by CVD or spin-on technologies,
- Alternative ultra-low-k approaches, e.g. airgaps ($k < 1.3$),
- Ultra thin CVD and ALD barriers,
- Self forming barriers,
- Airgap-compatible barriers and barriers for copper layers with extremely low resistivity.

Beyond CMOS is characterized by new designs and materials, like carbon nano tubes (CNTs). Fraunhofer ENAS has started basic research in that field in close cooperation with the Center for Microtechnologies at Chemnitz University of Technology. Bringing this research to an application is an important goal for the upcoming years.

Various functionalities integrated in two and three dimensional systems earmark "More than Moore" approaches. Forwarding development of integration concepts and technologies specifically directed to inter-chip interconnections is a central research topic within that area. Moreover, integration of novel BEOL materials in MEMS/NEMS applications is aimed for.

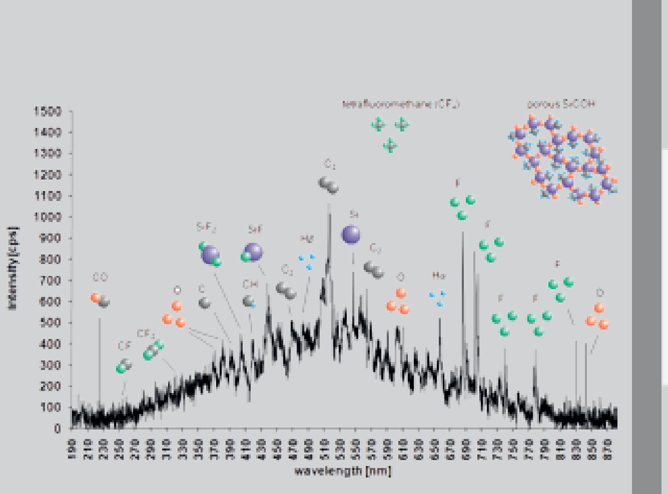


Fig. 1: Optical emission spectrum for the identification of plasma species.

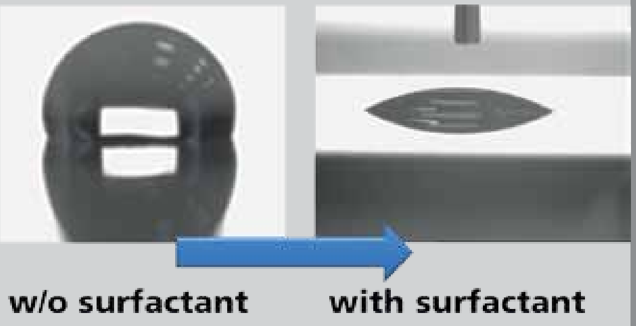


Fig. 2: Example of optimized wetting of a cleaning solution by application of surfactants.

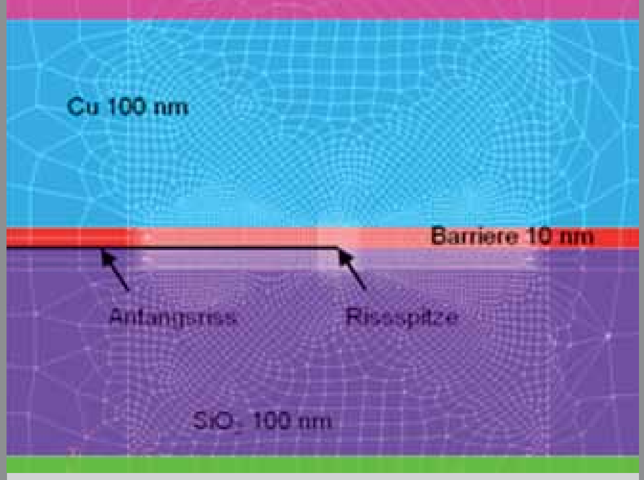


Fig. 3: FE model of a crack along the interface between barrier and dielectric.

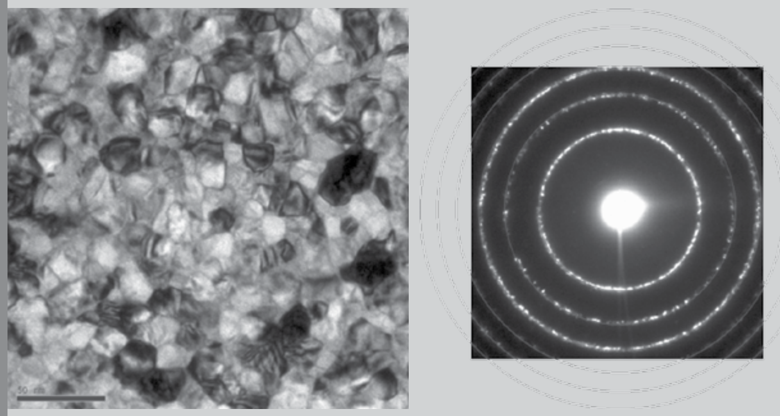


Fig. 4: TEM (left) and diffraction (right) picture of a TaN diffusion barrier layer.

ADVANCED INTERCONNECT SYSTEMS FOR NANOELECTRONICS

Nicole Ahner, Ellen Auerswald, Birgit Braemer, Ramona Ecke, Tobias Fischer, Ines Hartwig, Sven Rzepka, Knut Schulze, Sven Zimmeremann, Stefan E. Schulz

The introduction of new insulator materials like porous ultra low-k dielectrics into the copper-based interconnect system of integrated circuits leads to lower signal delay, less cross-talk and decreases power consumption of the devices. With ongoing miniaturization of the feature sizes the integration of those materials becomes more and more challenging as commonly used processing schemes for patterning, cleaning or metallization are not longer compatible. Fraunhofer ENAS with its departments BEOL and MMC develops new and optimized processes designed for the special needs of ultra low-k dielectric integration and metallization of sub-50 nm features in cooperation with GLOBALFOUNDRIES. Within the research projects STRUCTURE and NOLIMIT all major steps from patterning of the dielectric to copper metallization are covered.

Patterning of Porous Ultra Low-k Dielectrics by Dry Etching

In order to reduce the k-value of the dielectric, organic carbon species like methyl and additionally porosity are introduced into the material, which leads to less polarizability and prevents moisture uptake. Commonly applied plasma etching processes for dielectric material have turned out to damage the low-k dielectric as they tend to remove carbon from the material and to densify the upper most regions of the film. The identification of the plasma species which are responsible for carbon removal or densification is the key to develop optimized patterning processes. To achieve this, in situ plasma diagnostics like Optical Emission Spectroscopy, Quantum Cascade Laser Absorption Spectrometry and Quadrupole Mass Spectrometry are applied at the department BEOL. The results of the measurements are correlated to ex situ analytics like surface energy calculation by a software, developed at Fraunhofer ENAS to identify plasma species damaging the low-k dielectric.

Wetting Optimized Etch Residue Removal

Beside the challenges of ultra low-k integration from the material's point of view, wet chemical etch residue removal processes have to focus on wetting issues emerging as feature sizes decrease further. Especially due to their surface tension water based cleaning solutions may not be able to enter very small features like via holes and strong capillary forces have been shown to cause pattern collapse of long trench structures. A wetting optimized wet cleaning process using nonionic surfactants to reduce the surface tension of the applied cleaning liquids has been developed. By surface energy analysis, FTIR, spectral ellipsometry and CV measurements it has been shown that surfactant application is able to effectively reduce the surface energy of water based cleaning solutions while staying compatible to copper and low-k dielectrics.

Optimized k-Recovery Processes for Plasma Damaged Ultra Low-k Dielectrics

By destruction of Si-C bonds within the low-k dielectric by plasma processing, carbon is removed from the material, which leads to increased k-values. One main damage mechanism is the formation of highly polar silanol groups (Si-OH), which also lead to hydrophilization of the material. By application of silylation processes, e.g. using an OMCTS precursor, those silanols can be substituted by trimethylsilyl species and carbon is reintroduced into the dielectric. Additionally the recovery process has been shown to benefit from a thermal pre-treatment to remove water from the damaged dielectric and an UV curing after silylation, which supports the incorporation of the carbon species. By optimizing this processing regime the material parameters of damaged ultra low-k dielectrics have been distinctly improved.

Diffusion Barrier Deposition and Adhesion on Porous Low-k Dielectrics

With decreasing feature sizes also a need for thinner diffusion barrier layers arises, where ALD deposition could be a promising alternative to CVD barriers. Special focus is set to the characterization of the interface between the porous dielectric and the diffusion barrier layer. The porous structure of the dielectric could provide diffusion paths for metallic species or precursor molecules and therefore lead to material degradation. To inhibit diffusion into the porous material pore sealing processes, e.g. using nitrogen plasma, are investigated and the sealing effect is investigated by spectral ellipsometry. In cooperation with the physics department at the University Halle additionally Positronium Annihilation Spectroscopy is used to investigate the porous structure of the dielectric and is further developed to analyze whether or not metal species have been penetrating into the material.

Another issue of interest at the low-k/barrier interface is the adhesion of the barrier on differently processed porous low-k dielectrics. Analytical methods like Four Point Bending Tests or Modified Edge lift off Tests (MELT) are modified to face the special needs of thin dielectric layers. In addition, the Micro Materials Center MMC has developed experimental techniques such as nanoDAC and fibDAC to characterize the adhesion of the films and to extract input data for in-depth studies on the interface delamination mechanisms by numerical simulations.

Deposition of Copper in Sub 50 nm Structures

After deposition of the diffusion barrier and the copper seed layer the patterned structures are filled with copper, usually applying electrochemical deposition (ECD) techniques. But ECD is limited when feature dimensions decrease to 50 nm and below, as void free filling will be challenging and conformity issues due to very thin barrier and seed layers on porous dielectric surfaces may occur. As an alternative approach the copper filling can be done by CVD using metal organic copper precursors. At the department BEOL precursors like the well known CupraSelectTM and new precursors are tested. Analytics like TEM and AFM are used to evaluate grain growth and topography of the deposited metal and give information about the quality of the underlying adhesion layers.

Acknowledgement

Part of the work was financed by funds of the European Union and the Free State of Saxony. We would like to thank our research partners Leibniz INP Greifswald and Fraunhofer CNT Dresden.

GREEN AND WIRELESS SYSTEMS

According to the name the business unit "Green and Wireless Systems" aggregates all activities of Fraunhofer ENAS which belong to wireless, periodic data collection and/or monitoring to protect the environment (environmental monitoring) and the state of objects (Condition Monitoring). The business unit focuses on customer specific integration solutions for logistics and on system solutions for the condition monitoring based on MEMS/NEMS. It is divided in the two parts "Logistics" and "Smart Monitoring Systems".

Logistics

"Logistics" addresses the development and integration of components for manufacturing new smart labels which autonomously and wirelessly transfer data and to some extent energy with optimal quality at minimal production costs. They are used for instance in the automation of supply chains. Therefore application-specific antenna systems are designed and printed primary cells as well as wireless power supply systems based on near field coupling are developed. If necessary these customer specific products are produced at low cost with high throughput printing systems. Additionally a further focus is on the development of complex RF labels with integrated MEMS sensors for data acquisition. Electronic components, that are necessary for the RF technology and sensor systems, are supplied by industrial partners.

In the field of application-specific antennas, the intention is to analyze the dielectric environment of the material to be marked during the lifetime in advance and to include the results in the design of the RFID solution. In addition, beyond printing technology work is carried out in the field of antenna design in the ultra high frequency (UHF) and super high frequency (SHF) range and for matters of electro magnetic compatibility.

In order to bring together elements printed with silicon based chips in terms of a hybrid solution there is a strong cooperation with the core competences "Interconnect Technologies" and "System Integration Technologies" as well as with the business unit "Micro and Nanoelectronics / Back-end of Line".

This strategy targets at the growth market of packaging. Parallel to the activities of the pure packaging market, approaches are developed to integrate MEMS-based sensors in non-rigid, thin and smart labels, which collect, store and process data measured. Such complex systems are used e.g. for container labeling. They require an integrated, wireless power supply in addition to optimized dielectric antennas and sensor systems. For simple single-use applications, environmentally friendly primary batteries may be used, which are based on zinc-manganese dioxide and deliver voltages of 1.5 to 6 volts.

Therefore, highly efficient production technologies are used based on printing processes. They will be further developed to inexpensively produce thin, flexible energy reservoirs in (almost) any form. Competitive advantages exist for the printed batteries last but not least from the in-house design and the existing infrastructure for their characterization and reliability testing.

Fraunhofer ENAS offers the following services:

- Antenna design and modeling,
- Prototype antenna manufacturing and metrological characterization,
- System design for energy supply by wireless near-field coupling,
- Integration of sensors / MEMS in smart label,
- Development of assembling and packaging technologies of printed elements and silicon components,
- Adaptation of printing production technologies,
- Design and modeling of printed batteries and integration of these elements,
- Small batch production and metrological characterization of batteries.

Smart Monitoring Systems

"Smart Monitoring Systems" includes the development of system solutions for the condition monitoring using MEMS/NEMS based systems and optimized data analysis/communication.

Main focus is the application of silicon based micro opto electro mechanical systems MOEMS (transmission or reflection orders) in miniaturized spectrometers for gas analysis, environmental monitoring and medical applications. Today's customers are developers and users of IR detectors, spectrometers and analytical systems.

Smart monitoring systems are another aspect of this sub business unit. For example they are relevant for active flow control systems, which are currently intensively studied since the airline industry calls for monitoring of components to meet the very high standards for certification.

The Fraunhofer ENAS offers the following services:

- System design and modeling,
- Technology development,
- Manufacturing of prototypes with specific technologies,
- System test,
- Development of applications.

Fig. 1: First configuration of the modular R2R Digital Fabrication system microFLEX, consisting of a rotary screen printing and a drop-on-demand inkjet module. The system is a joint development of 3D-Micromac AG and Fraunhofer ENAS under the supervision of Tino Petsch and Prof. Reinhard R. Baumann (http://www.3d-micromac.com/press-release/articles/processing-of-thin-film-materials.html).

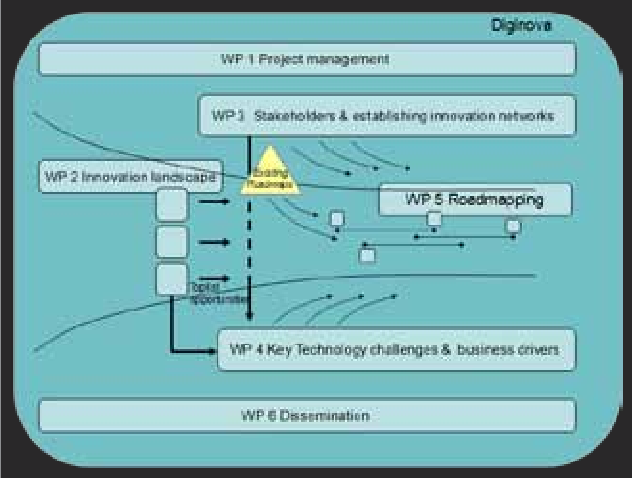


Fig. 2: Structure and interrelationship of DIGINOVA.

DIGINOVA – INNOVATIONS FOR DIGITAL FABRICATION

Andreas Willert, Reinhard R. Baumann

Introduction

Digital Fabrication as an industrial production strategy of the future will be a key technology for the perpetuation of the leadership of Europe's industries. Therefore the European Commission is funding the Coordination and Support Action DIGINOVA (agreement No. 290559) aiming for contributions to the digital industrial revolution. The project is led by Océ Technologies, Venlo/NL. The Printed Functionalities department of Fraunhofer ENAS together with its partner-company 3D-Micromac AG, both Chemnitz based, and further 18 partners from seven European countries are going for 2 years to conduct research for the development of recommendations on the implementation of digital manufacturing processes in Europe. The results will be GREEN TECHNOLOGIES: decentralized manufacturing strategies of additive material deposition, omitting material waste and huge transport efforts.

Digital Fabrication

Digital Fabrication basically employs highly efficient material deposition technologies that support the selective use of valuable materials by additive technologies. This concept supports the GREEN strategy of saving natural resources.

During the last decade the systematic use of Computer Numerical Controlled (CNC) machines got established. In our days in printed matter some business models offer a worldwide accessible web interface to drop print jobs. Instead of using only one facility and ship the printed matter to the customer, these companies spread print shops around the world and use the most qualified one for the job. The customer benefits from short reaction time and low prices.

In DIGINOVA this established business model shall be applied to additional markets. Not only books and brochures shall benefit from a Digital Fabrication concept but also other products.

Digital Fabrication Technologies

The well known and established Digital Fabrication concept CAD/CAM is currently applied to turning, milling, drilling and grinding, subtractive manufacturing technologies based on shaping by removing material. The disadvantage of these technologies is the amount of removed material which needs to be recycled in complex and expensive processes.

Most of the recycling processes can be avoided by implementing a sustainable manufacturing concept based on shape determined material deposition. Among qualifying additive manufacturing technologies the entity of printing techniques is very promising. Especially the digital techniques as inkjet and electrophotography enable deposition processes with short runlength and change over time. Although a single print run gives only a thin layer of a material pattern, stacks of different functional materials or even 3D objects can be manufactured by layer-by-layer deposition.

In many cases the deposited material layers require a subsequent process step (e.g. drying, curing, sintering) in which the targeted functionality is formed. If the functionality formation is caused by photonic processes, digital laser patterning processes qualify for a combination with digital printing / deposition techniques opening further facets of the fast developing world of Digital Fabrication.

Benefits of Digital Fabrication

Decentralization

Employing Digital Fabrication processes will enable many companies to manufacture a defined number of products – exactly when they are needed in the market. The companies address local markets, strengthen the local economies and minimize the warehousing while keeping the full, broad product variety. Consequently centralized distribution centers fades out in importance because a direct delivery of goods on demand becomes possible. Therefore transportation efforts decrease resulting in reduced environmental impact e.g. less CO_2 emission. DIGINOVA will identify promising products for first implementations.

Flexibility

Future machine concepts for Digital Fabrication processes shall take into account that flexibility in products is needed. Therefore modular production environments shall be able to be easily adapted to manufacture different products on one production line by simple reconfiguration opportunities of the arrangement of the process modules. Highly specialized machines for the production of only one product will vanish and be replaced by flexible, modular systems – specific application areas will be identified by DIGINOVA.

Customization

Customers will more and more rely on customized products. This is a continuation of a development which we already experience in some markets: e.g. VW claims that nearly no identical cars are built – they differ in power-train, color, interior, and add-ons remarkably. A comparable situation can be experienced ordering a notebook. The broad implementation of Digital Fabrication processes will open new markets for deeply customized products. Today customized decal foils for notebooks or cell phones are produced. By Digital Fabrication technologies a broader range of products will appear on the market. DIGINOVA will help to find potential markets.

Objectives of DIGINOVA

DIGINOVA will analyze the current status of Digital Fabrication, define the most potential future market segments and derive recommendations for the prioritization of further research and development areas (applications, materials, processes, machinery) to support the leadership of the European industry. For this goal material innovation and application domains will be mapped. Key technology challenges and new business opportunities will be identified. One aspect will be the identification of the main stakeholders and their connections in innovation networks that will help to identify business cases, to specify the added values and to find feasible routes for commercialization. The major result will be a roadmap that describes technology drivers and business opportunities.

COOPERATION

LONGTIME COOPERATION WITH X-FAB – AN INTERVIEW WITH UWE SCHWARZ

Uwe Schwarz, head of the MEMS process development team at X-FAB and member of the Fraunhofer ENAS advisory board, speaks about his experiences in cooperation projects with the Fraunhofer ENAS.

Fraunhofer ENAS: Mr. Schwarz, X-FAB and Fraunhofer ENAS have developed a long-term relationship of trust. What are the reasons for a foundry like X-FAB to cooperate with Fraunhofer-Gesellschaft?

