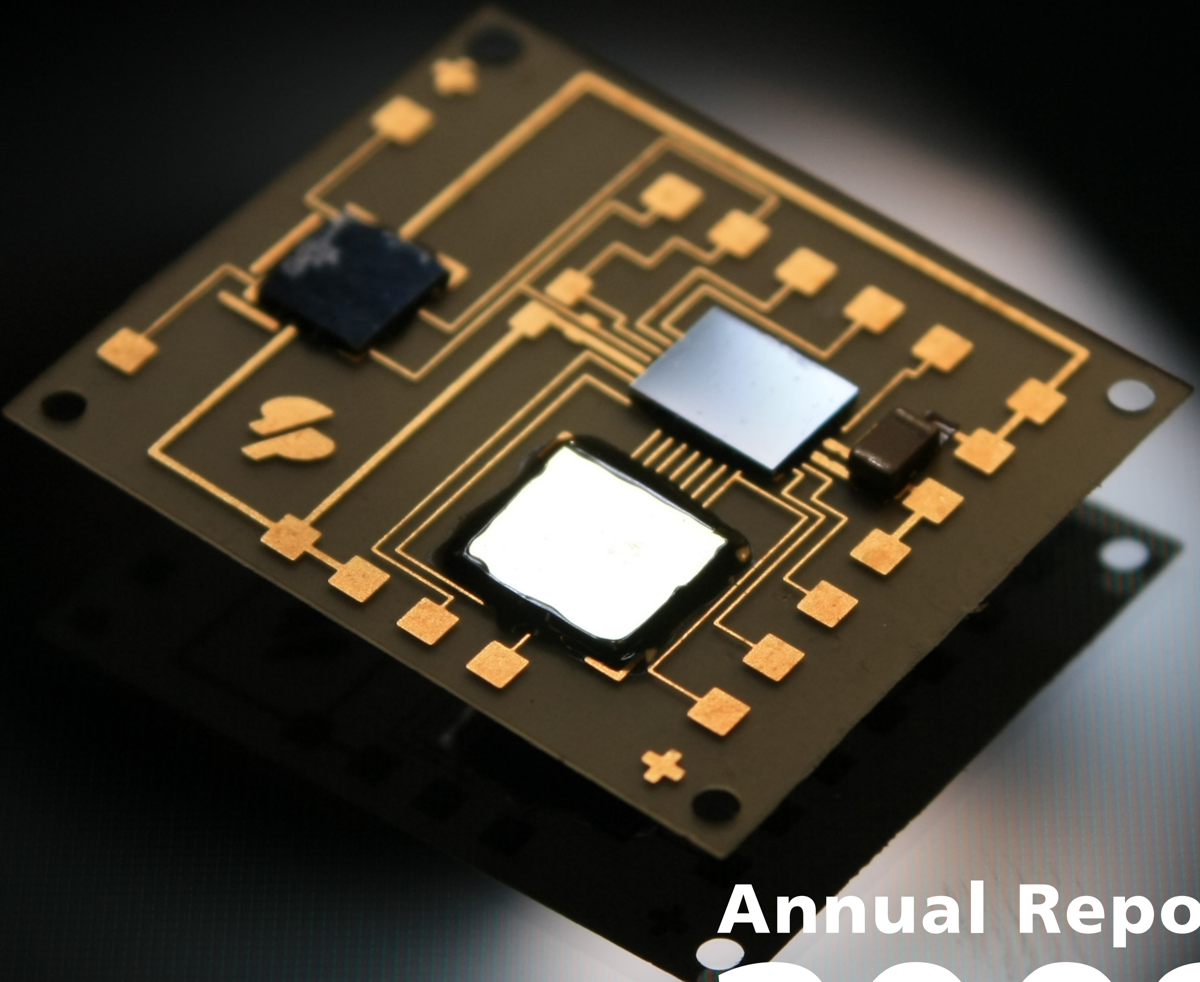
Fraunhofer
ENAS

FRAUNHOFER RESEARCH INSTITUTION FOR ELECTRONIC NANO SYSTEMS ENAS



Annual Report 2008

Fraunhofer
60 Jahre im Auftrag der Zukunft.

cover photo: Fraunhofer ENAS, Andreas Morschhauser

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Prof. Dr. Thomas Gessner
Director of Fraunhofer ENAS

FRAUNHOFER ENAS

PREFACE

Dear friends and partners of the Fraunhofer Research
Institution for Electronic Nano Systems,
dear ladies and gentlemen,

the Fraunhofer-Gesellschaft has extended their activities in the field of nano technologies in Saxony on July 1st, 2008. The Chemnitz branch of the Fraunhofer Institute for Reliability and Microintegration IZM became the independent Fraunhofer Research Institution for Electronic Nano Systems ENAS. This establishes new prospects not only for Fraunhofer ENAS but also for the Chemnitz city as an emergent business location and scientific landscape.