Uwe Schwarz: The cooperation between Fraunhofer ENAS and X-FAB started as a successful German government-funded project more than 10 years ago. At that time, X-FAB realized that Fraunhofer-Gesellschaft was very knowledgeable about wafer processes for MEMS devices and applications. So it was a logical step for X-FAB to develop the relationship with ENAS by starting more and more new common projects that were helpful for the X-FAB MEMS foundry portfolio.

Fraunhofer ENAS: What services of Fraunhofer ENAS does X-FAB use?

Uwe Schwarz: We cooperate with the Fraunhofer ENAS in several different ways. One way is that X-FAB, along with colleagues at Chemnitz, does some subcontracting for very special process steps – especially for low-volume products, for which it makes no sense to do in-house. The most important way is that X-FAB places process development projects at ENAS based on available process expertise and experience. In addition, X-FAB receives support and help in solving process issues that always seem to pop up overnight and require fast, immediate problem solving.

Fraunhofer ENAS: What has worked really well, what needs improvement?

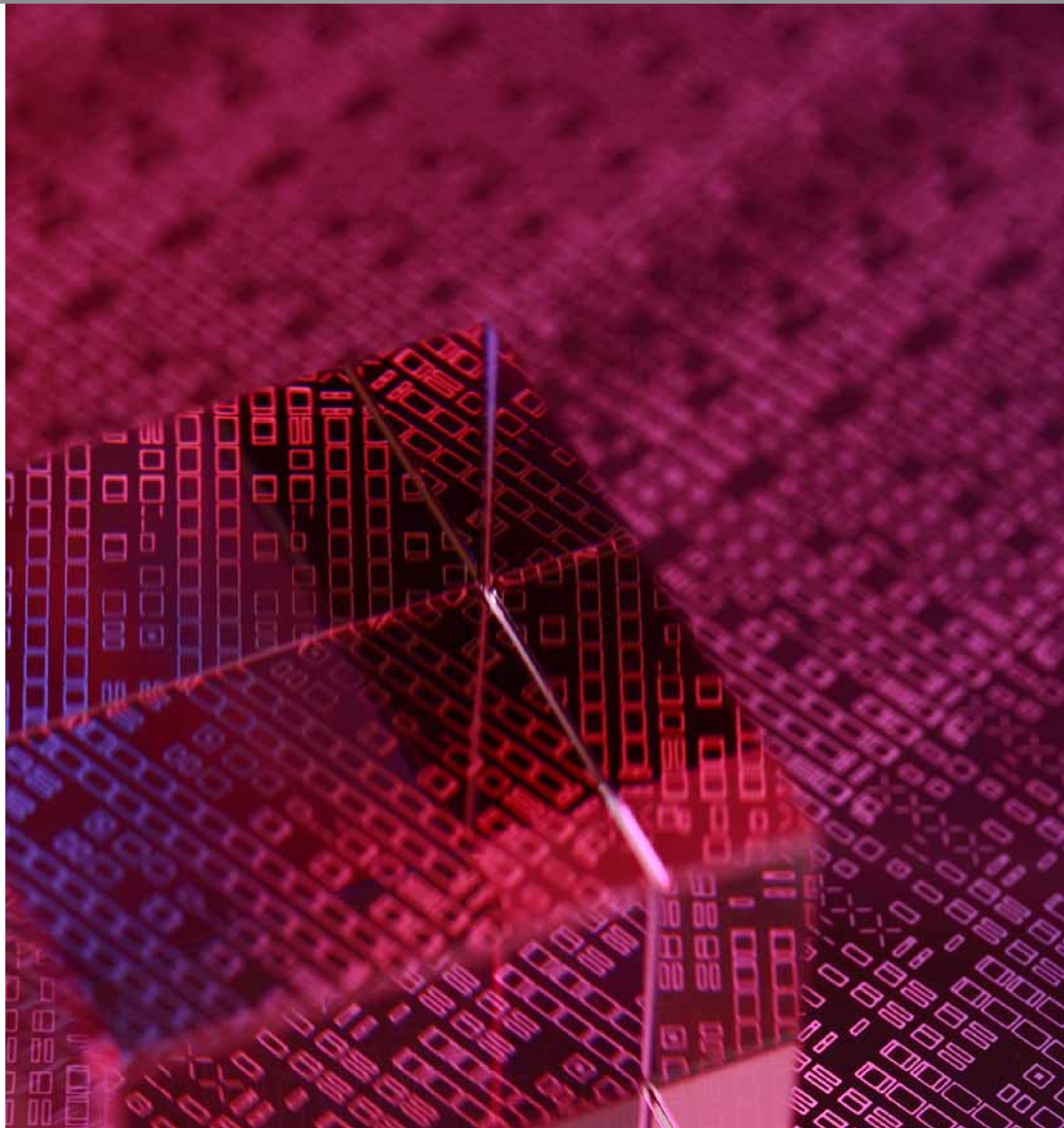
Uwe Schwarz: We are happy that our cooperation is not problematic. We know many ENAS staff members personally and can contact relevant partners and experts directly. Often it is helpful to have face-to-face meetings, which are very easy to organize because of the close proximity of Chemnitz and Erfurt. Of course we use all the other communication possibilities as well, such as Web-based meetings.

But I also have to add that the cooperation with Fraunhofer-Gesellschaft is not inexpensive for a medium-sized enterprise like X-FAB. It would help if the cost structure for bilateral projects could be improved.

About Uwe Schwarz: Uwe Schwarz obtained a degree in Physics at the University in Leipzig in 1988. He joined X-FAB in 1992. He worked first as a development and process engineer on photolithographic processing, and was also involved in some of the CMOS technology development programs of the company. In 1997 he started the first activities in the field of MEMS process development at X-FAB. He has been deeply involved in the development of a MEMS foundry business. From 2001 he has been head of the MEMS process development team.

About X-FAB: X-FAB is the leading analog/mixed-signal foundry group manufacturing silicon wafers for analog-digital integrated circuits (mixed-signal ICs). X-FAB maintains wafer production facilities in Erfurt and Dresden (Germany); Lubbock, Texas (US); and Kuching, Sarawak (Malaysia); and employs approximately 2,400 people worldwide. Wafers are manufactured based on advanced modular CMOS and BiCMOS processes with technologies ranging from 1.0 to 0.13 micrometers, for applications primarily in the automotive, communications, consumer and industrial sectors.
For more information, please visit www.xfab.com.

Screen printed frames for glass frit bonding on 8" wafer



PodiTrodi
Point-of-care diagnostics for tropical diseases

EUROPEAN-BRAZILIAN CONSORTIUM

The diagnosis and discrimination of infectious diseases (such as leishmaniasis, dengue, malaria, HIV, chagas) in geographic regions with poor or low-density medical infrastructure is of high socioeconomic importance. While so-called "rapid in-vitro diagnostic (ivD) tests" for single diseases are already on the market, more complex analytical protocols are necessary to clearly identify a certain tropical disease and to determine the status of the disease - the latter being crucial for proper treatment. Such complex analytical protocols would include liquid handling as well as sample preparation like transcription and amplification (PCR) of the virus` RNA (dengue, HIV) or the parasite (lechimaniasis, malaria, Chagas). These sample preparation steps are currently only available in laboratories and have not yet found their way in mass-producible, integrated point-of-care diagnostic tests.

Thus, the PodiTrodi project aims to overcome the draw-backs of current point-of-care tests by developing technologies for really integrated but low-cost sample preparation. The prototype to be developed for this proof of concept will be an instrument that integrates the heterogeneous microsystems (biosensors and microfluidics), control electronics, sensor read-out, human-machine interface, embedded processor and power supply, in a self-contained unit, suitable for point-of-care diagnosis of the diseases selected as first targets.

To achieve these challenging goals, PodiTrodi follows a multidimensional, multi-material system integration approach on four project "levels" (Heterogeneous System Integration, Instrumentation, Fabrication Infrastructure, Development Infrastructure). The Consortium comprises 8 partners from 5 European countries (Germany, France, Italy, Finland, Portugal) as well as 5 partners from Brazil (PodiTrodi-BR). They represent industry, research and academia and bring a range of complementary skills required for this multidisciplinary research project.

The European partners of the consortium are:

- Fraunhofer Institute for Electronic Nano Systems ENAS (Germany)
- CEA-LETI (France)
- Teknologian tutkimuskeskus VTT (Finland)
- ST Microelectronics (Italy)
- Häcker Automation GmbH (Germany)
- University of Aveiro (UAVR), Centre for Research in Ceramics and Composite Materials (Portugal)
- CNRS, Charles Coulomb laboratory (L2C) (France)
- BiFlow Systems GmbH (Germany)

The Brazilian partners of the consortium are:

- Centro de Tecnologia da Informação Renato Archer - CTI (Campinas, Brazil)
- CERTI Foundation (Florianópolis, Brazil)
- Fundação Oswaldo Cruz - FioCruz (Curitiba, Brazil)
- State University of Campinas, Center for Semiconductor Components - CCS (Campinas, Brazil)
- Universidade Federal do Paraná - UFPR (Curitiba, Brazil)

The project "PodiTrodi – Technology platform for Point-of-care diagnostics for tropical diseases" (EU-FP7-287770) started in September 2011 with a project time of 2.5 years.

More information are provided under:
http://www.enas.fraunhofer.de/kooperationen/allianzen/poditrodi

COOPERATION WITH INDUSTRY (SELECTION)

3D-Micromac AG, Chemnitz, Germany

Advaplan Inc., Espoo, Finland
Air Products and Chemicals, Inc., Allentown (PA) and Carlsbad (CA), USA
Alenia Aeronautics, Casoria, Italy
alpha-board gmbh, Berlin, Germany
AMO GmbH, Aachen, Germany
AMTEC GmbH, Chemnitz, Germany
Analog Devices, Raheen, Ireland
Arentz Optibelt, Höxter, Germany
austriamicrosystems AG, Unterpremstätten, Austria
AVANTOR Performance Materials, Europe
AXUS Technologies, Chandler AZ, USA

Benteler Automobiltechnik GmbH, Paderborn. Germany
Berliner Nanotest and Design GmbH, Berlin, Germany
Boehringer, Ingelheim, Germany
Robert Bosch GmbH, Reutlingen & Stuttgart, Germany

CAD-FEM GmbH, Grafing, Germany
Chemnitzer Werkstoffmechanik GmbH, Chemnitz, Germany
Christmann Informationstechnik + Medien GmbH, Ilsede, Germany
CLAAS KGaA mbH, Harsewinkel, Germany
Clean Tech Campus GmbH, Chemnitz, Germany
Continental AG, Germany
Continental Automotive GmbH, Regensburg, Germany
CST AG, Darmstadt, Germany

DBI – Gastechnologisches Institut gGmbH, Freiberg, Germany
DBI - Gas- und Umwelttechnik GmbH, Leipzig, Germany
Denso Corporation, Kariya, Japan
DiscoEurope, Kirchheim, Germany
Drägerwerk AG & Co. KGaA, Lübeck, Germany
Diehl Hydrometer, Arnsbach, Germany

EADS Deutschland GmbH, Corporate Research Center Germany, Department Microsystems, Munich, Germany
EADS Innovation Works, Munich, Germany
EDC Electronic Design Center, Chemnitz, Germany
ELMOS Semiconductor AG, Dortmund, Germany
elprotek GmbH, Buchen, Germany
Endress und Hauser AG & Co. KG, Germany
Envia M GmbH, Halle, Germany
EPCOS AG, Germany
EV Group Europe & Asia/Pacific GmbH, St. Florian am Inn, Austria
Exalos AG, Schlieren, Switzerland

FACRI, Research Institute, Xi´an, China
First Sensor Technology GmbH, Berlin, Germany
Flexo-Print Bedienfelder GmbH, Salzkotten, Germany
Freudenberg Co. KG, Germany
Frottana Textil GmbH & Co. KG, Großschönau, Germany
FSG Automotive GmbH, Oelsnitz, Germany

GEMAC, Chemnitz, Germany
Gemalto, La Ciotat, France
GFal, Teltow, Germany
GF Messtechnik, Teltow, Germany
Gesellschaft für Prozeßrechnerprogrammierung mbH (GPP), Chemnitz, Germany
GLOBALFOUNDRIES, Dresden, Germany
Gyrooptics Company Ltd., St. Petersburg, Russia

Hella, Lippstadt and Bremen, Germany
Helenic Aerospace Industry S.A., Schimatari, Greece
Hispano Suiza, Colombes (Paris), France
Hotoprint Elektronik GmbH & Co. KG – Leiterplatten, Lamspringe, Germany

IBM, Zurich, Switzerland
Inficon AG, Balzers, Liechtenstein
Infineon Technologies AG, Munich, Dresden and Warstein, Germany and Villach, Austria
InfraTec GmbH, Dresden, Germany
Intel, Sophia Antipolis, France
IoLiTec Ionic Liquids Technologies GmbH, Heilbronn, Germany

Jenoptik-LOT GmbH, Gera, Germany
Jenoptik Lasersystems, Jena, Germany
JUMATECH GmbH, Eckental, Germany

KSG Leiterplatten GmbH, Gornsdorf, Germany

LG Electronics, Korea

M&S Mikrotechnik und Sensorik GmbH, Hermsdorf, Germany
Magh und Boppert, Paderborn, Germany
MED-EL Medical Electronics, Innsbruck, Austria
MELEXIS, Bevaix, Switzerland
memsfab GmbH, Chemnitz, Germany
micro resist technology GmbH, Berlin, Germany
Microelectronic Packaging Dresden GmbH, Dresden, Germany
Microtech GmbH, Gefell, Germany
mikroglas chemtech GmbH, Mainz, Germany
Multitape GmbH, Büren-Ahden, Germany

NB Technologies GmbH, Bremen, Germany
neoplas control GmbH, Greifswald, Germany
Northroup Grumman LITEF GmbH, Freiburg, Germany
NXP, Eindhoven, The Netherlands, and Hamburg, Germany

Ocè B.V., Venlo, The Netherlands
Optibelt GmbH, Höxter, Germany

Panasonic Plasma Display Labaratory, Inc., Highland, New York, USA
paragon AG, Delbrück, Germany
Physikalisch-Technische Bundesanstalt Braunschweig (PTB), Germany
Philips Applied Technologies, Eindhoven, The Netherlands
printechnologics GmbH, Chemnitz, Germany
ProTec Carrier Systems GmbH, Siegen, Germany
PVATePla AG, Feldkirchen, Germany

Rainer Euskirchen Büro-Design GmbH, Bielefeld, Germany
RF-Embedded GmbH, Stephanskirchen, Germany
Ricoh Company, Ltd., Yokohama, Japan
Rohde & Schwarz GmbH & Co. KG, Munich, Germany
Rolf Schäfer Beschichtungskomponenten (robeko), Münchweiler, Germany
Roth & Rau AG, Hohenstein-Ernstthal, Germany
Roth & Rau Microsystems, Wüstenbrand, Germany
RWE AG, Essen, Germany

Sagem Orga GmbH, Paderborn, Germany
SAW Components Dresden GmbH, Germany
Schaeffler Group, Germany
Schenker Deutschland AG, Dresden, Germany
Schott Mainz & Schott Glas, Landshut, Germany
Sedemat GmbH, Oelsnitz, Germany
Senseor, Sophia Antipolis, France
Sentech Instruments GmbH, Berlin, Germany
SICK AG, Waldkirch & Ottendorf-Okrilla, Germany
Sensitec GmbH, Lahnau, Germany
SF Automotive GmbH, Freiberg, Germany
SHINKO ELECTRIC INDUSTRIES CO., LTD., Nagano, Japan
Siegert TFT GmbH, Hermsdorf, Germany
SMD-Production-Technology, Krefeld, Germany
SolviCore GmbH & Co. KG, Hanau, Germany
Solardynamik GmbH, Berlin, Germany
Sony Corp., Semiconductor Business Unit, Japan
STF Schweißtechnische Fertigung GmbH, Chemnitz, Germany
ST Microelectronics, Crolles, France
Suss Microtec AG, Munich, Germany

TDK-EPC AG & Co. KG, Berlin, Germany
Thales-Avionics, Valence and Orsay, France
Toyota, Japan
TQ-Systems GmbH, Chemnitz, Germany
Turboméca, Bordes, France

Vollmerhaus GmbH, Plettenberg und VOT AG, Chemnitz, Germany
Vowalun GmbH, Treuen, Germany
VW Oelsnitz, Germany

Wincor-Nixdorf, Paderborn, Germany

X-FAB SEMICONDUCTOR FOUNDRIES AG, Erfurt and Dresden, Germany

ZMD AG, Dresden, Germany
Zuken GmbH, Hallbergmoos, Germany

FRAUNHOFER ENAS

FRAUNHOFER ENAS – COOPERATION WITH NATIONAL AND INTERNATIONAL UNIVERSITIES

National Cooperation

Interdisciplinary cooperation is the key for success. The Fraunhofer Institute for Electronic Nano Systems cooperates with the faculties of Electrical Engineering & Information Technology, Natural Sciences and Mechanical Engineering of the Chemnitz University of Technology. The cooperation ensures synergies between the basic research conducted at the Chemnitz University of Technology (CUT) and the more application-oriented research at the Fraunhofer ENAS.

In 2011 the Chemnitz University of Technology celebrated its 175th anniversary. The technical education and innovation have a long history in Chemnitz. The foundations for the close link between engineering, science and culture in the south-west of Saxony, which still has a determining influence on study and research at CUT, go back to the 16th century. What is now CUT had its foundation with the establishment of the Royal Mercantile College (Königliche Gewerbschule) in 1836, which catered to the region's demand for a well-trained workforce.

The main cooperation partner at the Chemnitz University of Technology is the Center for Microtechnologies, which belongs to the faculty Electrical Engineering and Information Technology. Together with the Center for Microtechnologies the Fraunhofer ENAS carries out research and development in the fields micro and nanoelectronics, micro mechanics and microsystems technologies.

Main topics are:

- Development of technologies and components for micro and nano electro mechanical systems, like sensors, actuators, arrays
- Development of technologies for metallization systems in micro and nanoelectronics
- Design of components and systems
- Nanotechnologies, components and ultrathin functional layers

The cooperation results in a common use of equipment, facilities and infrastructure as well as in the cooperation in research projects, like nanett "nanosystem integration network of excellence" and international research training group "Materials and Concepts for Advanced Interconnects and Nanosystems".

Printed functionalities are a relatively new research topic of the smart systems integration. Printing technologies are just well established at the Chair of Digital Printing and Imaging Technology of the faculty of Mechanical Engineering of the CUT. Using printing technologies conducting, insulating and semiconducting materials are printed and used for different functionalities, starting from antennas up to batteries.

The department Advanced System Engineering located in Paderborn continues the close cooperation with the University Paderborn especially in the field of electromagnetic reliability and compatibility as well as SUPA technology.

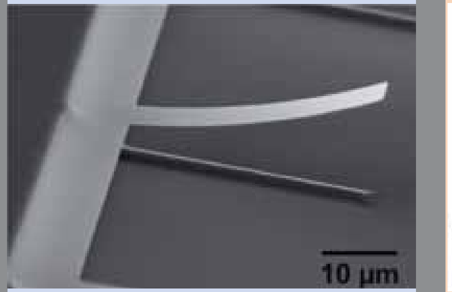
International Cooperation

The Fraunhofer Institute for Electronic Nano Systems ENAS maintains a close contact with numerous other universities and research institutes via participation in projects and European technology platforms. In Asia, long-term cooperation exists with the Tohoku University in Sendai, the Fudan University Shanghai and the Shanghai Jiao Tong University. Two examples will be given.