The core competence of the Fraunhofer ENAS is the development of micro and nano systems for the so-called smart systems integration. With this orientation Fraunhofer ENAS addresses the manufacturers and suppliers of components, systems, materials or semi finished products as well as the equipment manufacturer and user industry. For that reason Fraunhofer ENAS is able to support strongly the research and development of many small and medium size companies as well as large scale industry working in the fields of nano and micro electronics as well as micro system technologies. Derived from the future needs of the industry especially from the Saxon semiconductor industry, the automobile manufacturer and component suppliers, the mechanical and plant engineering, the micro system technologies as well as the medical engineering the Fraunhofer ENAS will focus on:

- development of nano systems, high-precision MEMS and NEMS (micro electro mechanical system and nano electro mechanical system),
- wafer level packaging of MEMS and NEMS,
- metallization and interconnect systems of micro and nano electronics as well as 3D-integration,
- novel concepts of systems based on innovative materials,
- implementation of printed functionalities in the system integration,
- reliability and security of micro und nano systems.

In general, the strategic alliance between the Fraunhofer ENAS and the Center for Microtechnologies ZfM of the Chemnitz University of Technology ensures strong synergies in technology and device development. Both, the Fraunhofer ENAS and the ZfM belong to the smart systems campus Chemnitz. Whereas the new clean room facilities of the ZfM have just been finished in 2007, the new building of Fraunhofer ENAS is still under construction. It will be finished in May 2009.

The strong cooperation with the Fraunhofer IZM Berlin will be continued in future especially in the field of nano assembly and packaging for MEMS and NEMS. The cooperation will include future-oriented topics like carbon nano tubes and nano needles as well as technological topics. Moreover the cooperation in the field of 3D-integration will be continued with Fraunhofer IZM in Berlin and Munich.

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

The smart systems integration addresses the trend to even smaller multi functional, self organizing systems with an interface for communication with the outside world. These new visionary products increasingly determine the success of the companies in all branches starting with automotive via medical engineering, mechanical engineering, consumer industries up to telecommunication and logistics. In order to dominate the international trend as well as the market, it is obviously necessary to use low-cost technologies and to combine and integrate different components based on different materials and technologies into one system. Especially more and more important are the implementation of nano aspects for single components and systems as well as multi aspects related to multi technologies, multi components, multi materials and multi functionality. The future smart product will work stand alone. They include their own energy sources. So they are completely energy

Liebe Freunde und Partner der Fraunhofer-Einrichtung für
Elektronische Nanosysteme,
sehr geehrte Damen und Herren,

zum 1. Juli 2008 verstärkte die Fraunhofer Gesellschaft ihre Aktivitäten zur Nanotechnologie in Sachsen. Aus dem Institutsteil Chemnitz des Fraunhofer-Instituts für Zuverlässigkeit und Mikrointegration IZM wurde die eigenständige Fraunhofer-Einrichtung für Elektronische Nanosysteme ENAS. Nicht nur für die Fraunhofer ENAS sondern auch für die Stadt Chemnitz als aufstrebende Wirtschafts- und Wissenschaftsregion eröffnen sich damit neue Chancen.