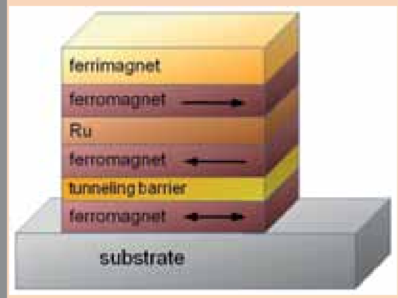
The cooperation of both, Fraunhofer ENAS and also Center for Microtechnologies, with the Tohoku University Sendai in Japan is a very successful one. As a principal investigator Prof. Dr. Thomas Gessner got an own WPI research group belonging to the devision Device/Systems within the WPI Advanced Institute for Material Research. The group is managed by Prof. Yu-Ching Lin since November 2008. Focus of the research is smart systems integration of MEMS/NEMS, especially the integration of heat generating materials for wafer bonding, the CMOS-MEMS integration and the fabrication of nanostructures using self organizing and self assembling. During the big earth quake in spring a scientist of Fraunhofer ENAS and a student of Chemnitz University of Technology have been in Sendai. Both had to return to Germany. As soon as it was possible the scientist Joerg Froemel went back to Sendai and continued to work on waferbonding there. On November 8th WPI-AIMR concluded a memorandum of understanding on academic exchange with the Fraunhofer Institute for Electronic Nano Systems.

Within the international graduate school "Materials and Concepts for Advanced Interconnects and Nanosystems" young engineers work together with researchers from other German and Chinese universities. They are specialized in electrical engineering and microelectronics, material sciences as well as physicists and chemists and develop together new materials and processes as well as new concepts for interconnect systems in integrated circuits. The project makes essential contributions not only to the solution of problems of nanoelectronics. It supports and requests an interdisciplinary and cross-cultural communication and cooperation. Participants at these projects are the Institute of Physics, the Institute of Chemistry and the Center for Microtechnologies of the Chemnitz University of Technology as well as the Technical University Berlin, the Fudan University Shanghai, the Shanghai Jiao Tong University, the Fraunhofer Institute for Microintegration and Reliability IZM and the Fraunhofer Institute for Electronic Nano Systems ENAS. The research program of the International Research Training Group comprises nine projects at the German institutions, as well as eight at Fudan University and three at Shanghai Jiao Tong University.

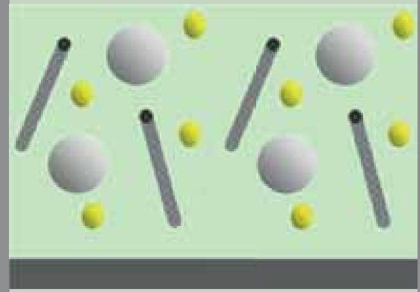
Micro-Nano-Integration



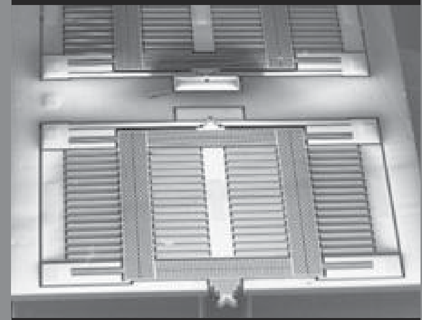
Novel Processes and Technologies



Nano Materials

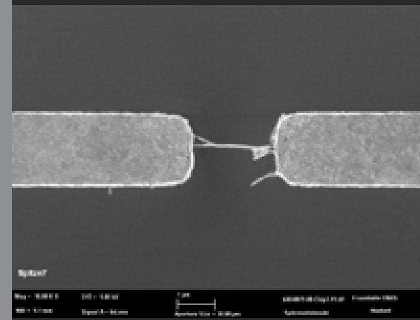


Silicon Nano Sensors



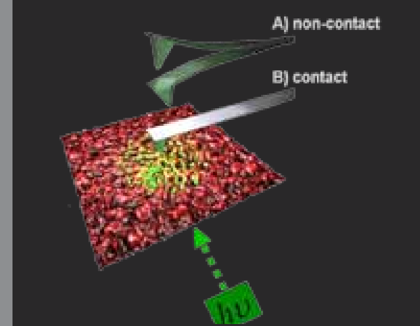
Micro Tension Experiment

Modeling and Integration of Nanotubes



SWCNTs between W Electrodes deposited by DEP

Novel Materials and Technologies for Sensor Applications



3D Structural and Chemical Imaging at the Nanoscale

NANETT – NANO SYSTEM INTEGRATION NETWORK OF EXELLENCE

The research consortium nanett "nano system integration network of excellence" is one of the successful initiatives of the program "Spitzenforschung und Innovation in den Neuen Ländern", funded by the Federal Ministry of Education and Research (BMBF). Under the direction of the Chemnitz University of Technology and the Fraunhofer Institute for Electronic Nano Systems this multi disciplinary network of nine partners was formed to bring together their different competences in the field of applied nanotechnologies. Using the approach of combining the capabilities of several renowned scientific institutions enables international and domestic top level research on a competitive basis. The grant of the BMBF for the whole R&D joint venture amounts 14 million Euros. The project started in November 2009 with a funding period of five years.

Nano System Integration this means the technological utilization of already known as well as new-found effects resulting from nano scale elements integrated in a material, a chip, an assembly or a complete system. The strategic direction of the network is the connection of fundamental with application oriented research in the promising domains of nanotechnology and system integration technology with the aims of transferring science into applications and being an attractive, competent and solid partner for the industry. To suit the scientific requirements of these highly interdisciplinary fields and due to huge investment costs for production and test equipment in the field of micro and nanotechnologies it is essential to use synergies created by collaborative work of different renowned research centers for successfully conducting competitive research and development.

As a basis for these activities important technological questions and application constraints have been identified and summarized in three areas of competence. In the first three years period, the research is focused on the integration of component level within the areas of competence. On the basis of concrete technological problems superordinate approaches will be investigated. In the second two year period, the flagship projects will be merged in order to focus on system level integration.

The three areas of competence with their research topics are:

Processes and technologies for nano scale material systems

- Application of quantum mechanical phenomena and effects of nano structures
- Patterning of nano structures in unconventional materials
- Characterization of magnetic properties

Micro-nano-integration

- Integration of nano structures with electromechanical functionalities
- System design and architecture of energy efficient sensor networks
- Technologies for autonomous sensor nodes

Nano materials

- Fabrication of functional nano composite materials
- Material integrated sensor functionality in lightweight structures
- Reliability of functional materials

The Fraunhofer Institute for Electronic Nanosystems takes part in all three areas of competence within the following research topics: atomic layer deposition, integration of nano structures with electromechanical functionalities, system design, fabrication of functional nano composite materials and reliability of functional materials.

For more information please visit our website:
http://www.nanett.org/

DFG RESEARCH UNIT 1713 SENSORIC MICRO AND NANO SYSTEMS

The Deutsche Forschungsgemeinschaft (DFG) has established the research unit 1713 "Sensoric Micro and Nano Systems" at the Chemnitz University of Technology for a period of three years, starting in March 2011. Besides the Fraunhofer Institute for Electronic Nano Systems ENAS, also professorships of the Center for Microtechnologies from the Faculty of Electrical Engineering and Information Technology, the Faculty of Natural Sciences and the Leibniz Institute for Solid State and Materials Research (IFW Dresden) are involved in the Research Unit. Speaker of the Research Unit is Prof. Thomas Gessner.

The scientific aim of the Research Unit is the integration of nano structures and novel materials, as well as the spatial and functional integration of heterogeneous components in micro and nano systems. Especially for the integration of nanotechnologies and the development of novel materials the collaboration between the Center for Microtechnologies and the Institutes of Physics and Chemistry are of great concern. Together with the Fraunhofer ENAS and the IFW Dresden the competences in the areas of design, fabrication, characterization and reliability of micro and nano structures and of integration and packaging technologies will be combined for working on the complex scientific tasks arising from the development of multifunctional micro and nano systems.

The realization of the research goals in the first funding period of the Research Unit 1713 is based on three independent technological routes:

- Silicon nano sensors,
- Modeling and integration of nanotubes,
- Novel materials and technologies for sensor applications.

Within the technological route "Silicon nano sensors", nano structures based on state of the art MEMS technologies will be integrated in microsystems for utilizing nano effects in transducers by incooperating nano structures. Such structures within transducer elements need new pathways for interconnecting the signal processing with the sensor element due to the decrease of the signal to noise ratio. Furthermore, new concepts for the design and the packaging of nano systems have to be developed, because flexibility and interactions between different components are essential for heterogeneous systems.

The second technological route "Modeling and integration of nanotubes" covers the whole bandwidth from atomistic modeling of carbon nanotubes (CNTs), over process development for deposition and integration of nanotubes, characterization by scanning probe techniques up to the application for microfluidics and sensors. For application oriented simulations structural defects, contact properties as well as contaminations by subsequent processes have to be taken into account. The evaluation of realistic models requires highly accurate characterization methods; therefore an analytics with a spatial resolution in the nanometer is necessary. The requirements on the integration processes will be investigated for applications of nanotubes within microfluidic systems and resonators as well as sensors.

Syntheses, patterning and integration of magnetic materials is in the focus of the third technological route "Novel materials and technologies for sensor applications". Novel geometric configurations like nano particle arrays will be reproducibly processed by self assembly and rolling up of thin film systems will be fabricated as well as they are studied fundamentally.

For more information, please have a look at our website:
http://www.zfm.tu-chemnitz.de/for1713/

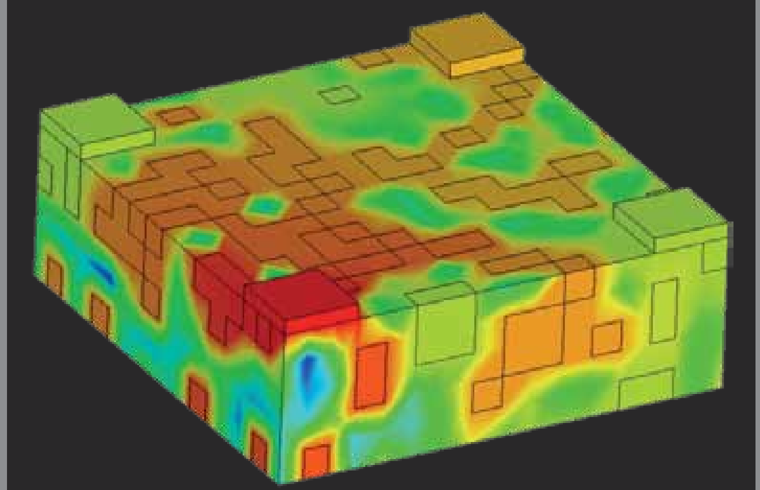


FIG. 1

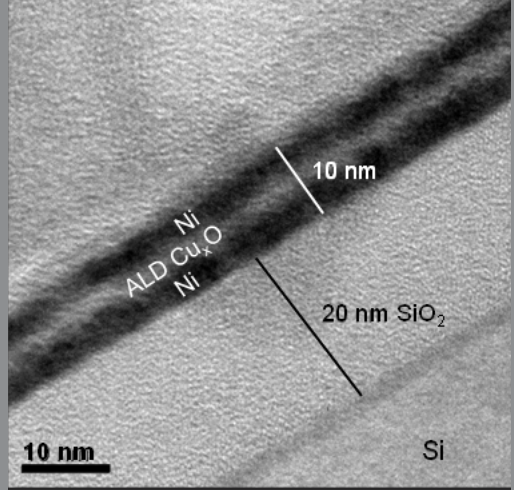


FIG. 2

FIG. 3

INTERNATIONAL RESEARCH TRAINING GROUP

"Materials and Concepts for Advanced Interconnects and Nanosystems"

At a Glance

From macro to micro, science and engineering have drastically been changing daily live for the last five decades. With nanotechnology, even more revolutions are expected from novel materials and new effects not discovered so far. Against this background, the International Research Training Group – Internationales Graduiertenkolleg 1215 – "Materials and Concepts for Advanced Interconnects" exists as an international Graduate School since April 2006, jointly sponsored by the German Research Foundation (DFG) and the Chinese Ministry of Education. Four institutions in Germany and two Chinese universities in Shanghai are cooperating in this project:

- Chemnitz University of Technology
  - Institute of Physics
  - Institute of Chemistry
  - Center for Microtechnologies
- Technische Universität Berlin
- Fraunhofer Institute for Reliability and Micro Integration IZM, Berlin
- Fraunhofer Institute for Electronic Nano Systems ENAS, Chemnitz
- Fudan University, Shanghai
- Shanghai Jiao Tong University

This International Research Training Group is the first of its kind at Chemnitz University of Technology. It is led by Prof. Ran Liu of Fudan University and Prof. Di Chen of Shanghai Jiao Tong University as the coordinators on the Chinese side, as well as Prof. Thomas Gessner as the coordinator on the German side. A graduate school like this offers brilliant young PhD students the unique opportunity to obtain their PhD degree within about three years in an international, multi-disciplinary environment.

Up to 18 PhD students in Germany and 20 at the Chinese partner universities are involved in this project. The different individual backgrounds of the partners bring together electrical and microelectronics engineers, materials scientists, physicists, and chemists. In particular, the IRTG is working to develop novel materials and processes for nanosystems as well as new concepts for connecting the individual transistors within nanoelectronic circuits. Smaller contributions are additionally made in the field of device packaging and silicides for device fabrication. In this respect, the IRTG is providing solutions for nanoelectronics and Smart Systems Integration.

Research Topics

The research program of the IRTG concentrates on both applied and fundamental aspects to treat the mid- and long-term issues of microelectronics metallization and nanosystem integration. For example, for the atomic layer deposition (ALD) of metals new precursors, processes and in-situ analytics methods are considered. Ultralow-k dielectrics are studied with respect to their properties and integration into nanoscaled metallization systems. New and innovative concepts for future interconnects based on carbon nanotubes (CNTs) are studied along with methods to create rolled-up nanostructures for electrochemical cells. Among the topics related to sensor applications, magnetic film systems on curved surfaces of nanoparticles are studied with respect to their performance as giant or tunnel magnetoresistance (GMR or TMR) sensor. Further works are related to polymer composite materials to be used in thermoelectric systems.

Study Program and PhD Student Exchange

The research within the IRTG graduate school is accompanied by a specially tailored study program to provide the PhD students with specific knowledge and skills related to their fields of work. Apart from lectures, lab courses and seminars, annual schools held either in China or Germany are an essential part of the qualification project. These events bring together the PhD students of all institutions involved, as well as their professors and scientific advisors to discuss recent results and the progress of their individual topics.

Moreover, an exchange period of three to six months for every PhD student at one of the foreign partner institutions is another essential component. Besides gaining special know-ledge in the scientific field, working abroad for a certain time also provides intercultural competencies that cannot easily be gained otherwise. In that respect, the IRTG also prepares the PhD students for an ever more international economy.

Highlights in 2011

One of the greatest highlights for the IRTG in 2011 was the Summer School held in Shanghai in April. Together with their professors and scientific advisors, 16 PhD students from the German institutions took part in the school that was organized by the partners from Shanghai Jiao Tong University. It was the third event of this kind held in Shanghai. Apart from the German participants, 16 PhD students from Fudan and Jiao Tong University gave talks about their scientific work. Vivid discussions often evolved between the PhD students and professors from both the German and Chinese sides. The technical program also comprised several presentations by professors, giving broader reviews about specific topics. Prof. Zheng Li-Rong, dean of the Microelectronics Department at Fudan University, gave a presentation on "Micro/Nano Devices for Pervasive Healthcare", bridging the gap between the more fundamental topics of the IRTG towards an important application area of electronic devices. Looking further into the future, Prof. Oliver G. Schmidt, head of the department for Integrative Nanoscience at Leibniz IFW Dresden and Professor for Materials Systems of Nanoelectronics at Chemnitz University of Technology, presented impressive results his research group obtained in the field of hybrid nanomembranes. As always, the scientific program of the Summer School was accompanied by cultural and social events, such as a boat tour on Huangpu River along the skyline of Shanghai and a very interesting visit to the Shanghai Urban Planning Exhibition Center.

For three of the German PhD students, the Summer School also was the starting point of their exchange period in Shanghai. Two of their colleagues followed later in the year to begin a research stay of three months, while two PhD students from Shanghai started an even longer exchange in Chemnitz.

All the activities of the IRTG in 2011 resulted in 19 new contributions at international conferences and 12 additional papers in peer-reviewed international journals. Several joint publications of Chinese and German PhD students express the successful cooperation in the project.

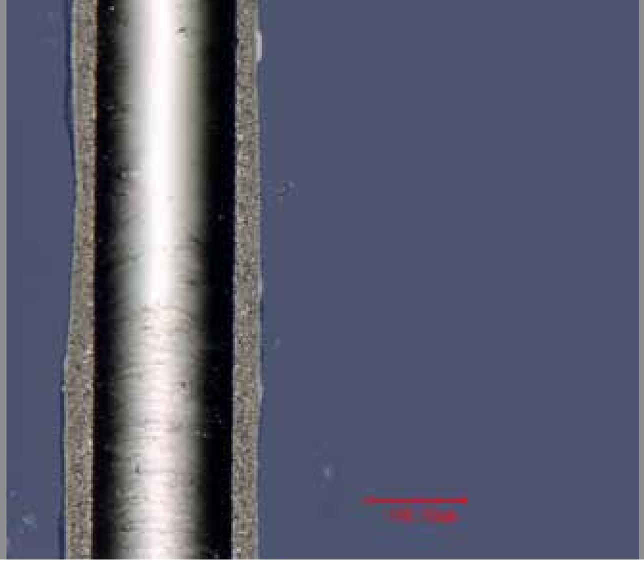
Further information about the IRTG is available online at http://www.zfm.tu-chemnitz.de/irtg

Legend

Fig. 1: Electrical conductivity simulation of a silver/polymer composite, related to the work of Ms. Petra Streit, who is preparing her PhD in the IRTG. (Petra Streit)

Fig. 2: Transmission electron micrograph (TEM) of an ALD copper oxide film integrated with nickel for possible applications in nanoelectronic interconnects and magnetic sensor systems, obtained by Mr. Steve Müller, PhD student in the IRTG. (Steve Müller)

Fig. 3: Summer School of the IRTG taking place at the Key Laboratory for Thin Film and Microfabrication at Shanghai Jiao Tong University.



GESSNER GROUP – A RESEARCH GROUP OF WPI-AIMR IN JAPAN

Joerg Froemel, deputy head of department System Packaging, speaks about his work within the Gessner Group in Sendai/Japan in 2011

During my stay at the WPI-AIMR two main objectives could have been achieved. The scientific focus was on the development of a novel process to bond materials even with a highly different thermal expansion coefficient. Therefore the process temperature needs to be as near as possible to room temperature. Additionally the bond has to be stable at temperatures higher than the initial bonding temperature to allow the application of the technology in useful devices. This can basically be achieved with the solid liquid interdiffusion bonding (SLID). In this technology usually a combination of one material with low temperature melting point and one material with higher melting point is chosen. At temperatures slightly above the melting point of the lower melting point material the much increased diffusion speed will lead to the rapid formation of an alloy and additional intermetallic phases depending on volume ratio. The alloy usually has a much higher melting point than the low melting point material. Up to now material combination with the lowest processing temperature that is in application is based on indium and silver. This combination allows process temperatures just above 141 °C and is known already since a long time with many applications. [1]

The lowest theoretical applicable material combination is gallium and gold slightly above 30 °C. It will form the $AuGa_2$ alloy that has a melting point of 491 °C. Whereas the material system Au/Ga has already been extensively researched [2], there is to our best knowledge no application in micro devices yet. The reason is linked to the difficult process ability of the gallium. Many known processes in micro and nanotechnology cannot be used because of the low melting point of 29.8 °C. Basically three different processes are needed to enable the application: deposition of gallium, micro structuring of gallium and the bonding process itself.

During my stay at the GI3 lab I could successfully develop a deposition process based on electroplating that allows the precise thin film deposition of gallium. With this process layers ranging from several 100 nm to several µm can be realized now. The application in micro devices requires structuring of the gallium thin film within several 10 µm structures. This could be achieved by using patterns of photosensitive polymers (resist) that are applied before the deposition process. Lastly with the deposited and structured thin films the bonding process could be successfully demonstrated at a temperature of 40 °C. With this result the whole needed process chain is available now and the possibility to finally apply the Au/Ga SLID technology in micro devices is within reach. (picture on the next page)

During experiments hints have been found that the even below melting temperature of the gallium extremely high interdiffusion coefficient [3] may lead to a solid-solid interdiffusion bonding that create the $AuGa_2$ alloy without liquid phase. This would be a highly interesting novel technology and requires further investigation. Currently a journal paper is being prepared based on the results of the research work.

Additional to the scientific objective also it was a target of the stay in Sendai to increase the cooperation between the WPI-Advanced Institute for Materials Research and Fraunhofer Institute for Electronic Nano Systems ENAS. As a result on November 8th, 2011, a memorandum of understanding could be signed by WPI-AIMR Director Prof. Yamamoto and Fraunhofer ENAS Director Prof. Gessner in presence of Mayor of Sendai Ms. Okuyama, Fraunhofer President Prof. Bullinger and Tohoku University Executive Vice President Prof. Iijima. It is anticipated to form even more stronger international relation between the two organisations in the future.

During my stay I could acquire many new skills and experiences related to material science, micro technology and Japanese scientific environment.

I would like to thank Prof. Esashi, Prof. Yamamoto and Prof. Gessner for their support and giving me the opportunity to contribute to the research at the excellent WPI-AIMR.

References

[1] L. Bernstein and H. Bartholomew: Applications of solid liquid interdiffusion (SLID) bonding in integrated circuit fabrication. Trans. Metall. Soc. AIME, 236, March (1966), p. 405.

[2] C.J. Cooke, W. Hume-Rothery: The equilibrium diagram of the system gold-gallium. Journal of the Less Common Metals, Volume 10, Issue 1, January 1966, pp. 42 – 51.

[3] V. Simič, Ž. Marinković: Thin film interdiffusion of Au and Ga at room temperature. Thin Solid Films, Volume 34, Issue 1, 4 May 1976, Pages 179 – 183.

About WPI-AIMR

In 2007 the Japanese Government has created so called World Premier International Research Center (WPI) at five excellent universities with the goal to promote outstanding, international visible research. This activity is comparable with the German Exzellenzinitiative. In this framework Prof. Gessner has been invited as a Principal Investigator (PI) from the WPI-AIMR (World Premier International Research Center Initiative – Advanced Institute for Materials Research) of Tohoku University. The group has been build up since the end of 2008. It now consists of 3 permanent stuff members and several visiting scientists and students. The group is managed by assistant Prof. Yu-Ching Lin since November 2008. Within the WPI-AIMR there is close fusion research going on with the group of Prof. Esashi and other research groups.

In 2011 mainly three research topics have been focused on in Gessner Group:

- Metallic glass as a material for semiconductor wafer bonding,
- Nanoporous metals,
- MEMS actuators made from metallic glass.

COOPERATION WITH UNIVERSITIES AND RESEARCH INSTITUTES (SELECTION)

ACREO, Kista, Sweden
Aix-Marseille Universite, CNRS IM2NP, Marseille, France

CEA-LETI, Grenoble, France
CEA-Liten Grenoble, France
Centre Suisse d'Electronique et de Microtechnique (CSEM), Neuchâtel, Switzerland
Centrum für intelligente Sensorik Erfurt e.V., Erfurt Germany
Chemnitz Universtity of Technology, Chemnitz, Germany
Chongqing University, Chongqing, China

Delft University of Technology, The Netherlands
Deutsches Zentrum für Luft- und Raumfahrt e.V., Institut für Kommunikation und Navigation, Wessling, Germany

École Nationale Supérieure des Mines de St-Étienne, France
ESISAR, Institut Polytechnique De Grenoble, Groupe INP Grenoble, Valence, France
ETH Zurich, Switzerland

Femto-ST, Besançon, Frankreich
Forschungszentrum Rossendorf, Germany
Fraunhofer CNT, Dresden, Germany
Fraunhofer EMFT, Munich, Germany
Fraunhofer IAP, Golm, Germany
Fraunhofer IBMT, Potsdam, Germany
Fraunhofer IFAM, Bremen and Dresden, Germany
Fraunhofer IISB, Erlangen, Germany
Fraunhofer IPMS, Dresden, Germany
Fraunhofer ISIT, Itzehoe, Germany
Fraunhofer IWM & CSP, Halle, Germany
Fraunhofer IWS, Dresden, Germany
Fraunhofer IWU, Chemnitz, Germany
Fraunhofer IzfP, Dresden, Germany
Fraunhofer IZM, Berlin and Dresden, Germany
Fraunhofer LBF, Darmstadt, Germany
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
Friedrich-Schiller-Universität, Jena, Germany
Fudan University, Shanghai, China
Fundacao Centros de Referencia em Tecnologias Inovadoras – CERTI, Florianopolis, Brazil

GFaI Gesellschaft zur Förderung angewandter Informatik e.V., Berlin, Germany

Helmholtz-Zentrum Berlin, Germany
Holst Center, Eindhoven, The Netherlands
HTWK, Leipzig, Germany

IMEC, Leuven, Belgium
Institut für Solarenergieforschung Hameln-Emmerthal, Germany

Joanneum Research, Graz, Austria
Johannes Kepler Universität, Linz, Austria
Joseph Fourier University, Grenoble, France

Katholieke Universiteit Leuven, Leuven, Belgium
KIMM, Daejeon, Korea
Konkuk University, Chungju, Korea
Kungliga Tekniska Högskolan KTH, Stockholm, Sweden

Laboratoire d'Electronique, Antennes et Télécommunications, Sophia Antipolis (Nice), France
Leibniz IFW, Dresden and Chemnitz, Germany
Leibniz IHP, Frankfurt/Oder, Germany
Leibniz INP, Greifswald, Germany
Leibniz IOM, Leipzig, Germany
Leibniz IPF, Dresden, Germany
Linköping University, Linköping , Sweden

Massachusetts Institute of Technology, Cambridge/Boston, USA
Max-Planck-Institut (MPI) für Mikrostrukturphysik, Halle, Germany
Mid Sweden University, Sweden
MIRDC, Kaohsiung, Taiwan

NanoTecCenter Weiz, Austria

Royal Institute of Technology, Stockholm, Sweden
RWTH Aachen, Germany

Shanghai Jiao Tong University, Shanghai, China
Sunchon National University, Sunchon, Korea
Swerea IVF, Mölndal (Gothenburg), Sweden

Technische Universität Berlin, Germany
Technische Universität Dresden, Germany
Technische Universiteit Eindhoven, Eindhoven, The Netherlands
Tohoku University, Sendai, Japan
TSINGHUA University, Beijing, China
Tyndall National Institute, Cork, Ireland

Universidade Federal de Pernambuco, Recife, Brazil
Universitat Autònoma de Barcelona CAIAC, Barcelona, Spain
Universität Paderborn, Institut für Elektrotechnik und Informationstechnik, Fachgebiet Sensorik, Paderborn, Germany
Université de Rouen, ESIGELEC, Saint-Etienne du Rouvray Cedex, France
University of Applied Siences Mittweida (FH), Laser Application Center, Germany
University of California, Berkley, USA
University of Nevada, Reno, USA
University of Nice-Sophia Antipolis, France
University Paris Diderot, France
University of Technology Chemnitz, Germany
University of Tokyo, Research Center for Advanced Science & Technology (RCAST) and Department Electrical Engineering (Someya), Tokyo, Japan

VTT Technical Research Centre, Finland

Westsächsische Hochschule Zwickau (FH), Zwickau, Germany

Xiamen University, Xiamen, China

SMART SYSTEMS CAMPUS CHEMNITZ

The Smart Systems Campus Chemnitz is an innovative network with expertise in micro and nano technologies as well as in smart systems integration. This technology park provides renowned scientific and technical centers with entrepreneurial spirit and business acumen and an economic boost at a location where everything is on the spot. A close cooperation of science, applied research and industry is there an everyday reality and reflects a strategy that is being fulfilled.

The partners of the Smart Systems Campus Chemnitz are:

- Chemnitz University of Technology with Institute for Physics, Center for Microtechnologies (ZfM) and Center for Integrated Lightweigth Construction (ZIL),
- Fraunhofer Institute for Electronic Nano Systems ENAS,
- Young companies within the start-up building,
- Companies within the business park.

The Chemnitz University of Technology is the main partner for basic research. The Institute of Physics belongs to the faculty of natural sciences. The research is characterized by an exemplary close intertwining between chemistry and physics. It is reflected particularly in the focused research topics overlapping between both institutes of the faculty.

The Center for Integrated Lightweigt Construction (ZIL) belongs to the Institute of Lightweight Structures of the faculty for mechanical engineering. The scientific work is focused on the development and investigation of integrative plastic processing technologies for the resource efficient manufacturing of lightweight structures and systems. The coupled structure and process simulation together with analytical and numerical methods provide important information for optimized structure and process parameters.

The Center for Microtechnologies (ZfM), founded in 1991, belongs to the faculty of electrical engineering and information technology. It is the basis for education, research and developments in the fields of micro and nanoelectronics, micro mechanics and microsystem technologies in close cooperation with various chairs of different CUT departments.

The ZfM's predecessor was the "Technikum Mikroelektronik" which was established in 1979 as a link between university research and industry. So the Chemnitz University of Technology has had a tradition and experience for more than 30 years in the fields of microsystem technology, micro and nanoelectronics, as well as opto-electronics and integrated optics.

The key of success is the interdisciplinary cooperation of different chairs within the ZfM. The board of directors consists of:

- Chair Microtechnology (Prof. Gessner),
- Chair Microsystems and Precision Engineering (Prof. Mehner),
- Chair Circuit and System Design (Prof. Heinkel),
- Chair Electronic Devices of Micro and Nano Technique (Prof. Horstmann),
- Chair Electrical Measurement and Sensor Technology (Prof. Kanoun),
- Chair Power Electronics and Electromagnetic Compatibility (Prof. Lutz),
- Chair Materials and Reliability of Microsystems (Prof. Wunderle).

Additionally two departments belong to the ZfM, the department Lithograpy/Etch/Mask as well as the department Layer Deposition. The ZfM facilities include 1000 m² of clean rooms, whereby 300 m² of them belong to clean- room class ISO4. Modern equipment was installed for processing of 4", 6" and 8" wafers.

The start-up building for companies related to the sector mentioned before forms an important part of the campus. There is space for approx. 15 start-up companies. In the present time the following companies are working there:

- Berliner Nanotest und Design GmbH (common labs with EUCEMAN, Chemnitzer Werkstoffmechanik GmbH, AMIC Angewandte MicroMesstechnik GmbH, Amitronics GmbH, SEDEMAT GmbH, Clean Technologies Campus GmbH),
- memsfab GmbH, common lab with Leibniz IFW,
- EDC Electronic Design Chemnitz GmbH,
- LSE Lightweigth Structure Engineering GmbH,
- SiMetrics GmbH,
- saXXocon GmbH,
- BiFlow Systems GmbH,
- Turck Duotec GmbH.

The campus does not only open doors for young entrepreneurs in the start-up building, but expanding companies can also make use of neighboring space on a business park. Companies can build their own building according to their requirements on an area measuring up to 7 hectares.

The first company in the park is the 3D-Micromac AG which develops and manufactures highly efficient and innovative machines for laser micro machining. Since October 2011 there is a second building under construction – the microFLEX Center. The building will be rent by 3D-Micromac AG and Fraunhofer ENAS as a common research and production line. The microFLEX Center will be finished end of April 2012.

Currently all partners of the Smart Systems Campus Chemnitz want to transform the campus into a research campus. Thereby alliances with further partners will be established.

smart systems campus
TechnoPark Chemnitz


20th Anniversary of the
Center for Microtechnologies
Fraunhofer ENAS:
Conversion into a Fraunhofer Institute

EVENTS

Photos:
left page: Prof. Dr. Reinhard Baumann welcomes the attendees to the Chemnitz Workshop of the department Printed Functionalities.
right page: In 2011, Dr. Jörg Nestler recieved the first research prize of Fraunhofer ENAS . He is shown together with Prof. Dr. Thomas Gessner (Director of Fraunhofer ENAS).

EVENTS OF THE FRAUNHOFER ENAS

Fraunhofer ENAS opened its doors to the public and to partners

Chemnitz Workshop on Nanotechnology, Nanomaterials, Nanoreliability

Also in 2011 Fraunhofer ENAS organized the Chemnitz workshops on Nanotechnology, Nanomaterials, Nanoreliability. This series started in 2010, managed by the department manager of the Micro Materials Center Chemnitz Prof. Bernd Michel. In 2011 each department organized a special half day workshop with experts from industry and research.

The first workshop took place on March 15th 2011. The department Printed Functionalities had invited Prof. Subramanian, University of California - Berkeley USA, Mr. Slot, Océ Technologies Venlo The Netherlands, Dr. Kirchmeyer, Heraeus Clevios GmbH Leverkusen and Mr. Thiele, printechnologics GmbH Chemnitz.

It was followed by the nano structures related workshop on May 24th organized by department Back-end of Line. Dr. Schwierz from the TU Ilmenau gave a presentation on graphene transistors - status, prospects, and problems. Prof. Dr. Mantl, Forschungszentrum Jülich / JARA focussed on conceps for energy efficient transistors. Dr. Weber from NamLab gGmbH Dresden and Dr. Stephan from GLOBALFOUNDRIES Dresden also belong to the invited speakers of the second workshop in 2011.

The third workshop in 2011 took place on July 8th in Paderborn. It was related to reliability and energy aspects for microelectronics organized by department Advanced System Engineering. It had been held in cooperation with the chair sensor technology of the University Paderborn Prof. Hilleringmann. After a introduction this workshop was splittet into the two topics: energy aspects of the future and reliability of systems. Scientists from Fraunhofer ENAS, from the University Paderborn as well as the partners Infineon Technologie AG Warstein, University Erlangen, Christmann and Continental gave interesting presentations to design, electrical simulation and characterization of micro and nano electronic systems as well as microsystems.

MEMS for biomedical applications was the topic of the fourth workshop on September 22nd organized by the department Multi Device Integration. Prof. Dr. Zengerle from Albert-Ludwigs-Universität Freiburg, Dr. W. Dürr from Siemens AG Erlangen, Dr. Weber from Analytik Jena AG and Mr. Engelke from Bruker BioSpin GmbH Rheinstetten presented actual results.

Reliability test and simulation have been in the focus of the workshop on September 23rd 2011 organized by the department Micro Materials Center. The departmet had invited speakers from industry among them Dr. Hauck, Freescale Halbleiter Deutschland GmbH München, Mr. Schneider, Microelectronic Packaging Dresden GmbH Dresden, Dr. Knechtel, X-Fab Semiconductor Foundries Erfurt and Dr. Shirangi, Bosch Mahle Turbo Systems GmbH & Co KG Stuttgart .

The last workshop in 2011 was focussed on integration concepts and nano effects for wafer level packaging. It was held on November 24th organized by the department System Packaging. They invited Prof. Niklaus from Universität Stockholm, Mrs. Schömbs and Mr. Gabriel from SUSS MicroTec Lithography GmbH, Dr. Rainer Käsmaier from L-Foundry, Mr. Brokmeier from Cassidian Electronics (EADS) and Dr. Hedges from Neotech Services MTP to give presentations.

This series of workshops will be continued in 2012. The presentations will be published within an issue of MICROMATERIALS & NANOMATERIALS, which is a publication series of the Micro Materials Center of Fraunhofer ENAS.

First Research Prize of Fraunhofer ENAS

The researcher Dr. Joerg Nestler got the first research prize of the Fraunhofer Institute for Electronic Nano Systems ENAS for his outstanding scientific work and research in the field of microfluidics.

Dr. Nestler, CEO of BiFlow Systems GmbH, received his doctorate in 2010 at the Chemnitz University of Technology on integrated microfluidic actuators. Together with researchers from the Fraunhofer-Gesellschaft, he worked for several years on a project for the development of a microfludic platform, so-called lab-on-a-chip. The result of this project is a chip card. With this card, for example, blood samples are tested for infectious agents, without any need to send the sample to a laboratory. These analyzes can be used in conflict areas or far away from big cities and metropolitan areas, if there is a need for a rapid diagnosis and treatment of diseases. In a new research project Nestler is working with European and Brazilian researchers on the development of such analytical instruments for tropical disease Chargas, which costs each year some 15,000 lives worldwide, especially in Central and South America.

The Fraunhofer ENAS Research Award will go annually to scientists who can demonstrate excellent results in a research field of microelectronics and microsystems technology.

Days of Industrial Culture in Chemnitz

Within the Days of industrial culture in Chemnitz September 2nd – 4th 2011 at Friday night, manufacturing companies and research institutes opened their doors to the public. Fraunhofer ENAS took part at this event.

More than 105 visitors have been at Fraunhofer ENAS to learn more about microelectronics, micro sensors and smart systems. So the staff of Fraunhofer ENAS showed for instance the Fabry-Perot interferometer, reliability test methods, a smart sealing ring, printing technologies for antennas and batteries as well as high precision inclination and acceleration sensors. Moreover pupils and parents had the possibility to get more information about the apprenticeship in the field of micro technologies annually offered by Fraunhofer ENAS.

Photos:
left page: Prof. Dr. Ulrich Buller, Senior Vice President Research Planning of Fraunhofer-Gesellschaft, speaks at the official ceremony on June 29, 2011.
right page: Prof. Dr. Thomas Gessner with Georg Felsmann and Dagmar Zemke at the vernissage of the art exhibition in the building of Fraunhofer ENAS.

FRAUNHOFER ENAS BECAME A FRAUNHOFER INSTITUTE

2011 - Fraunhofer ENAS became a well established Fraunhofer Institute and the main partner the Center for Microtechnologies of Chemnitz University of Technology celebrated its 20 anniversary

On June 29th 2011 the staff of Fraunhofer ENAS and the Center for Microtechnologies of the Chemnitz University of Technology together with partners, customers and guests celebrated the 20 anniversary of the Center for Microtechnologies after its new foundation in 1991 as well as the conversion of the Fraunhofer Research Institution to the Fraunhofer Institute for Electronic Nano Systems ENAS at the beginning of 2011.

The department managers of Fraunhofer ENAS and the chairs of the ZfM presented current research topics in an anniversary symposium. 260 attendees listened to the presentations in the fields of micro and nanoelectronics, micro- and nanosensors and systems / system integration, energy supply and communication interface for Smart Systems as well as characterization and reliability. An accompanying poster presentation addressed the same topics.

In the evening there was an official ceremony with 360 participants in the city hall of Chemnitz. Guests from Germany and abroad celebrated together with the Fraunhofer researchers and the researches of the Center for Microtechnologies the successful development of both research institutes.

Prof. Buller, Senior Vice President Research Planning of Fraunhofer-Gesellschaft, pointed out, that such a positive development is based on both an excellent management and excellent staff. In the case of Fraunhofer ENAS the positive development bases additionally on the strong cooperation with the Center for Microtechnologies of Chemnitz University of Technology.

Dr. Hasenpflug, Saxon State Ministry of Science and Art SMWK, stated that the success is based also on the intensive cooperation with industry of both research institutes as well as the transfer of research results in new products and services.