Die Kernkompetenzen der Fraunhofer ENAS liegen auf dem Gebiet der Entwicklung von Mikro- und Nanosystemen für die sogenannte Smart Systems Integration. Mit dieser Ausrichtung spricht die Fraunhofer ENAS sowohl die Komponentenindustrie als auch die Systemhersteller, Materialhersteller, Halbzeughersteller, Technologiegeräteindustrie und Anwenderindustrie an. Damit ist die 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. Abgeleitet vom zukünftigen Bedarf der Industrie, insbesondere der sächsischen Halbleiterindustrie, der Automobilhersteller und -zulieferer, des Maschinen- und Anlagenbaus, der Mikrosystemtechnik und der Medizintechnik wird sich die Fraunhofer ENAS Chemnitz fokussieren auf:

- Entwicklung von Nanosystemen, hochpräzise MEMS und NEMS (micro electro mechanical system und nano electro mechanical system),
- das Waferlevelpackaging von MEMS und NEMS,
- Metallisierungs- und Interconnectsysteme für die Mikro- und Nanoelektronik sowie die 3D-Integration,
- neuartige Systemkonzepte mit innovativen Materialsystemen,
- Einbeziehung von gedruckten Funktionalitäten in die Systemintegration,
- Zuverlässigkeit und Sicherheit von Mikro- und Nanosystemen.

Die strategische Allianz zwischen der Fraunhofer ENAS und dem Zentrum für Mikrotechnologien ZfM der Technischen Universität Chemnitz sichert Synergien in der Technologie und Systementwicklung. Beide Forschungseinrichtungen gehören zum Smart Systems Campus Chemnitz. Während der neue Reinraum des ZfM bereits 2007 fertiggestellt wurde, befindet sich das Gebäude der Fraunhofer ENAS im Bau. Im Mai 2009 wird es an uns übergeben werden.

Für die inhaltliche Weiterentwicklung in Richtung der Mikro- und Nanosysteme wird auch in Zukunft die enge Kooperation mit dem Fraunhofer IZM Berlin, insbesondere auf dem Gebiet der Nano-Aufbau- und Verbindungstechnik, weitergeführt. Die Kooperation wird von Zukunftsthemen (Carbon Nano Tubes CNT, Nanorasen) bis hin zur technologischen Zusammenarbeit reichen. Mit den Institutsteilen des Fraunhofer IZM in Berlin und München besteht darüber hinaus eine Kooperation im Bereich 3D-Integration.

Mit der 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 die Fraunhofer ENAS international aufgestellt.

Die Smart Systems Integration adressiert den Trend zu immer kleineren multifunktionalen, sich selbst organisierenden Systemen mit Schnittstellen zur Kommunikation mit der Außenwelt. Diese neuen visionären Produkte bestimmen in zunehmendem Maße den Erfolg der Unternehmen in self-sufficient. They communicate via RFID with the outside world. Sensors and actuators are able to measure single or multiple data, which are processed in the processor and stored in the memory. The processed data will be communicated.

The Fraunhofer Research Institution for Electronic Nano Systems is positioning itself to meet these challenges. The basic requirement for our continued success in research and development is, of course, the committed work of our staff.

In our capacity as a research institution 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 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 optimism as well as the support of many our business partners and sponsors.
We would like to express our thanks to all of them.

Director of the Fraunhofer Research Institution for Electronic Nano Systems ENAS

Prof. Dr. Thomas Gessner

allen Branchen angefangen von der Automobilindustrie über Medizintechnik, Maschinenbau bis hin zur Konsumgüterindustrie, Telekommunikation und Logistik. Um den internationalen Trend und den Markt mit zu bestimmen, ist der Einsatz preiswerter neuer Technologien sowie die Kombination und Integration verschiedener Komponenten basierend auf verschiedenen Materialien und Technologien in ein Gesamtsystem unabdingbar. Besondere Bedeutung kommen dabei der Einbeziehung von Nanoaspekten hinsichtlich der einzelnen Komponenten und Systeme, aber auch Multi-Aspekten hinsichtlich Multi-Technologien, Multi-Komponenten, Multi-Materialien, Multi-Funktionalisierung und Multi-Funktionalität zu. Die intelligenten Systeme der Zukunft werden energieautark arbeiten. Sie beinhalten eigene Energiequellen. Über RFID kommunizieren die Systeme mit der Umwelt. Sensoren und Aktoren erfassen einzelne bzw. mehrere Größen, die Daten werden in Prozessoren verarbeitet und in Speichern gespeichert. Die aufbereiteten Daten werden kommuniziert.

Die Fraunhofer ENAS stellt sich diesen Herausforderungen. Grundvoraussetzung für unsere erfolgreichen Forschungs- und Entwicklungsleistungen ist der engagierte Einsatz der Mitarbeiterinnen und Mitarbeiter unseres Hauses.