Prof. Matthes – the former President of the Chemnitz University of Technology, pointed out that the strategic alliance between the Center for Microtechnologies ZfM and the Fraunhofer Institute for Electronic Nano Systems ensures synergies in the technology and system development. The ZfM's predecessor was the "Technikum Mikroelektronik" which was established in 1979 as a link between university research and industry. So the Chemnitz University of Technology has has a tradition and experience for more than 30 years in the fields of microsystem technology, micro and nanoelectronics, as well as opto-electronics and integrated optics. He addressed especially the projects network of excellence nanett, the international research training group „Materials and Concepts for Advanced Interconnects and Nanosystems" as well as the DFG Research Unit 1713 „Sensoric Micro and Nano Systems".

The series of speakers had been completed by Prof. de Albuquerque – the former head of the department micro and nano systems of the European Commission, Ms. Ludwig – the Lord Major of the City of Chemnitz, Prof. Neugebauer – the Director of Fraunhofer IWU Chemnitz, Prof. Reichl – the former director of Fraunhofer IZM Berlin, Ms. Eckstein from GLOBALFOUNDRIES and Dr. Marek from Robert Bosch GmbH.

SCIENCE MEETS ARTS

The Art Exhibitions within the building of Fraunhofer ENAS have been continued

The Fraunhofer ENAS goes on with the series of art exhibitions titeled "Science Meets Arts" in 2011. The institute invites two local painters to exhibit their paintings and printmaking in the building of Fraunhofer ENAS. In 2011, the first event in the series was the gallery talk with Christian Lang. The Chemnitz painter started his exhibition in October 2010. The gallery talk completed the exhibition with giving the opportunity to employees and guests to meet and get into a dialog with the artist.

The first vernissage of the year had Steffen Volmer in May. He showed works from the last 20 years. Many guests and employees took this occasion to attend and speak with this famous painter. Anja Richter from the Kunstsammlungen Chemnitz held the encomium of the evening. In September, Steffen Volmer talked about his works, topics and techniques during a gallery talk. The talk ended with a tour through the exhibition guided by the painter.

The first female artist is shown in the exhibition since November 2011. It is the Chemnitz painter Dagmar Zemke. She presents paintings of women and themes from Asia.

We want to express our thanks to Georg Felsmann who strongly supports us in organizing the exhibition and the cooperation with the painters.

Photos:
left page: Attendees of the SSI 2011 discuss during the poster session.
right page: The WaferBond `11 in Chemnitz welcomed about 100 guests from 15 countries worldwide.

FRAUNHOFER ENAS AT EVENTS

In 2011 the Fraunhofer ENAS attended and organized various events, conferences and trade fairs all around the world.

Smart Systems Integration SSI 2011 in Dresden, Germany

The fifth SMART SYSTEMS INEGRATION, European Conference and Exhibition on Integration Issues of Miniaturized Systems took place from 22 to 23 March 2011 in Dresden Germany. It closed with a significant plus of participants of 23%. 303 experts from 21 countries (Europe, USA, Asia, Africa) met to exchange experiences in 18 sessions.

"We have held an extremely successful conference in the field of smart systems integration in Dresden, Germany. Internationally, in the US, in Japan and in Europe generally the topics of microsystem technology and the system integration will be key technologies in several application areas. Globally acting companies presented the latest system developments, also the representatives of the small and medium-sized enterprises introduced successful developments. Nevertheless it has become clear that the significance of smart systems integration needs to be fostered within the German support policies", said Prof. Gessner, head of the Fraunhofer Institute ENAS and chairman of the SMART SYSTEMS INTEGRATION.

At the accompanying exhibition 25 exhibitors and 16 publishers from Germany, Switzerland, Belgium, France, United Kingdom and Italy presented themselves to a broad target group of stakeholders, industry representatives and scientists.

The 5th Smart Systems Integration conference SSI2011 addressed application as well as basic aspects and showed a snap shot of the European work on this field. Special emphasis was given to best practice examples in the EPoSS session on the first day as well as in the other application oriented session on the second conference day. In order to develop and to manufacture reliable, multifunctional, energy autonomous smart systems it is necessary to develop and evaluate technologies, materials, designs, components, packaging and integration as well as the whole systems. To integrate different components 3D integration is a hot topic worldwide. A special workshop gave an overview about this topic. First time there was a session dealing with cooperation with East-European countries.

The smart systems integration conference is part of the activities of EPoSS - the European technology Platform on Smart Systems Integration. Starting from 2012 the conference will be an international one.

The global demand for highly integrated smart systems will increase dramatically in the next years. High growth rates are particularly expected in the area of medical technologies, mobility and security, and in the consumer and communication sector. The need for higher resource efficiency, reduction of emissions and the increasing demand for "portable" solutions will further stimulate the smart systems market. The high added value of smart systems manufacturing make this technology particularly attractive.

Review Waferbond '11 – International Conference on Wafer Bonding for MEMS technologies and Wafer Level Integration

The WaferBond '11 took place in Chemnitz, Germany organized by Fraunhofer ENAS from 6th to 8th December 2011. It was the fifth event in a row and attracted about 100 researchers from science and industry. The attendees came from over 15 countries worldwide, e.g. USA, Japan, China, and almost 10 European countries. From 49 contributions 27 oral presentations and 15 posters were shown. Every session was introduced by an excellent keynote presentation held by experts on the field of wafer bonding e.g. Kevin Turner (USA), Tatadomo Suga (Japan), and Matthias Petzold (Germany).

The conference is focused on industrial components, integration of wafer bonding into MEMS fabrication, process developments of wafer bonding techniques and addresses as well quality and reliability issues. Next to the state of the art in science presented by research organizations and universities also the industrial relevance was recognized by global players like Bosch, EPCOS, Fresenius.

Furthermore the conference was friendly supported by companies like PVATepla, Endress und Hauser, AML, EVGroup, SUSS microtec, Brewer Science, Soitec, nanotec, and X-FAB. The chair of the conference, Roy Knechtel said, that there is a quite qualified and interesting community focused on wafer bonding technologies and he was impressed by the relaxed atmosphere and the chats and talks beside the presentations. His goal of a networking event was totally reached.

Guests and participants were absolutely surprised by the surrounding activities, organized by Fraunhofer ENAS. Especially the pre-evening reception at the Kunstsammlungen Chemnitz with a guided tour through the Renior exhibits found high fascination. After the first conference day the sociall event and networking evening took place at one of the most beautiful castle in Saxony "Augustusburg". There the guests were taken by the elector August of Saxony into the middle of the 16th century and the long day found its end.

Maik Wiemer, organizing co-chair, from Fraunhofer ENAS said, that it was a great opportunity to organize the conference and got some reputation and publicity for the 2 years young Fraunhofer Institute for Electronic Nano Systems in Chemnitz. The next conference will take place in Stockholm 2013 and will be organized by KTH Stockholm Frank Niklaus. More information can be found on the conference web-site: www.microtesting.de.

Review MAM 2011 – 20th European Workshop „Materials for Advanced Metallization" held together with the 14th International Interconnect Technology Conference (IITC)

From May 9th to May 12th the 20th MAM took place in Dresden. For the first time the conference was co-organized with the IITC - the International Interconnect Technology Conference. General Chairs of the joint conference were Prof. Stefan E. Schulz (Fraunhofer ENAS / TU Chemnitz) and Prof. Ehrenfried Zschech (Fraunhofer IZFP). More than 300 participants from industry, research institutes and academia visited this common event. The conferences addressed mainly interconnect topics in the "More Moore" area but also some "More than Moore" subjects. Dedicated sessions addressed Back-End Memories, Power and Automotive Interconnects as well as Chip-Package Interaction.

Photos:
left page: impressions from the status workshop nanett
right page: signed memorandum of understanding

4th MicroCar Conference organized by the Micro Materials Center of Fraunhofer ENAS: Innovations in Electro Mobility and Clean Microtechnologies join the Discussion

MicroCar - the conference series on micromaterials, nanomaterials for automotives - was held for the 4th time in Leipzig, Germany, on March 1, 2011.

To the new topics of the 4th conference belong perspectives on how innovations in micro and nanotechnologies drive the market for electro mobility and Clean Microtechnologies (green microtechnologies). As a more traditional topic of MicroCar, the conference again focused on new developments in micro and nano materials, and what they meant for automotive electronics in particular. Especially solutions for reliability, lifetime and safety issues, were addressed by presentations, workshops and poster discussions.

The list of speakers included members from well-known automotive industry and electronics manufacturers, such as BMW, Daimler, VW, Bosch, Infineon, Globalfoundries and Siemens, as well as renowned scientists from the Fraunhofer Gesellschaft, universities and colleges. However, the MicroCar Conference is also a forum for small and medium-sized businesses, which add valuable contributions as suppliers, and often have been the driving force of change.

About 70 conference papers are published in issue 13 (2011) of the "Micromaterials and Nanomaterials" publication series which is regularly issued by Fraunhofer ENAS in cooperation with EUCEMAN – the European Center for Micro- and Nanoreliability.

Status Workshop of the network of excellence NANETT in Chemnitz, Germany

On November 3, 2011 the second status workshop of the nano system integration network of excellence – nanett – took place at the Chemnitz University of Technology. After two years of intensive collaborative research within the network the scientists presented their latest results to more than 120 participants from science and industry. Beside the summarizing talks of the three flagship projects 28 poster presentations gave the opportunity to inform oneself in detail about the research .

Nanett is one of the successful initiatives of the second phase of the "Spitzenforschung und Innovation in den Neuen Ländern" program, funded by the Federal Ministry of Education and Research (BMBF).

Beside the four involved working groups of Fraunhofer ENAS (Process Integration, Metrology, MEMS/NEMS Design, Optical and Nanocomposite-based Systems) four faculties of the Chemnitz University of Technology (Faculty of Electrical Engineering and Information Technology, Faculty of Natural Sciences, Faculty of Mechanical Engineering and Faculty of Computer Science), the University of Applied Sciences Mittweida, two further Fraunhofer Institutes (Fraunhofer IZM and Fraunhofer IAP), three Institutions of the Leibniz Association (IHP, IFW and IPF) and the Helmholtz Zentrum Berlin (HZB) are linked in the nano system integration network of excellence.

7th Fraunhofer-Gesellschaft Symposium in Sendai, Japan

Within the "German – Japanese Micro/Nano Applied Technology Symposium" the 7th Fraunhofer Symposium in Sendai was held. The president of Fraunhofer-Gesellschaft and Fraunhofer Institutes presented their latest activity in MEMS research. The symposium took place November 8th 2011.

The Fraunhofer Symposium is an event which has already been well established. It is an event, which has been designed to give an overview of the latest developments in smart systems integration of micro electronics and micro system technologies. This event has attracted scientists and researchers from all over Germany and Japan. In 2011 Fraunhofer ISE, Fraunhofer IPMS, Fraunhofer IZFP, Fraunhofer IWM and Fraunhofer ENAS have presented recent developments in energy supply from renewable sources, smart systems integration, organic semiconductors, nano science, high-resolution microscopy as well as system reliability and failure analysis.

On November 8th WPI-AIMR concluded a Memorandum of Understanding on academic exchange with the Fraunhofer Institute for Electronic Nano Systems. The agreement was signed between Yoshinori Yamamoto (Director, WPI-AIMR) and Thomas Gessner (Director, Fraunhofer ENAS), Georg Rosenfeld (Division Director of the corporate Development, Fraunhofer-Gesellschaft) in the presence of Emiko Okuyama (Mayor of Sendai) and Hans-Jorg Bullinger (President, Fraunhofer-Gesellschaft), Toshio Iijima (Executive Vice President, Tohoku University), the other persons concerned at the signing ceremony held in Sendai.

Continuation of Representatives Office of the Fraunhofer ENAS in Manaus, Brazil

On 23 July 2011 Ms. Flavia Skrobot Barbosa Grosso (Superintendentin of the free trade zone of Manaus - SUFRAMA) and Prof. Dr. Thomas Gessner (Director of the Fraunhofer ENAS) signed a mutual cooperation agreement.

Already since 2007, Fraunhofer ENAS maintains an office in Manaus, Brazil. With the signing of the agreement this status is extended for another two years.

In 2006 and 2008, the Fraunhofer ENAS assisted SUFRAMA in organizing the technology seminar MINAPIM. The third MINAPIM took place from 26th – 28th October 2011 in Manaus co-organized by Fraunhofer ENAS.

The office in Manaus supports Fraunhofer ENAS in project acquisition and project management on site. Beginning in September 2011, a European-Brazilian consortium led by the Fraunhofer ENAS will jointly develop an on-site test which allows the quick and reliable detection of an infection with the pathogen Trypanosoma cruzi. This chagas disease belongs to the top 20 of the most "neglected" diseases. This has been stated by the World Health Organization. More than ten million people suffer from the infection, most of them in Latin America and one fifth thereof, in Brazil. The project "Technology platform for point-of-care diagnostics for tropical diseases" (EU-FP7-287 770) will have a duration of 2.5 years. As a technology platform, the system can later be used for other tropical diseases.

Fraunhofer ENAS Trade Fair Activities 2011

In 2011 Fraunhofer ENAS presented its manifold activities at 17 tradeshows and exhibitions in Germany and abroad. Fraunhofer ENAS took part in six international trade fairs in Japan, China, USA, and France and presented its research results at six accompanying exhibitions of conferences. Fraunhofer ENAS visited one trade fairs in the USA together with two partners from the industry, GEMAC and InfraTec Dresden GmbH.

The nano tech exhibition in Tokyo/Japan was the first fair of the year for Fraunhofer ENAS. We showed technologies and components together with the Gessner group of the WPI-AMIR in Sendai/Japan and GEMAC- Gesellschaft für Mikroelektronikanwendung Chemnitz mbH.

The departement Advanced System Engeneering presented the Near-Field Scanning System in cooperation with Magh und Boppert GmbH at the EMV in Stuttgart. The SUPA technology achieved high attention at the CeBIT in Hannover. Together with the project partner Euskirchen Manufaktur and with Fujitsu, the department demonstrated the SUPA technology energizing wirelessly a monitor on a conference table.

The worldwide biggest industrial fair, the HANNOVER MESSE, took place in April 2011. Fraunhofer ENAS presented the project ASTROSE at the "IVAM Produktmarkt . In the project a self-creating sensor network is developed for monitoring the condition and capacity of power lines. The project partners are Fraunhofer IZM, Center for Microtechnologies of the Chemnitz University of Technology, enviaM, amprion and other.

At the fair SENSOR+TEST in Nuermberg, the institute showed an high-temperature stable vacuum sensor. The international trade fair for sensors, measuring and testing technologies showed a complete and interdisciplinary overview about the entire spectrum of measuring and testing systems expertise.

Fraunhofer ENAS presented together with GEMAC and InfraTec Dresden current sensor systems at the Sensors Expo and Conference in Rosemont, Illinois, USA. The research partners showed an IR detector based on Fabry-Perot interferometer for gas analysis and inclination sensors.

The Fraunhofer institutes working in the European CleanSky project shared one booth at the SIAE 2011 in Paris. Here they presented the project progress and some results like synthetic and pulsed jet actuators and the microDAC, a optical deformation measurement method.

The LOPE-C is one of the most important platforms for the department Printed Functionalities. The department exibited printed batteries, antennas and actual activities for roll-to-roll processes.

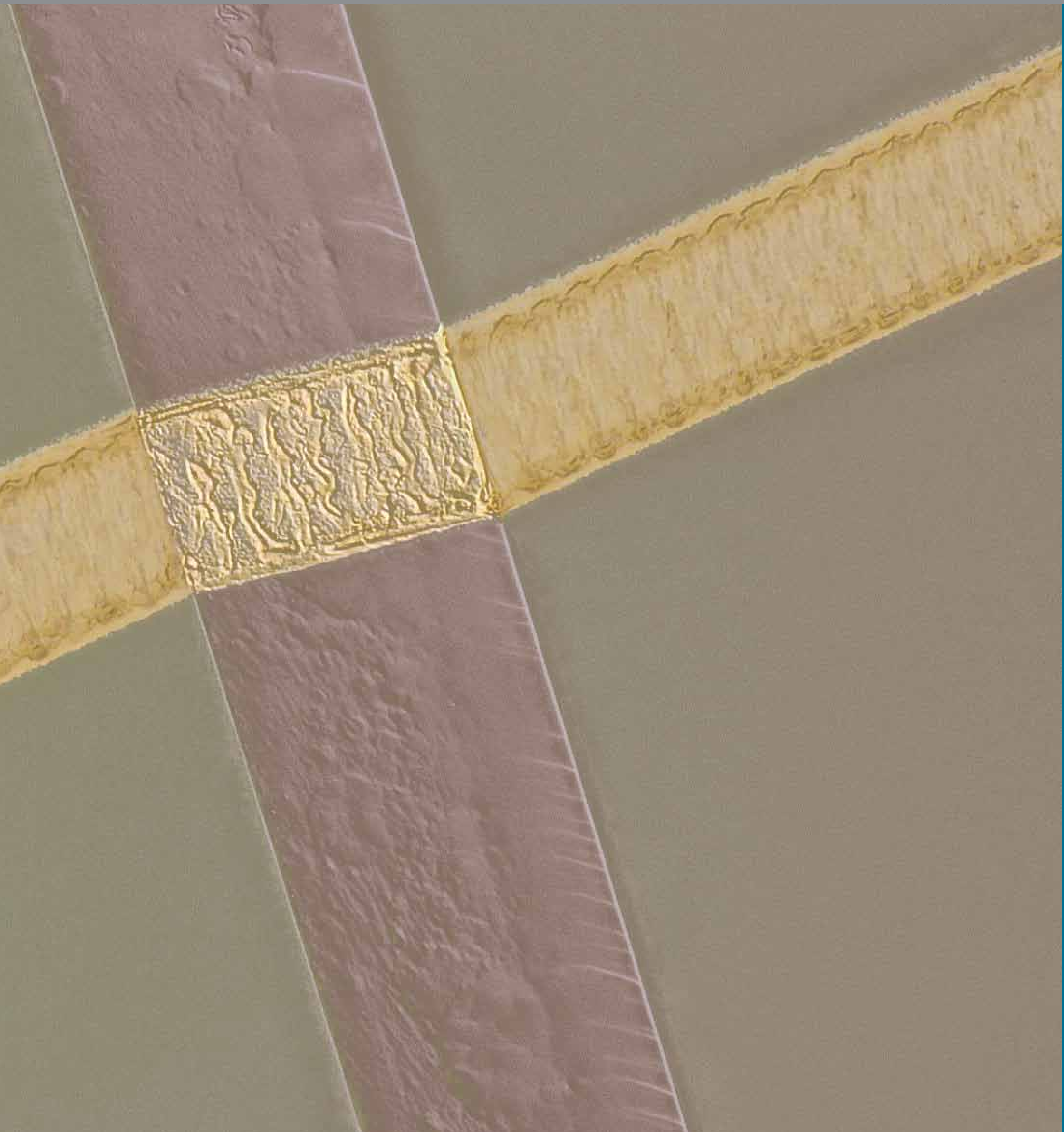
The second visited trade fair in Japan in 2011 was the exhibition Micromachine/MEMS in Tokyo. Fraunhofer ENAS presented new developments in the fields of MEMS and wafer level packaging for MEMS.

In October 2011 the SEMICON Europa took place in Dresden again. The booth of Fraunhofer ENAS was localed together with the booth of the Fraunhofer Group Microelectronics within the Science Park. The focus of the exhibits of Fraunhofer ENAS was on technologies for Back-end of Line and waferbonding as well as on carbon nanotubes.

In parallel, the institute attended the Mikrosystemtechnik-Kongress in Darmstadt with some conference talks and an own booth at the exhibition.

FRAUNHOFER ENAS PARTICIPATION IN TRADE FAIRS 2011

February		
	nano tech 2011 – International Nanotechnology Exhibition & Conference	Tokyo, Japan
March		
	CeBIT	Hannover, Germany
	Silicon Saxony Day	Dresden, Germany
	EMV – International Exhibition with Workshops on Electromagnetic Compatibility	Stuttgart, Germany
	SEMICON China	Shanghai, China
	SMART SYSTEMS INTEGRATION 2011 – European Conference & Exhibition	Dresden, Germany
April		
	HANNOVER MESSE 2011 - MicroNanoTec	Hannover, Germany
May		
	MAM/IITC – Materials for Advanced Metallization and the 14th International Interconnect Technology Conference	Dresden, Germany
	SENSOR+TEST 2010 – The Measurement Fair	Nuermberg, Germany
June		
	Sensors Expo & Conference	Rosemont, USA
	SIAE 2011 – International Paris Air Show	Paris le Bourget, France
	LOPE-C – Large Area, Organic & Printed Electronics Convention	Frankfurt/Main, Germany
	Nanotech Conference & Expo 2011	Boston, USA
July		
	Exhibition Micromachine/MEMS 2011	Tokyo, Japan
September		
	4th NRW Nano-Conference 2011	Dortmund, Germany
October		
	Mikrosystemtechnik-Kongress	Darmstadt, Germany
	SEMICON Europa 2011	Dresden, Germany



FACTS AND FIGURES

FRAUNHOFER ENAS IN FACTS
FRAUNHOFER ENAS IN ZAHLEN

Human Resources Development

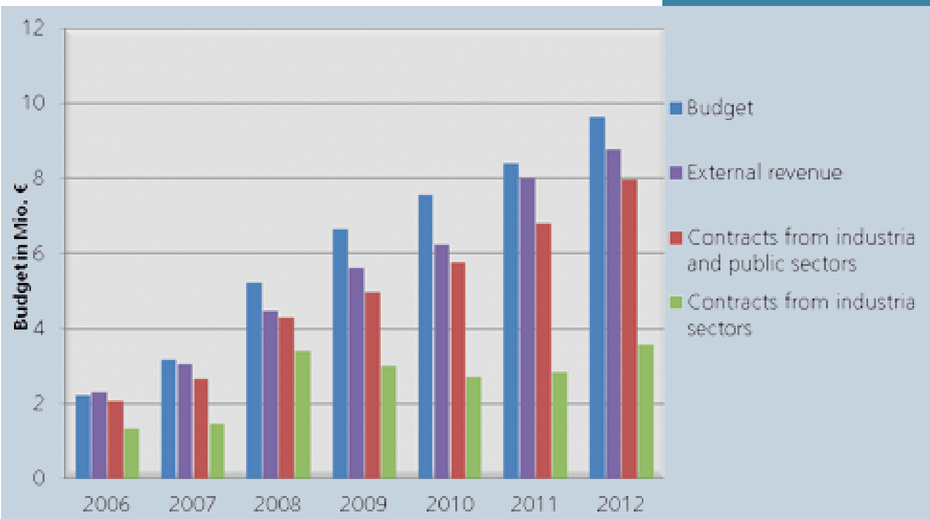
Due to the increase of turnover, the staff level of Fraunhofer ENAS increased in 2011. Overall, 11 employees joined the team, bringing the total staff at Fraunhofer ENAS in Chemnitz and Paderborn to 102 at the end of 2011. Fraunhofer ENAS offers job training as micro technologist. Currently there are five trainees employed.

The institute also supports students with the opportunity to combine their studies with practical scientific work in the laboratories and offices of Fraunhofer ENAS. On an annual average 40 interns, undergraduates and students assistants were working.The latter are proving to be a growing source for coming new scientists and technicians.

Personalentwicklung

Basierend auf der Steigerung der Erträge erhöhte sich 2011 der Personalbestand des Fraunhofer ENAS. Es wurden 11 Neueinstellungen vorgenommen, sodass zum Jahresende 102 Mitarbeiterinnen und Mitarbeiter an den Fraunhofer ENAS Standorten Chemnitz und Paderborn beschäftigt waren. Fraunhofer ENAS bildet seit 2009 Mikrotechnologen aus. Zurzeit befinden sich fünf Mikrotechnologen in der Ausbildung.

Zusätzlich bietet das Institut Studentinnen und Studenten die Möglichkeit, ihr Studium mit praktischer wissenschaftlicher Arbeit in den Büros und Laboratorien des Fraunhofer ENAS zu kombinieren. Im Jahresdurchschnitt wurden 40 Praktikanten, Diplomanden und studentische Hilfskräfte betreut. Dieser Mitarbeiterstamm erweist sich in wachsendem Maße als Quelle für den Nachwuchs von Wissenschaftlern und Technikern.



Financial Status, Equipment and Laboratory Investment

Within 2011, the Fraunhofer ENAS reached a clearly increased revenue of external funds of 7.98 million Euros with a reduced operating budget of 8.41 million Euros. The revenue quota is excellent with 94.9 per cent. Contracts from German and international industry and trade associations reached just 2.84 million Euros, or in other words almost 34.2 per cent of the total operating budget.

Own equipment investment of 0.6 million Euros was realized in 2011. Additionally 0.9 million Euros have been invested as basic equipment for the building and special financing.

Finanzielle Situation und Geräteinvestition

Im Jahr 2011 erzielte das Fraunhofer ENAS bei einem reduzierten Betriebshaushalt von 8,41 Millionen Euro deutlich gestiegene Drittmittelerträge von 7,98 Millionen Euro. Die Ertragsquote liegt damit bei exzellenten 94,9%. Die Aufträge aus deutschen und internationalen Industrieunternehmen erreichten eine Summe von 2,84 Millionen Euro, was einem Industrieanteil am Betriebshaushalt von 34,2 % entspricht. Die eigenen Geräteinvestitionen im vergangenen Jahr betrugen 0,6 Millionen Euro. 0,9 Millionen Euro wurden für die Erstausstattung des Gebäudes bzw. Sonderfinanzierung investiert

MEMBERSHIPS (SELECTION)

MEMBERSHIPS OF FRAUNHOFER SCIENTISTS

acatech (Council of Technical Sciences of the Union of German Academies of Sciences)	Prof. T. Gessner	member
Academy of Sciences of Saxony, Leipzig, Germany	Prof. T. Gessner	member
Academy of Sciences, New York, USA	Prof. B. Michel	member
Advanced Metallization Conference AMC, Sematech, USA	Prof. S. E. Schulz	member of the executive committee
Arnold Sommerfeld Gesellschaft zu Leipzig	Prof. B. Michel	scientific advisory board
Board of "KOWI", Service Partner for European R&D funding, Brussels, Belgium	Prof. T. Gessner	member
Deutscher Verband für Schweißen und verwandte Verfahren e. V.	Dr. M. Wiemer	chairman AG A2.6 „Waferbonden"
Digital Fabrication Conference (DF) of IS&T	Prof. R. R. Baumann	conference chair, chair steering team
Dresdner Fraunhofer Cluster Nanoanalytics	Dr. S. Rzepka	steering committee member
Engineering and Physical Science Research Council, UK	Prof. B. Michel	referee
EPoSS (European Platform on Smart Systems Integration)	Prof. T. Gessner	member of the steering group
European Center for Micro- and Nanoreliability (EUCEMAN)	Prof. B. Michel Dr. S. Rzepka Prof. B. Wunderle J. Hussack	president committee member committee member committee member
EuroSimE, Bourdeaux, France	Prof. B. Wunderle Dr. R. Dudek	members of the conference committee
German Science Foundation	Prof. T. Gessner	referee
Humboldt Foundation	Prof. B. Michel	referee
International Conference on R2R Printed Electronics (Asia)	Prof. R. R. Baumann	advisory committee
International Conference ICEPT, Shanghai, China	Dr. J. Auersperg	technical committee member

International Conference IPTC, Singapore	Dr. J. Auersperg	technical committee member
International Symposium for Flexible Organic Electronics (IS-FOE)	Prof. R. R. Baumann	advisory board
International Symposium Technologies for Polymer Electronics TPE	Prof. R. R. Baumann	advisory committee
International Young Scientists Conference Printing Future Days	Prof. R. R. Baumann	general chair
ITherm Conference	Prof. B. Wunderle	program committee member
KOMINAS	Prof. T. Gessner	member
Large-area, Organic and Printed Electronics Convention LOPE-C	Prof. R. R. Baumann	advisory board, scientific chair
Materials for Advanced Metallization MAM	Prof. S. E. Schulz	member of scientific program committee
MEMS Industry Group, Executive Congress Europe 2012	Dr. M. Vogel	committee member
MicroCar 2011 Conference	Dr. S. Rzepka Prof. B. Michel	conference chairs
Microsystems Technology Journal	Prof. B. Michel	editor-in-chief
National Research Agency, France	Prof. B. Michel	referee
Nanotechnology Conferences, NSTI, USA	Prof. B. Michel	reliability track chairman
Organic Electronics Association (OE-A)	Prof. R. R. Baumann	member of the board
Senatsausschuss Evaluierung der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (WGL)	Prof. T. Gessner	member
SEMICON Europa	Prof. T. Gessner Dr. M. Vogel	program committee members of MEMS conference
Smart Systems Integration Conference	Prof. T. Gessner Prof. T. Otto Prof. B. Michel Dr. C. Hedayat Dr. K. Hiller	conference chair members of program committee

MEMBERSHIPS OF FRAUNHOFER ENAS

Silicon Saxony e.V.
Cool Silicon e.V.
International Association of Companies and Institutes in the Field of Microtechnology, Nanotechnology and Advanced Materials IVAM
Nano Technology Center of Competence "Ultrathin Functional Films"
European Center for Micro and Nano Reliability EUCEMAN
European Platform on Smart Systems Integration EPoSS
Organic Electronics Association OE-A
Organic Electronics Saxony e.V. OES
MEMS Industry Group™ in USA

PATENTS

Patent Applications and Publication:

Title: Sensormodul und Verfahren zum Herstellen eines Sensormoduls
Country: DE Patent Number: DE 102011001 422.5-54
Date of Application: March 21, 2011

Title: Mikromechanisches Bauteil zum elektrisch gesteuerten Verbinden und Unterbrechen eines Signalpfades
Country: TW Patent Number: TW 100116686
Date of Application: May 12, 2011

Title: Flexibles mikrofluidisches System
Country: DE Patent Number: DE 102010061910.8
Date of Publication: May 31, 2011

Title: Permanent beschreibbares Photolumineszenz Quantum Dot Display
County: DE Patent Number: DE 102011076535
Date of Application: May 26, 2011

Title: Mikromechanisches Bauteil zum elektrisch gesteuerten Verbinden und Unterbrechen eines Signalpfades
Country: US Patent Number: US 13/155,002
Date of Application: June 7, 2011

Title: Mikromechanisches Bauteil zum elektrisch gesteuerten Verbinden und Unterbrechen eines Signalpfades
Country: CN Patent Number: CN102290289A
Date of Application: June 13, 2011

Title: Galvanische Nanoschichtsysteme für Fügeverfahren in der Mikrosystem- und Sensortechnik
County: EP Patent Number: EP 10708091.3-2203
Date of Application: July 7, 2011
Date of Publication: November 2, 2011

Title: Abstimmbares Fabry-Perot-Filter und Verfahren zu seiner Herstellung
Country: EP Patent Number: PCT/EP2011/061610
Date of Application: July 8, 2011

Title: Erzeugung einer Zwischenschicht-nanostruktur mit Kohlenstoff-nanoröhren und Anwendungsfälle
Country: DE Patent Number: DE 2011051705.7
Date of Application: July 8, 2011

Title: Inertialer Wecker
Country: PCT Patent Number: PCT/IB2011/053913
Date of Application: September 7, 2011

Title: RFID-Antennenstrukturen
Country: DE Patent Number: DE 202011105148.3
Date of Application: September 30, 2011

Title: Möbelbauteil für Stromversorgung
Country: PCT Patent Number: PCT/DE2011/001805
Date of Application: October 6, 2011

Title: Vorrichtung zur effizienten Energieübertragung mit hoher Frequenz
Country: DE Patent Number: DE 1020111157216
Date of Application: October 12, 2011

Title: Fluidischer Aktor mit verformbarer Membran und langer Lagerfähigkeit
Country: PCT Patent Number: PCT/EP2011/070061
Date of Application: November 14, 2011

Title: Mikrofluidisches System mit Temperierung
Country: PCT Patent Number: PCT/EP2011/070664
Date of Application: November 22, 2011

Title: Flexibles mikrofluidisches System
Country: PCT Patent Number: PCT/EP2011/070788
Date of Application: November 23, 2011

Title: Metallischer Trägerkörper mit Transponder
Country: DE Patent Number: DE 102011087928.5
Date of Application: December 7, 2011

Title: Mikromechanisches Bauteil zum elektrisch gesteuerten Verbinden und Unterbrechen
Country: EP Patent Number: EP 10401078
Date of Application: December 14, 2011

Patent Grants:

Title: Galvanische Nanoschichtsysteme für Fügeverfahren in der Mikrosystem- und Sensortechnik
Country: DE Patent Number: DE 102009006822B4
Date of Patent: March 21, 2011

Title: Herstellung dünner Schichten von Kupferoxid und Kupfer mittels Atomic Layer Deposition
Country: DE Patent Number: DE 10 2007 058 571.5
Date of Patent: October 1, 2011

Photo:
Volker Geneiss, Fraunhofer ENAS, presents the SUPA technology at the Fraunhofer Symposium Netzwert in November 2011.

Photo:
Prof. Dr. Karla Hiller with Prof. Dr. Klaus-Jürgen Matthes (President of the Chemnitz University of Technology) and Prof. Dr. Thomas Gessner (Director ZfM and Fraunhofer ENAS).

AWARDS IN 2011

SUPA – Smart UniversalPower Antenna

Recharging a mobile phone by simply putting it on the table? Or supplying the electric car in a parking box with new energy without any cable while you go shopping? This all sounds like a vision, but this vision becomes reality. The Paderborn department Advanced System Engineering of the Fraunhofer Institute for Electronic Nano Systems ENAS has developed the SUPA technology for wireless energy and data transmission.

At the design competition Fraunhofer Venture 10 groups had been elected from 100 candidates for the next round. These 10 groups were able to present their ideas to the jury. In only three minutes Christian Hedayat, Maik-Julian Buker and Volker Geneiß had to present the innovative approach to the members of the Fraunhofer Venture and Venture Capital investors. They used small cubes. When they put them on the table, the cubes were lighted showing that the SUPA technology (Smart Universal Power Antenna) really works.

The principle of electrical induction forms the basis for supplying the devices with power: This means that the transmitting and receiving units are both very flat coils. The electric modules can be manufactured on carrier material that can be as little as 125 µm thick and integrated into the wooden structure. The transmitting unit is installed seamlessly into or below the surface. The unit uses an antenna structure to transmit both power and data to the end device, such as a smartphone or notebook, which must be equipped with a SUPA-compatible receiver.

The decisive challenge is to design the infrastructure in such a way that the complete surface of the furniture can be supplied with the necessary power or data. Current solutions usually require that the devices be placed at a defined location to ensure that enough power flows. With SUPA, however, users will be able to place their end devices anywhere on the table and they will be guaranteed to receive a power supply.

As well as banishing miles of cables from the conference room, the SUPA technology promises other benefits. “By directing the transmitting antennas intelligently, electromagnetic emissions can be reduced drastically,” explains Maik-Julian Büker from Fraunhofer ENAS. The scientists have deliberately minimized the range for data and energy transmission to about 5 cm. On the one hand this ensures very low exposure to radiation, and on the other it makes data networks less susceptible to interception. The 2–10 GHz broadband antennas needed for data transmission are integrated into the transmission structure. There are also some savings to be made in supplying buildings with power and data, as several user units can be supplied with a single power and data cable.Fraunhofer ENAS and the participating industrial partners are currently carrying out comprehensive market surveys to establish SUPA commercially – the best approach to ensuring that cables soon disappear from the conference room table. Sitting at a wired-up table will soon be a thing of the past.

- Universal Design Award 2011 for the furniture system “Tension powered by SUPA“
- Consumer Favorit 2011: 100 people of different age and professions formed the consumer jury. To be awarded a positive voting of 75 per cent is neccessary.
- 1st prize of the Fraunhofer Venture Ideenwelten 2011: .
- Nomination for the Designpreis Deutschland 2012: This award is the highest German Design award.
- 2nd prize of the entrepreneur-camp OWL 2011
- 1st prize of the Ideenwettbewerb Fraunhofer Netzwert 2011

PHD / APPOINTMENTS IN 2011

PhD

May 20, 2011

PhD:	Hendrik Specht
Topic:	MEMS Laser Display System: Analysis, Implementation and Test Procedure Development
Institution:	Chemnitz University of Technology

September 19, 2011

PhD:	Sascha Hermann
Topic:	Growth of carbon nanotubes on different support/catalyst systems for advanced interconnects in integrated circuits
Institution:	Chemnitz University of Technology

Appointments

On August 31th 2011 Dr.-Ing. habil. Karla Hiller got an appointment as an extraordinary professor of the faculty for electrical engineering and information technology of the Chemnitz University of Technology. Within a special workshop of the faculty she gave a presentation about micromechanical gyroscopes - overview, design, technologies, projects and results in Chemnitz.

Prof. Karla Hiller is the deputy director of the Center for Microtechnologies of the Chemnitz University of Technology. Her scientific work focusses on high precision silicon based MEMS. Prof. Karla Hiller lectures technology of micro and nano systems at the Chemnitz University of Technology.

LECTURES

Chemnitz University of Technology

Process and Equipment Simulation
Lecturers: Prof. Dr. T. Gessner, Dr. R. Streiter

Advanced Integrated Circuit Technology
Lecturers: Prof. Dr. S. E. Schulz, Dr. R. Streiter

Microelectronics Technology
Lecturers: Prof. Dr. T. Gessner, Prof. Dr. S. E. Schulz, Dr. R. Streiter

Mikrotechnologie
Lecturers: Prof. Dr. T. Gessner, Dr. C. Kaufmann, Dr. A. Bertz

Microoptical Systems
Lecturer: Prof. Dr. T. Otto

Technology of Micro and Nano Systems
Lecturers: Prof. Dr. T. Gessner, Dr. K. Hiller

Technologien für Mikro- und Nanosysteme
Lecturers: Prof. Dr. T. Gessner, Dr. K. Hiller

Prüftechnik Mikrosystemtechnik
Lecturer: Dr. S. Kurth

Micro- and Nanoreliability
Lecturer: Prof. Dr. B. Wunderle

Introduction to Finite Element Method, in the lecture course Micro- & NanoReliability
Lecturer: Dr. S. Rzepka

Technische Zuverlässigkeit
Lecturer: Dr. S. Rzepka

Qualitätssicherung
Lecturers: Dr. S. Rzepka, J. Paul (Globalfoundries), F. Roscher

Werkstoffe der Mikrotechnik
Lecturer: Prof. Dr. B. Wunderle

Werkstoffe der Elektrotechnik
Lecturer: Prof. Dr. B. Wunderle

Ausgabesysteme I - Druckausgabegeräte allgemein
Lecturers: Prof. Dr. R. R. Baumann, F. Siegel

Ausgabesysteme II / Output Systems II- Druckausgabegeräte Inkjet + Elektrofotografie
Lecturers: Prof. Dr. R. R. Baumann, J. Hammerschmidt

Digital Fabrication – digitale Fabrikationstechniken
Lecturer: Prof. Dr. R. R. Baumann

Druckvorstufe I - Druckdatenaufbereitung
Lecturers: Prof. Dr. R. R. Baumann, F. Siegel

Druckvorstufe II - Vertiefung Druckdatenaufbereitung
Lecturers: Prof. Dr. R. R. Baumann, F. Siegel

Farbtheorie/Farbmetrik - farbliche Wirkung insb. von Druckprodukten
Lecturers: Prof. Dr. R. R. Baumann, Dr. A. Willert

Medientechnisches Kolloquium
Lecturer: Prof. Dr. R. R. Baumann

Output Systems II - Druckausgabegeräte Inkjet + Elektrofotografie
Lecturers: Prof. Dr. R. R. Baumann, J. Hammerschmidt

Prepress II – Algorithms and Data Management of Prepress
Lecturers: Prof. Dr. R. R. Baumann, F. Siegel

Visuelle Wiedergabequalität - technische Beurteilung von Druckausgaben
Lecturers: Prof. Dr. R. R. Baumann, Dr. A. Willert

Typografie und Gestaltung
Lecturers: Prof. Dr. R. R. Baumann, A. Grimm

Lectures of International Research Training Group at the Chemnitz University of Technology

Microelectronics Technology
Lecturers: Prof. Dr. T. Geßner, Prof. Dr. S. E. Schulz

Interconnect Processes and Technology
Lecturer: Prof. Dr. S. E. Schulz

Technische Universität Dresden

Einführung in die Finite Element Methode
Lecturer: Dr. S. Rzepka

Interconnect Reliability: Elektro- und Stressmigration, in the lecture course Mikroelektroniktechnologie
Lecturer: Dr. S. Rzepka

University of Paderborn

Theorie und Anwendung von Phasenregelkreisen (PLL-Systeme)
Lecturer: Dr. C. Hedayat

Mikrosensorik
Lecturer: Prof. Dr. U. Hilleringmann

RFID-Funketiketten: Aufbau und Funktion
Lecturer: Prof. Dr. U. Hilleringmann

Technologie hochintegrierter Schaltungen
Lecturer: Prof. Dr. U. Hilleringmann

Integriert-optische Sensoren
Lecturer: Prof. Dr. U. Hilleringmann

Halbleiterbauelemente
Lecturer: Prof. Dr. U. Hilleringmann

Halbleiterprozesstechnik
Lecturer: Prof. Dr. U. Hilleringmann

Mikrosystemtechnik
Lecturer: Prof. Dr. U. Hilleringmann

PUBLICATIONS (SELECTION)

Books

Dudek , R.: Popcorn Cracking. book chapter in G. Grossmann, C. Zardini (eds.): The ELFNET Book on Failure Mechanisms, Testing Methods, and Quality Issues of Lead-Free Solder Interconnects. Springer Verlag, London, 2011. DOI: 10.1007/978-0-85729-236-0.