Als Einrichtung 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 Landes 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 der Einrichtung beruht auf Kreativität, Leistungsbereitschaft und Optimismus der Mitarbeiterinnen und Mitarbeiter sowie der Unterstützung durch zahlreiche Geschäftspartner und Förderer.

Ihnen allen gilt mein besonderer Dank.

der Leiter der Fraunhofer-Einrichtung für Elektronische Nanosysteme ENAS

Prof. Dr. Thomas Geßner

FRAUNHOFER-GESELLSCHAFT - PROFILE

60 years of dedication to the future.

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 57 Fraunhofer Institutes. The majority of the 15,000 staff are qualified scientists and engineers, who work with an annual research budget of €1.4 billion. Of this sum, more than €1.2 billion is generated through contract research. Two thirds of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Only one third 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 research centers and representative offices in Europe, the USA and Asia 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 - IM PROFIL

60 Jahre im Auftrag der Zukunft.

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 57 Institute. 15 000 Mitarbeiterinnen und Mitarbeiter, überwiegend mit natur- oder ingenieurwissenschaftlicher Ausbildung, bearbeiten das jährliche Forschungsvolumen von 1,4 Milliarden Euro. Davon fallen 1,2 Milliarden Euro auf den Leistungsbereich Vertragsforschung. Zwei Drittel dieses Leistungsbereichs erwirtschaftet die Fraunhofer-Gesellschaft mit Aufträgen aus der Industrie und mit öffentlich finanzierten Forschungsprojekten. Nur ein Drittel wird 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.

Niederlassungen in Europa, in den USA und in Asien 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. Studentinnen und Studenten 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), der als Forscher, Erfinder und Unternehmer gleichermaßen erfolgreich war.

FRAUNHOFER GROUP FOR MICROELECTRONICS

The Fraunhofer Research Institution for Electronic Nano Systems ENAS belongs to the Fraunhofer Group for Microelectronics VµE since its foundation. This Fraunhofer group coordinates the activities of the Fraunhofer institutes working in the fields of microelectronics and micro integration. The Fraunhofer CNT, Fraunhofer ENAS, Fraunhofer ESK, Fraunhofer HHI, Fraunhofer IHF, Fraunhofer IIS, Fraunhofer IISB, Fraunhofer IMS, Fraunhofer IPMS, Fraunhofer ISIT, Fraunhofer IZM and the guest Fraunhofer FOKUS as well as Fraunhofer IDMT belong to this Fraunhofer group.

Its purpose is to recognize and anticipate new trends in microelectronics applications and to incorporate them in the future strategic plans of the member institutes. This is generally done by defining joint focal areas of research and through joint projects. This method of working enables the cooperating institutes to offer their customers, in particular innovative small and medium-sized firms, access to cutting-edge research and developments in applications at an extremely early stage, thus giving them a distinct competitive advantage.

The office of the Fraunhofer Group for Microelectronics serves as a central liaison point for the twelve member institutes. Acting in an advisory function, it provides support to the steering committee of the Group for Microelectronics in matters related to the coordination of research content and the planning of future work.

The central office of Fraunhofer Group for Microelectronics coordinates all activities, working closely with the member institutes to forge durable contacts between science, industry and politics.

Business areas:

- Automation
- Networked assistance systems
- Communication and entertainment
- Light
- Microsystems and medicine
- Mobility
- »More Moore« and »Beyond CMOS«
- Security
- Smart System Integration

Further information: www.vue.fraunhofer.de

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FRAUNHOFER-VERBUND MIKROELEKTRONIK

Die Fraunhofer-Einrichtung für Elektronische Nanosysteme ist seit ihrer Gründung Mitglied im Fraunhofer-Verbund Mikroelektronik (VµE). Dieser Verbund koordiniert die Aktivitäten der auf den Gebieten Mikroelektronik und Mikrointegration tätigen Fraunhofer-Institute: Fraunhofer CNT, Fraunhofer ENAS, Fraunhofer ESK, Fraunhofer HHI, Fraunhofer IHF, Fraunhofer IIS, Fraunhofer IISB, Fraunhofer IMS, Fraunhofer IPMS, Fraunhofer ISIT, Fraunhofer IZM und den Gastinstituten Fraunhofer FOKUS und Fraunhofer IDMT.

Seine Aufgabe besteht dabei im frühzeitigen Erkennen neuer Trends bei mikroelektronischen Anwendungen und deren Berücksichtigung bei der strategischen Weiterentwicklung der Verbundinstitute. Dies geschieht vorwiegend in Form gemeinsamer Themenschwerpunkte und Projekte. Auf diesem Wege kann der Verbund insbesondere innovativen mittelständischen Unternehmen rechtzeitig zukunftsweisende Forschung und anwendungsorientierte Entwicklungen anbieten und so entscheidend zu deren Wettbewerbsfähigkeit beitragen.

Die Geschäftsstelle des Fraunhofer-Verbunds Mikroelektronik fungiert als zentrales Koordinierungsbüro für zwölf Verbundinstitute. Sie berät und unterstützt das Direktorium des Verbunds Mikroelektronik bei Fragen der inhaltlichen Abstimmung und der fachlichen Zukunftsplanung.

Die Geschäftsstelle des Fraunhofer-Verbunds Mikroelektronik ist das zentrale Koordinierungsbüro. In enger Zusammenarbeit mit den Instituten bildet sie das Bindeglied zwischen Wissenschaft, Wirtschaft und Politik.

Geschäftsfelder:

- Automatisierungstechnik
- vernetzte Assistenzsysteme
- Kommunikation und Unterhaltung
- Licht
- Mikrosysteme und Medizin
- Mobilität
- »More Moore« und »Beyond CMOS«
- Sicherheit
- Smart System Integration

Weitere Informationen: www.vue.fraunhofer.de

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FRAUNHOFER ENAS - PROFILE

Smart Systems Integration by using Micro and Nanotechnologies

The growing complexity and miniaturization of innovative products lead to the fact that systems integration will be getting more and more important for the scientific and technical development. Thereby, not only multi functionality but also the implementation of different devices (multi device) consisting of different materials (multi materials) play an important role. The integration of nano materials as well as printed functionalities causes new challenges and requires new approaches in terms of design, testability, and reliability.

The Fraunhofer Research Institution for Electronic Nano Systems ENAS in Chemnitz focuses on research and development in the fields of smart systems integration by using micro and nano technologies with partners in Germany, Europe and world wide.

The micro and nano system technologies as well as electronics are playing a key role in today's product development and industrial progress. They enable the integration of mechanical, electrical, optical, chemical, biological and other functions into a very small space with dimensions ranging from sub micrometres up to some millimetres. Combined with intelligence, power supply and communication ability, these systems are multi-device integrated and should be developed for use inside the host. Systems integration will determine the economic success of manufacturers and users coming mostly from consumer electronics, telecommunication, mechanical engineering, medical technology, and automotive. To ensure long-term competitiveness, a sophisticated technological potential is necessary. The Fraunhofer ENAS is positioning itself to meet these challenges and participates very actively in the further development of Smart Systems Integration and the required bridging of the gap from NANO to MICRO and to the MACRO world.

The main research activities of the Fraunhofer ENAS can be classified into the following topics:

Multi Device Integration:
development of MEMS/NEMS, prototyping of sensor and actuator devices, integration of such devices together with micro- and nanoelectronic components into systems, design of components and systems, development and implementation of test and characterization of MEMS/NEMS. Examples are miniaturized spectrometer, inclination sensors, high-precision acceleration sensors and gyroscopes, Fabry Perot Interferometer.

Development of Advanced Technologies:
core competence in development and application of wafer bonding processes for MEMS/NEMS packaging (chip and wafer bonding including combinations of new materials and bonding at low temperatures), 3D patterning technologies for silicon and non-silicon materials, CMP (chemical mechanical polishing).

Reliability of Micro and Nano Systems:
thermo-mechanical reliability of micro and nano components in high-tech systems, core competence combination of thermo-mechanical simulation with advanced experimental methods, security.