Dudek , R.; Auerswald, E.: Thermal Fatigue Analysis. book chapter in G. Grossmann, C. Zardini (eds.): The ELFNET Book on Failure Mechanisms, Testing Methods, and Quality Issues of Lead-Free Solder Interconnects. Springer Verlag, London, 2011. DOI: 10.1007/978-0-85729-236-0.

Freed, Y.; Rzepka, S.: An implementation of an accelerated testing methodology to obtain static, creep and fatigue master curves of a T300/913 unidirectional composite material. Proc 26th ICAF Symposium, Montreal. June 1 – 3, 2011; in: Komorowski, J.: ICAF 2011 Structural Integrity: Influence of Efficiency and Green Imperatives. Part 3, Springer Verlag 2011, pp 145-153. DOI: 10.1007/978-94-007-1664-3_11.

Papers

Auersperg, J.; Vogel, D.; Auerswald, E.; Rzepka, S.; Michel, B.: Nonlinear Copper Behavior of TSV for 3D-IC-Integration and Cracking Risks during BEoL-Built-up. Proc. 13th Electronics Packaging Technology Conference EPTC 2011, Singapore, on Stick file: F5.1-P0129.PDF.

Auersperg, J.; Dudek, R.; Oswald, J.; Michel, B.: Interaction Integral and Mode Separation for BEoL-cracking and -delamination Investigations under 3D-IC Integration Aspects. Proc. 12th Int. Conf. on Thermal, Mechanical and Multiphysics Simulation and Experiments in Micro-Electronics and Micro-Systems, EuroSimE 2011, Linz, Austria, 2011 April 18 – 20, on Conf-CD, 068.pdf .

Auersperg, J.; Vogel, D.; Lehr, M.U.; Grillberger, M.; Rzepka, S.; Michel, B.: Aspects of Chip/Package Interaction and 3-D Integration Assessed by the Investigation of Crack and Damage Phenomena in low-k BEoL Stacks. Proc. 2011 IEEE Int. Conf. IITC/MAM, 2011 May 8 – 12.

Balaj, I.; Raschke, R.; Baum, M.; Uhlig, S.; Wiemer, M.; Gessner, T.: New generation of electrostatic carrier technology (T-ESC)for reversible thin wafer clamping with seal glass bonding. Conference on Wafer Bonding for Micro Systems, 3D- and Wafer Level Integration, Chemnitz (Germany), 2011 Dec 6 – 8; Proceedings, p 111.

Baum, M.; Besser, J.; Vetter, C.; Sanchez Ordonez, S.; Wang, X.; Harazim, S.; Schmidt, O.; Wiemer, M.; Gessner, T.: Nano patterned surfaces and their influence on living cells. Biomedizinische Technik 2011, Freiburg (Germany), 2011 Sep 27 – 30; Proceedings Biomed Tech 2011, 56 (Supplement 1) (2011), p Poster P86. ISSN: 0939-4990.

Baum, M.; Roscher, F.; Froemel, J.; Jia, C.; Rank, H.; Hausner, R.; Reichenbach, R.; Wiemer, M.; Gessner, T.: Metal Thermo Compression Bonding at Wafer Level and its Capabilities for 3D Integration. Conference on Wafer Bonding for Micro Systems, 3D- and Wafer Level Integration, Chemnitz (Germany), 2011 Dec 6 – 8; Proceedings (CD-ROM, p 83).

Baum, M.; Wiemer, M.: An investigation of nano patterned surfaces and their influence on cell behavior. Tech Connect World - BioNanotech 2011, Boston (USA), 2011 Jun 13 – 6.

Baumann, R. R.: Printed Functionalities and the Concept of Functional Layer Separations. (keynote), WAN-IFRA Printing Summit 2011, April 6 – 7, 2011, Mainz / Germany. URL: http://www.wan-ifra.org/events/printing-summit-2011

Baumann, R. R.: Printed Smart Objects and their Digital Fabrication. (invited), International Conference on Additive Manufacturing, Loughborogh University, Loughborogh/ United Kingdom, July 12, 2011; URL: http://www.am-conference.com/index.php?main_page=index&cPath=17&sort=20a&page=2

Baumann, R. R.: Digital Manufacturing of Printed Smart Objects. (invited), German-Thai Symposium on Nanoscience and Nanotechnology 2011 on GREEN NANOTECHNOLOGY FOR THE FUTURE, Nakhon Ratchasima / Thailand, September 14, 2011. URL: http://www.eng.chula.ac.th/index.php?q=en/node/3712

Baumann, R. R.: Printed Smart Objects and their Digital Fabrication. (keynote), IS&T's Digital Fabrication Conference 2011, Minneapolis /Minnesota, USA, October 10, 2011. URL: http://www.imaging.org/ist/conferences/df/NIP27%20DF2011%20Prelim%20Program.pdf

Baumann, R. R.: Printing Beyond Color: Printed Smart Objects and their Digital Fabrication. (keynote), ISL Asia 2011 – International Symposium on Laser-Microprocessing, Hong Kong Science Park, Hong Kong October 20, 2011. URL: http://www.islasia.org/programme_rundown.php

Baumann, R. R.: Functionality Formation in Printed Flexible Electronics. (invited), International workshop on "Subsecond thermal processing of Advanced Materials 2011" (subtherm-2011), Dresden / Germany, 2011 October 27. URL: http://www.subtherm.de/programme/?node=49

Baumann, R. R.: Digital Manufacturing of Printed Electronics. (invited), Symposium on Roll-to-Roll Processing of Printed Electronics and Functional Films, Singapore Institute of Manufacturing Technology, November 23, 2011. URL: http://www.simtech.a-star.edu.sg/simcorp/loadContent.do?id=1.6&currId=1.6.2&cid=4718603&pid=4816899

Baumann, R. R.: Organic and Printed Electronics enabling Electronics Everywhere. (keynote), swiss e-print conference on printed electronics and functional materials, Basel / Switzerland, December 1, 2011. URL: http://www.swiss-eprint.ch/program.php

Belsky, P.; Streiter, R.; Wolf, H.; Schulz, S.E.; Aubel, O.; Gessner, T.: Modeling of TDDB in advanced Cu interconnect systems under BTS conditions. Advanced Metallization Conference 2010 (AMC 2010), Albany, NY (USA), 2010 Oct 5 – 7; Microelectronic Engineering. (2011), in press, corrected proof. DOI:10.1016/j.mee.2011.04.070.

Besser, J.; Braeuer, J.; Wiemer, M.; Gessner, T.: Elektrochemische Abscheidung von Pd/Zn-Multilagen für das Fügen mit reaktiven Materialsystemen. MikroSystemTechnik Kongress, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings (CD-ROM, Paper 159). ISBN: 978-3-8007-3367-5.

Bigot, S.; Nestler, J.; Dorrington, P.; Dimov, S.: A Costing Methodology for Products Based on Emerging Micro and Nano Manufacturing Technologies. Journal for Micro and Nanosystems, 3 (2011), pp 254-262. ISSN: 1876-4029.

Braeuer, J.; Besser, J.; Wiemer, M.; Gessner, T.: Room-temperature reactive bonding by using nano scale multilayer systems. Transducers 11, Beijing (China), 2011 Jun 5 – 9; Proceedings, pp 1332-1335. ISBN: 978-1-4577-0157-3.

Braeuer, J.; Besser, J.; Wiemer, M.; Gessner, T.: Room-temperature reactive bonding: An overview of integrated nano scale multilayer systems. Conference on Wafer Bonding for Microsystems 3D- and Wafer Level Integration, Chemnitz (Germany), 2011 Dec 6 – 8; Proceedings (CD-ROM, pp 79 – 80).

Ding, S.-F.; Xie, Q.; Mueller, S.; Waechtler, T.; Lu, H.-S.; Schulz, S.E.; Detavernier, C.; Qu, X.-P.; Gessner, T.: The Inhibition of Enhanced Cu Oxidation on Ruthenium/Diffusion Barrier Layers for Cu Interconnects by Carbon Alloying into Ru. Journal Electrochemical Society, 158 (2011), pp H1228-H1232. ISSN: 0013-4651.

Dudek, R.; Pufall, R.; Seiler, B.; Michel, B.: Studies on the Reliability of Power Packages Based on Strength and Fracture Criteria. Proceedings EuroSimE 2011, Brussels, Belgium, May 2011.

Ebermann, M.; Meinig, M.; Kurth, S.; Hiller, K.; Gittler, E.; Neumann, N.: Tiny MID- and Long-Wave Infrared Spectrometer Module with a MEMS Dual-Band Fabry-Pérot Filter. SENSOR + TEST Conferences, Nürnberg (Germany), 2011 Jun 7 – 9; Proceedings IRS². DOI: 10.5162/irs11/i4.4.

Ebermann, M.; Neumann, N.; Meinig, M.; Kurth, S.; Hiller, K.; Gittler, E.: Tunable micromachined Fabry-Pérot Filters for infrared spectroscopy: current state and prospects. Smart Systems Integration, Dresden (Germany), 2011 Mar 22 – 23; Proceedings (CD-ROM). ISBN: 978-3-8007-3324-8.

Frers, T.; Assion, F.; Berth, G.; Zrenner, A.; Hilleringmann, U.: Variable Coupling of Microcavities with Poly-Silicon Heater. Smart System Integration 2011, Dresden, 2011, Paper 67 (4 pages). ISBN: 978-3-8007-3324-8.

Fiedler, H.; Hermann, S.; Rennau, M.; Schulz, S.E.; Gessner, T.: Fabrication and characterisation of CNT via interconnects for application in ULSI circuits. Poster Presentation; 2011 Advanced Metallization Conference (AMC 2011), San Diego (USA), 2011 Oct 4 – 6. ISSN: 1048-0854.

Fiedler, H.; Hermann, S.; Schulz, S.E.; Gessner, T.: Influence of copper on catalytic carbon nanotube growth process. IITC / MAM, Dresden (Germany), 2011 May 9 – 12; IEEE Proceedings. ISBN: 978-1-4577-0502-1.

Fischer, T.; Ahner, N.; Zimmermann, S.; Schulz, S.E.: Influence of thermal cycles on the silylation process for recovering k-value and chemical structure of plasma damaged ultra-low-k materials. Microelectronic Engineering 2011. ISSN: 0167-9317. DOI: 10.1016./j.mee.2011.04.021.

Froemel, J.; Baum, M.; Wiemer, M.; Roscher, F.; Haubold, M.; Jia, C.; Gessner, T.: Investigations of Thermocompression Bonding with thin Metal Layers. Transducers'11, Beijing (China), 2011 Jun 5 – 9; Proceedings, pp 990 – 994. ISBN: 978-1-4577-0156-1.

Fronk, M.; Mueller, S.; Waechtler, T.; Schulz, S.E.; Mothes, R.; Lang, H.; Zahn, D.R.T.; Salvan, G.: Magneto-optical Kerr-effect studies on copper oxide thin films produced by atomic layer deposition on SiO_2. E-MRS Spring Meeting, Nice (France), 2011 May 9 – 13.

Gossler, C.; Kunzer, M.; Baum, M.; Wiemer, M.; Moser, R.; Passow, T.; Koehler, K.; Schwarz, U.T.; Wagner, J.: Aluminum-Germanium Wafer Bonding of (AlGaIn)N Thin Film Light-Emitting Diodes. Conference on Wafer Bonding for Micro Systems, 3D- and Wafer Level Integration, Chemnitz (Germany), 2011 Dec 6 – 8; Proceedings, p 23f.

Graaf, H.; Frideriszik, F.; Wagner, C.; Borczyskowski, C.v.: Optical spectroscopy of trap states in amorphous perylene derivative films. Journal of Physical Chemistry C, 115 (2011), pp 8150-8154. DOI: 10.1021./jp1121323.

Hammerschmidt, J.; Baumann, R. R.: Inkjet Printed Functionalities in Chemnitz. 7th ROND Conference, Örnsköldsvik, Sweden, March 1, 2011. URL: http://www.miun.se/sv/Forskning/Var-forskning/forskargrupper/dpc/Om-DPC/Seminarier-och-konferenser/ROND-2011/

Hammerschmidt, J.; Weise, D.; Baumann, R. R.: Micro-three-dimensional patterning by inkjet printing of UV curable inks. Proceedings of NIP27 – 27th International Conference on Digital Printing Technologies / Digital Fabrication 2011, Minneapolis, USA, October 2 – 6, 2011. page 811 – 814. ISBN: 978-0-89208-296-4.

Haubold, M.; Baum, M.; Schubert, I.; Leidich, S.; Wiemer, M.; Gessner, T.: Low Temperature Wafer Bonding Technologies. 18th European Microelectronics Packaging Conference EMPC 2011, Brighton (United Kingdom), 2011 Sep 12 – 15; Proceedings (CD-ROM). ISBN: 0956808603; 978-0956808608.

Haubold, M.; Baum, M.; Wiemer, M.; Gessner, T.: Mechanical and electrical packaging technologies by the application of functional layers at micro and nano scale. 4. Fachkongress MicroCar 2011, Leipzig (Germany), 2011 March 1; Micromaterials and Nanomaterials; Band 13; ISSN: 1619-2486.

Haubold, M.; Schubert, I.; Leidich, S.; Wiemer, M.; Gessner, T.: Entwicklung einer Verkappungstechnologie für optisch transparente NEMS/MEMS Gehäuse mit niedrigem Temperatureintrag. MikroSystemTechnik Kongress, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings (CD-ROM, pp 249-252). ISBN: 978-3-8007-3367-5.

Heinrich, M.; Schulze, R.; Wegener, M.; Kroll, L.; Walter, M.; Schueller, M.; Gessner, T.: Polymer-based piezoelectric modules by microinjection moulding technology for SHM. 5th International Conference on Structural Health Monitoring of Intelligent Infrastructure (SHMII-5), Cancún (Mexico), 2011 Dec 11 – 15.

Hermann, S.; Ecke, R.; Schulz, S.E.; Gessner, T.: Novel nanostructure with vertically aligned carbon nanotubes: Synthesis, structural properties and applications. International Conference on the Science and Application of Nanotubes (NT2011), Campridge (UK), 2011 Jul 10 – 16.

Hilleringmann, U.; Wolff, K.; Assion, F.; Vidor, F. F.; Wirth, G. I.: Semiconductor Nanoparticles for Electronic Device Integration on Foils. Africon 2011, NF-001074 (6 pages). ISSN: 2153-0025.

Hölck, O.; Dermitzaki, E.; Wunderle, B.; Bauer, J.; Michel, B.: Basic thermo-mechanical property estimation of a 3D-crosslinked epoxy/SiO2 interface using molecular modeling. J. Microelectronics Reliability, Vol. 51, pp. 1027 – 1034, 2011.

Hofmann, T., Sommer, J.-P., Michel, B.: Project VISA: Fully Integrated Power Electronic Systems for Automotive Electronics. Poster MicroCar 2011, 1. März 2011, Leipzig. Proc. MicroCar 2011, Leipzig, Series Micromaterials and Nanomaterials, Issue 13 2011, 234 – 235. ISSN: 1619-2486.

Imhof, S.; Wagner, C.; Chernikov, A.; Koch, M.; Koester, N.S.; Kolata, K.; Chatterjee, S.; Koch, S.W.; Lu, X.; Johnson, S.R.; Beaton, D.A.; Tiedje, T.; Rubel, O.; Thraenhardt, A.: Evidence of two disorder scales Ga(AsBi). Physica Status Solidi B: Basic Research, 248 (2011), pp 851 – 854. ISSN: 1521-3951. DOI: 10.1002/pssb.201000835.

Imhof, S.; Wagner, C.; Thraenhardt, A.; Chernikov, A.; Koch, M.; Koester, N.S.; Kolata, K.; Chatterjee, S.; Koch, S.W.; Rubel, O.; Lu, X.; Johnson, S.R.; Beaton, D.A.; Tiedje, T.: Luminescence dynamics in Ga(AsBi). Applied Physics Letters , 98 (2011) p 161104. ISSN: 1077-3118. DOI: 10.1063/1.3580773.

Jaschinsky, P.; Erben, J.; Choi, K.-H.; Schulze, K.; Gutsch, M.; Freitag, M.; Schulz, S.E.; Steidel, K.; Hohle, C.; Gessner, T.; Kuecher, P.: Variable-shaped e-beam lithography enabling process development for future copper damascene technology. Microelectronic Engineering, 88 (2011), 8, pp 1978 – 1981. ISSN: 0167-9317. DOI: 10.1016/j.mee.2011.02.035.

Krasselt, C.; Schuster, J.; von Borczyskowski, C.: Photoinduced hole trapping in single semiconductor quantum dots at specific sites at silicon oxide interfaces. Physical Chemistry Chemical Physics, 13 (2011), 38, pp 17084 – 17092. ISSN: 1463-9076. DOI:10.1039/C1CP22040C.

Kurth, S.; Leidich, S.; Bertz, A.; Nowack, M.; Kaufmann, C.; Faust, W.; Gessner, T.: Reliability enhancement of Ohmic RF MEMS switches. SPIE Photonics West, San Francisco (USA), 2011 Jan 22 – 27; Proceedings, Vol. 7928-11 (2011). URL: http://dx.doi.org/10.1117/12.875424.

Kurth, S.; Seifert, M.; Zajadacz, J.; Ebermann, M.; Hiller, K.; Neumann, N.; Gessner, T.: Application of sub-wavelength structures in infrared optical filters. Smart System Integration, Dresden (Germany), 2011 Mar 22 – 23; Proceedings (CD-ROM). ISBN: 978-3-8007-3324-8.

Kurth, S.; Voigt, S.; Leidich, S.; Nowack, M.; Bertz, A.; Gessner, T.: Kapazitiver MEMS-Mischer und Signalfilter für wake up receiver. MikroSystemTechnik Kongress 2011, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings, pp 988-991. ISBN: 978-3-8007-3367-5.

Leidich, S.; Kurth, S.; Nowack, M.; Bertz, A.; Froemel, J.; Kaufmann, C.; Gessner, T.: HF-MEMS Schalter mit ohmschen Kontakt und lateraler Bewegungsrichtung. MikroSystemTechnik Kongress 2011, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings, pp 976-979. ISBN: 978-3-8007-3367-5.

Mager, T.; Reinhold, C.; Hedayat, C.: Three Dimensional Near Field Scanning Measurement Techniques for Im-proved RF Design. Congress MicroCar 2011, March 1 2011, Leipzig, Germany, Micromaterials and Nanomaterials; Band 13.

Magorian-Friedlmeier, T.; Ahlswede, E.; Romanyuk, Y.; Uhl, A.; Tiwari, A.; Baumann, R. R.; Kololuoma, T.; McAdam, C.; Kaelin, M.; Cemernjak, M.; Van Genechten, D.; Stassin, F.; Quintilla, A.: Non-Vacuum Processes for Deposition of the CIGS Active Layer in PV Cells. 26th EU PVSEC, September 5 – 9, 2011, Hamburg, paper ID 3DV.1.15. URL: http://www.eupvsec-planner.com/presentations/c10677/nova-cigs_non-vacuum_processes_for_deposition_of_the_cigs_active_layer_in_pv_cells.htm

Marjanovic, N.; Hammerschmidt, J.; Perelaer, J.; Farnsworth, S.; Rawson, I.; Kus, M.; Yenel, E.; Tilki, S.; Schubert,U.; Baumann, R. R.: Inkjet printing and low temperature sintering of CuO and CdS as functional electronic layers and Schottky diodes. Journal of Materials Chemistry 35, 13634-13639 (2011). ISSN: 1573-4803 (electronic version). DOI: 10.1039/C1JM11237F.

Marjanovic, N.; Sridhar, A.; Kus, M.; Ozel, F.; Akin, I.;Yenel, E.; Baumann, R. R.: Low temperature processing of inkjet printed metal oxides and nanoparticles. Proceedings of Large-Area, Organic and Polymer Electronics Convention 2011 (LOPE-C 11), Frankfurt/M., June 2011, page 111. Organic Electronics Association (OE-A), ISBN: 978-3-00-034957-7.

Martin, J.; Piasta, D.; Kiessling, T.; Otto, T.; Gessner, T.; Staudinger, U.; Demir, E.; Poetschke, P.; Voit, B.: Materialintegrierte Sensorschicht basierend auf Quantum-Dot Limineszenz. MikroSystemTechnik Kongress, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings (CD-ROM). ISBN: 978-3-8007-3367-5.

Martin, J.; Piasta, D.; Otto, T.; Gessner, T.: Influence of Charges on the Photolumindescence of Semiconductor Nanocrystals. Smart System Integration (SSI), Dresden (Germany), 2011 Mar 22 – 23; Proceedings (CD-Rom, Paper 85). ISBN: 978-3-8007-3324-8.

Martin, J.; Piasta, D.; Weiss, A.; Otto, T.; Gessner, T.: The Fluorescence of Semiconductor Nanocrystals - From Basics to Nanosensor Technology. MicroCar, Leipzig, 2011 Mar 1; Micromaterials, Nanomaterials for Automotives; Micromaterials and Nanomaterials; Band 13; pp 202 – 205. ISSN: 1619-2486.

Meinig, M.; Ebermann, M.; Neumann, N.; Kurth, S.; Hiller, K.; Gessner, T.: Dual-band MEMS Fabry-Pérot filter with two movable reflectors for mid- and long-wave infrared microspectrometers. TRANSDUCERS, Beijing (China), 2011 Jun 5 – 9; Proceedings, pp 2538-2541. ISBN: 978-1-4577-0157-3. DOI:10.1109/TRANSDUCERS.2011.5969764.

Meinig, M.; Kurth, S.; Hiller, K.; Neumann, N.; Ebermann, M.; Gittler, E.; Gessner, T.: Tunable mid-infrared filter based on Fabry-Perot interferometer with two movable reflectors. SPIE, San Francisco (USA), 2011 Jan 22 – 27; Proceedings, 7930 (2011), p 79300K. ISSN: 0277-786X. DOI:10.1117/12.875428.

Meyer zu Hoberge, S.; Hilleringmann, U.; Jochheim, C.; Liebich, M.: Piezoelectric Sensor Array with Evaluation Electronic for Counting Grains in Seed Drills. Africon 2011, NF-003069 (6 pages). ISSN: 2153-0025.

Mueller, M.; Roscher, F.; Sowade, E.; Seifert, T.; Wiemer, M.; Gessner, T.; Baumann, R.R.: Aerosol Jet as a Deposition Method for Conductive Layers in Micro-System-Technology using Nanoparticle Inks. 4th Printing Future Days 2011, Chemnitz (Germany), 2011 Nov 7 – 10. VWB-Verlag für Wissenschaft und Bildung, 2011, pp 275 – 281. ISBN: 978-3-86135-623-3.

Mueller, S.; Waechtler, T.; Tuchscherer, A.; Mothes, R.; Gordan, O.; Lehmann, D.; Haidu, F.; Schulz, S.E.; Gessner, T.; Lang, H.; Zahn, D.R.T.: An Approach for Cu ALD via Reduction of Ruthenium- Containing CuxO Films for the Metallization in Spintronic and ULSI Interconnect Systems. 11th International Conference on Atomic Layer Deposition (ALD 2011), Cambridge, Massachusetts (USA), 2011 June 26 – 29; Proceedings (DVD-ROM).

Mueller, S.; Waechtler, T.; Tuchscherer, A.; Mothes, R.; Gordan, O.; Lehmann, D.; Haidu, F.; Ogiewa, M.; Gerlich, L.; Ding, S.-F.; Schulz, S.E.; Gessner, T.; Lang, H; Zahn, D.R.T.; Qu, X.-P.: Thermal ALD of Cu via Reduction of CuxO films for the Advanced Metallization in Spintronic and ULSI Interconnect Systems. Semiconductor Conference Dresden, Dresden, 2011 Sep 27 – 28; IEEE Proceedings. ISBN 978-1-4577-0431-4. DOI:10.1109/SCD.2011.6068736.

Nowack, M.; Leidich, S.; Reuter, D.; Kurth, S.; Kuechler, M.; Bertz, A.; Gessner, T.: Lokales Mikroschweißen als post-process Technologie zur permanenten Reduzierung des Elektrodenabstandes von HARMS. MikroSystemTechnik Kongress 2011, Darmstadt (Germany) 2011 Oct 10 – 12; Proceedings, pp 610-613. ISBN: 978-3-8007-3367-5.

Nowack, M.; Leidich, S.; Reuter, D.; Kurth, S.; Kuechler, M.; Bertz, A.; Gessner, T.: Novel Post-Process Gap Reduction Technology of High Aspect Ratio Microstructures Utilizing Micro Welding. Transducers 11, Beijing (China), 2011 Jun 5 – 9; Proceedings, pp 1352-1355. ISBN 978-1-4577-0156-6.

Reinhold, C.; Hangmann, C.; Mager, T.; Hedayat, C.; Hilleringmann, U.: Plane Wave Spectrum Expansion from Near-Field Measurements on Non-Planar Lattices. 5th International Conference on Electromagnetic Near-Field Characterization and Imaging – ICONIC 2011 (IEEE), November 30 – December 2, 2011, Rouen, France.

Rzepka, S.; Walter, H.; Pantou, R.; Freed, Y.; Michel, B.: Accelerated fatigue testing methodology for reliability assessments of fiber reinforced composite polymer materials in micro/nano systems. Proc. 12th Int. Conf. on Thermal, Mechanical and Multiphysics Simulation and Experiments in Micro-Electronics and Micro-Systems, EuroSimE 2011, Linz, Austria, April 18 – 20, 2011, on Conf-CD, 058.pdf.

Rzepka, S.: Smart and Compact Battery Cell Management System for Fully Electrical Vehicles. Invited Talk; Expert Workshop "Europe's Strengths, Competencies and Job Opportunities in Electric Vehicle Battery Manufacturing"; Brussels, Dec 7, 2011.

Schueller, M.; Schulze, R.; Gebauer, C.; Lipowski, M.; Kaulfersch, E.; Nestler, J.; Otto, T.; Gessner, T.: Netzwerkmodellierung von Doppelwandler Synthetic Jet Aktoren. Deutscher Luft- und Raumfahrtkongress 2011, Bremen (Germany), 2011 Sept 27 – 29; http://www.dlrk2011.dglr.de/.

Schueller, M.; Schulze, R.; Zeising, V.; Gebauer, C.; Otto, T.; Gessner, T.: Model based design of micro actuators for flow control applications. Smart System Integration, Dresden (Germany), 2011 Mar 22 – 23; Proceedings (CD-ROM, Paper 97). ISBN: 978-3-8007-3324-8.

Schulz, B.; Taeuber, D.; Schuster, J.; Baumgaertel, T.; von Borczyskowski, C.: Influence of mesoscopic structures on single molecule dynamics in thin smectic liquid crystal films. Soft Matter, 7, 16 (2011), pp 7431 – 7440. ISSN: 1744-683X. DOI:10.1039/C1SM05434A.

Schulze, R.; Heinrich, M.; Wegener, M.; Schueller, M.; Kroll, L.; Gessner, T.: Microsystems based on Multi Component Micro Injection Moulding Technology. MikroSystemTechnik Konferenz 2011, Darmstadt (Germany), 2011 Oct 10 – 12, Proceedings (CD-ROM), pp 583-586. ISBN: 978-3-8007-3367-5.

Sommer, J.-P., Hofmann, T., Gottwald, T., Podlasly, A.: Leistungselektronik im Automobil mit hoher Integrationsdichte. Vortrag, MicroCar 2011, 1. März 2011, Leipzig. Proc. MicroCar 2011, Leipzig, Series Micromaterials and Nanomaterials, Issue 13 2011, 126 – 129. ISSN: 1619-2486.

Sowade, E.; Hammerschmidt, J.; Blaudeck, T.; Baumann, R. R.: In-flight inkjet self-assembly of spherical nanoparticle aggregates. Advanced Engeneering Materials. ISSN: 1527-2648 (electronic version). DOI: 10.1002/adem.201100245.

Specht, H.; Meinig, M.; Kurth, S.; Hiller, K.; Ebermann, M.; Neumann, N.; Gittler, E.; Gessner, T.: Neuartiger frequenz- und amplitudenabstimmbarer Infrarotfilter. MikroSystemTechnik Kongress, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings (CD-Rom), pp 106-109. ISBN: 978-3-8007-3367-5.

Sridhar, A.; Blaudeck, T.; Baumann, R. R.: Inkjet Printing as Key Enabling Technology for Printed Electronics. Material Matters 6 (1), 12 – 15 (2011). ISSN: 1933-9631.

Sridhar, A.; Baumann, R. R.: Printed Smart Objects for the Internet of Things. Industrial Materials 292, 101 – 106 (04/2011). ISSN: 1022-9787.

Tonndorf, P.; Hietschold, M.; Schulze, S.; Erben, J.-W.; Korodi, I.: Low Energy SEM - High Resolution, Low Charging, Low Damage. Microscopy Conference 2011 – MC 2011, Kiel (Germany), 2011 Aug 28 – Sep 2. URL: http://www.mc2011.de/.

Vidor, F. F.; Wolff, K.; Hilleringmann, U.: Performance Improvement and Hysteresis Reduction for Printable ZnO-Nanoperticle Thin-Film Transistors. Smart System Integration 2011, Dresden, 2011, Paper 22 (6 pages). ISBN: 978-3-8007-3324-8.

Vogel, K.; Wuensch, D.; Shaporin, A; Mehner, J.; Billep, D.; Wiemer, M.: Crack propagation in micro-chevron-test samples of direct bonded silicon-silicon wafers. Frattura ed Integrità Strutturale, 15 (2011), pp 21- – 28. ISSN: 1971-8993.

Voigt, S.; Nowack, M.; Bertz, A.; Leidich, S.; Meinig, M.; Kurth, S.; Gessner, T.; Grosser, V.; Braunschweig, M.; Krumm, R.: Autarkes Sensornetzwerk zur Überwachung von Hochspannungsleitungen. MikroSystemTechnik Kongress 2011, Darmstadt (Germany), 2011 Oct 10 – 12; Proceedings, pp 354-357. ISBN: 978-3-8007-3367-5.

Waechtler, T.; Ding, S.-F.; Hofmann, L.; Mothes, R.; Xie, Q.; Oswald, S.; Detavernier, C.; Schulz, S.E.; Qu, X.-P.; Lang, H.; Gessner, T.: ALD-grown seed layers for electrochemical copper deposition integrated with different diffusion barrier systems. In: Microelectronic Engineering, 88 (2011), pp 684 – 689. ISSN: 0167-9317. DOI: 10.1016/j.mee.2010.07.004.

Waechtler, T.; Mueller, S.; Hofmann, L.; Mothes, R.; Ding, S.-F.; Schulz, S.E.; Lang, H.; Qu, X.P.; Gessner, T.: Copper Films Grown via Copper Oxide ALD Integrated with Different Liner Materials for Interconnect Applications. 11th International Conference on Atomic Layer Deposition (ALD 2011), Cambridge, Massachusetts (USA), 2011 Jun 26 – 29; Proceedings (DVD-ROM). http://www2.avs.org/conferences/ALD/2011/index.html.

Waechtler, T.; Mueller, S.; Mothes, R.; Tuchscherer, A.; Schubert, C.; Lehmann, D.; Haidu, F.; Schaefer, P.; Schulz, S.E.; Lang, H.; Albrecht, M.; Zahn, D.R.T.; Gessner, T.: Copper ALD for Applications in ULSI Metallization Systems and Spintronic Layer Stacks. IMEC Workshop on Atomic Layer Deposition for Applications in Nanotechnology, Leuven (Belgium), 2011 Nov 28 – 29.

Wagner, C.; Imhof, S.; Thraenhardt, A.; Chatterjee, S.; Koch, M.; Koch, S.W.; Johnson, S.R.; Beaton, D.A.; Kolata, K.; Koester, N.S.; Lu, X.; Rubel, O.; Tiedje, T.: Disorder Effects in Ga(AsBi). DPG Frühjahrstagung, Dresden, 2011 Mar 13 – 18.

Weiss, A.; Martin, J.; Piasta, D.; Otto, T.; Gessner, T.: Fabrication of an all-spin-coated CdSe/ZnS Quantum Dot Light-Emitting Diode. SPIE Photonics West 2011, San Francisco (USA) , 2011 Jan 22 – 27; Proceedings SPIE 7945, 79452Q. DOI:10.1117/12.882496.

Weiss, A.; Martin, J.; Piasta, D.; Otto, T.; Gessner, T.: Fabrication of an all-spincoated CdSe/ZnS Quantum Dot Light-Emitting Diode. Smart System Integration, Dresden (Germany), 2011 Mar 22 – 23; Proceedings (CD-ROM, Paper 106). ISBN: 978-3-8007-3324-8.

Wiegand, C.; Hangmann, C.; Hedayat, C.; Hilleringmann, U.: Modeling and Simulation of Arbitrary Ordered Nonlinear Charge-Pump Phase-Locked Loops. SCD 2011, Sep. 2 – 28 2011, Dresden.

Wiemer, M.; Baum, M.; Braeuer, J.; Wuensch, D.: Fügetechnologien zur Integration von MEMS und Elektronik. 2. GMM Workshop Packaging von Mikrosystemen, Magdeburg (Germany), 2011 Mar 17; Proceedings (CD-ROM).

Wiemer, M.; Braeuer, J.; Besser, J.; Wuensch, D.: Development trends in the field of wafer bonding technologies. Conference on Wafer Bonding for Microsystems, 3D- and Wafer Level Integration, Chemnitz (Germany), 2011 Dec 6 – 8; Proceedings (CD-ROM), pp 13 – 14.

Wietstruck, M; Kaynak, M.; Tillak, B.; Kurth, S.; Erler, B.: Materialcharakterisierung eines komplexen Metallschichtstapels für einen monolithischintegrierten RF-MEMS-Schalter. MikroSystemTechnik Kongress, Darmstadt (Germany), 2011 Oct 10 – 12. ISBN: 978-3-8007-3367-5.

Willert, A.; Hammerschmidt, J.; Baumann, R. R.: Mass Printing Technologies for Technical Applications. Scientific Papers of the University of Pardubice, Series A, Vol. 17, 2011.

Wolff, K.; Hilleringmann, U.: Integration Technique for Optically Transparent ZnO Nanoparticle Thin-film Transistors. Smart System Integration 2011, Dresden, 2011, Paper 71 (4 pages). ISBN: 978-3-8007-3324-8.

Wolff, K.; Hilleringmann, U.: Inverter circuits on glass substrates based on ZnO-nanoparticle thin-film transistors. Solid-State Electronics 67(1), pp. 11 – 16, 2012.

Wolff, K.; Hilleringmann, U.: Solution processed inverter based on zinc oxide nanoparticle thin-film transistors with poly(4-vinylphenol) gate dielectric. Solid-State Electronics 62(1), pp. 110 – 114, 2011. DOI: 10.1016/j.sse.2011.01.046.

Zichner, R.; Baumann, R. R.: 3-D transponder antennas for future SHF RFID applications. Advances in Radio Science 9, 401 – 405 (2011). ISSN (printed): 1684 – 9965. ISSN (electronic): 1684-9973. DOI: 10.5194/ars-9-401-201.

Zienert, A.; Schuster, J.; Streiter, R.; Gessner, T.: Quantum mechanical methods for the simulation of electronic transport through carbon nanotubes. IITC/MAM, Dresden (Germany), 2011 May 9 – 12; Proceedings. ISBN 978-1-4577-0503-8. DOI: 10.1109/IITC.2011.5940363.

Zimmermann, S.; Ahner, N.; Fischer, T.; Schaller, M.; Schulz, S.E.; Gessner, T.: Talk: A less damage patterning regime for a successful integration of ultra low-k materials in modern nanoelectronic devices. MRS Spring Meeting

FRAUNHOFER ENAS

2011, San Francisco (USA), 2011 Apr 25 – 29; In: MRS Online Proceedings Library. ISSN: 1946-4274. DOI:10.1557/opl.2011.1240.

Zimmermann, S.; Reich, R.; Zacher, M.; Schulz, S.E.; Gessner, T.: Prediction of wafer homogeneity maps using a virtual metrology scheme consisting of time resolved OES measurements and a neural network. 11th European Advanced Equipment Control / Advanced Process Control Conference, (AEC/APC 2011), Dresden (Germany), 2011 Apr 4 – 6; Proceedings (CD-ROM). ISBN: 978-1-61839-085-1.

Editorial Notes

Editor
Fraunhofer Institute for Electronic Nano Systems ENAS
Technologie-Campus 3
09126 Chemnitz
Germany

Phone: +49 (0) 371 45001-0
Fax: +49 (0) 371 45001-101
Email: info@enas.fraunhofer.de
Internet: http://www.enas.fraunhofer.de/

Director: Prof. Dr. Thomas Gessner

Editorial
Dr. Martina Vogel

Photos
Fraunhofer ENAS
Ines Escherich
Jürgen Lösel
Dirk Hanus

Layout & Design
Andrea Messig-Wetzel

Print
Förster & Borries GmbH & Co. KG

CD Production
CMS Compact Media Service GmbH