FRAUNHOFER ENAS - IM PROFIL

Smart Systems Integration unter Nutzung von Mikro- und Nanotechnologien

Die steigende Komplexität und Miniaturisierung innovativer Produkte führt dazu, dass die Systemintegration immer bedeutender für die wissenschaftliche und technische Entwicklung wird. Dabei spielen Multifunktionalität sowie die Implementierung verschiedener Bauteile (multi devices), die ihrerseits aus verschiedenen Materialien (multi materials) bestehen, eine wesentliche Rolle. Die Integration von Nanomaterialien sowie gedruckter Funktionalitäten führt zu neuen Herausforderungen und verlangt neue Ansätze hinsichtlich Zuverlässigkeit, Test, Design und Sicherheit.

Im Fokus der Fraunhofer-Einrichtung für Elektronische Nanosystem ENAS in Chemnitz steht die Forschung und Entwicklung auf dem Gebiet der Smart Systems Integration unter Nutzung von Mikro- und Nanotechnologien gemeinsam mit Partnern in Deutschland, Europa und der Welt.

Die Mikro- und Nanotechnologien sowie die Elektronik sind Schlüsseltechnologien gegenwärtiger Produktentwicklungen und des industriellen Fortschritts. Sie gestatten die Integration mechanischer, elektrischer, optischer, chemischer, biologischer und weiterer Funktionen auf engen Raum mit Dimensionen im Bereich von Submikrometern bis zu einigen Millimetern. Ausgestattet mit Intelligenz, einer autarken Energiequelle und der Möglichkeit der Kommunikation sind solche Systeme hoch integriert und für die Anwendung im Host entwickelt. Systemintegration wird zunehmend den ökonomischen Erfolg der Hersteller und Anwender der Konsumgüterelektronik, Telekommunikation, Maschinenbau, Medizintechnik und Automobilbau bestimmen. Um langfristig wettbewerbsfähig zu sein, ist ein hoch entwickeltes technologisches Potential unabdingbar. Die Fraunhofer ENAS stellt sich diesen Herausforderungen und arbeitet sehr aktiv an der weiteren Entwicklung der Smart Systems Integration. Sie verbindet damit die Nano- und der Mikrowelt der Forscher und Entwickler mit der Makrowelt der Anwender.

Die Hauptforschungsgebiete der Fraunhofer ENAS sind:

Multi Device Integration:
die Entwicklung von MEMS/NEMS (micro and nano electro mechanical systems), ihre Integration mit mikro- und nanoelektronischen Komponenten zu Systemen, die Entwicklung und Implementierung von Test und Charakterisierung von MEMS und NEMS. Beispiele sind miniaturisierte Spektrometer, Neigungssensoren, hoch präzise Beschleunigungssensoren, Fabry-Perot Interferometer.

Technologien:
Entwicklung und Anwendung von Waferbondverfahren für MEMS/NEMS-Packaging, 3D-Patterning Technologien für Silizium und Nicht-Silizium-Materialien, CMP (Chemical Mechanical Polishing).

Zuverlässigkeit von Mikro-und Nanosystemen:
Thermo-mechanische Zuverlässigkeit von Mikro- und Nanokomponenten in Hightech-Systemen, Kombination von thermo-mechanischer Simulation mit experimentellen Methoden, Sicherheit.

Printed Functionalities:
utilizing ink-jet and mass printing technologies for efficient industrial fabrication processes of printed components for smart systems, technology development and adapted measurement techniques.

Back-end of Line (BEOL):
material, process and technology development for manufacturing on-chip interconnects and metallization for nanoelectronics / 3D-integration / multi device integration, simulation and modelling of processes, equipment and interconnect systems.

Advanced System Engineering:
electromagnetic reliability and compatibility, development and design of custom-specific electronic modules.

The main research areas of Fraunhofer ENAS are clearly visible in the structure of this institution. Five departments belong to Fraunhofer ENAS:

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

Gedruckte Funktionalitäten:
Anwendung von Inkjet und Massendruckverfahren für effiziente industrielle Herstellungsprozesse von gedruckten Komponenten für intelligente Systeme, Technologieentwicklung und Entwicklung adaptierter Messtechnik.

Back-end of Line (BEOL):
Materialien, Prozess- und Technologieentwicklung für die Herstellung von On-Chip-Interconnects und Metallisierung für 3D-Integration sowie Multi-Device-Integration, Simulation und Modellierung von Prozessen, Geräten und Interconnect-systemen.

Advanced System Engineering:
Elektromagnetische Zuverlässigkeit und Verträglichkeit, Entwicklung und Design von kundenspezifischen elektronischen Modulen.

Die wesentlichen Forschungsgebiete der Fraunhofer ENAS spiegeln sich in der Struktur der Einrichtung wieder. Zur Fraunhofer ENAS gehören fünf Abteilungen:

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

DEPARTMENTS AND CORE COMPETENCES

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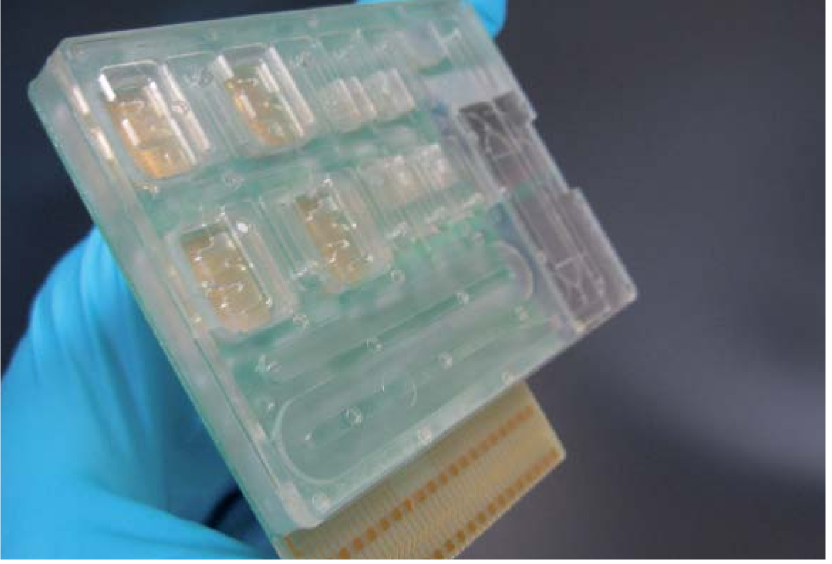
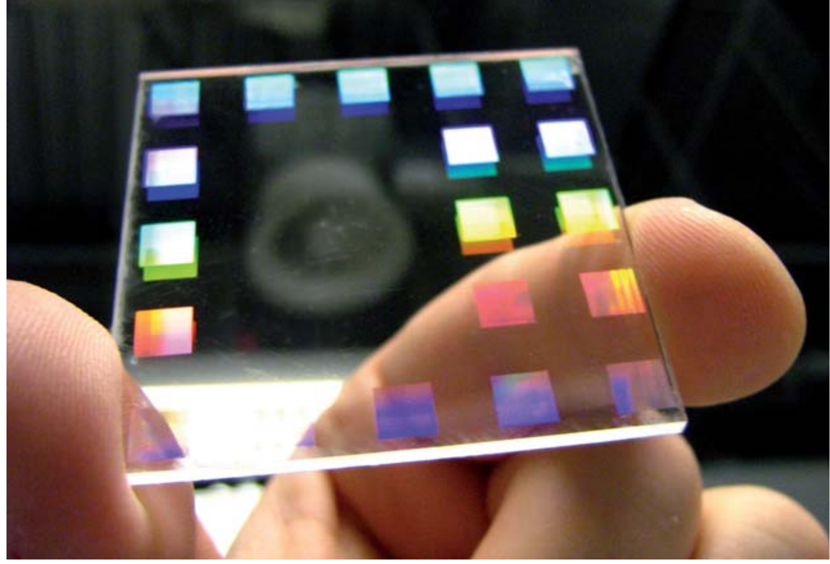




DEPARTMENT MULTI DEVICE INTEGRATION

Head of the department: Prof. Dr. Thomas Otto

Multi Device Integration

The development of MEMS/NEMS, prototyping of sensor and actuator devices, integration of such devices together with micro and nanoelectronic components to systems, design of component and systems, development of Advanced Technologies (waferbonding and packaging) and development and implementation of test and characterization of MEMS/NEMS are the main activities of the Department Multi Device Integration. Examples are micro mirror spectrometer, inclination sensors, gyroscopes and Lab-on-Chip systems.

These core competences are described in detail for the following four groups.

MEMS/NEMS Components and Systems

Besides the development of classical microsystems the group 'Systems and Components' is mainly focused on systems which are based on polymers and nanocomposites. An important part of the group activities deals with microfluidics and low cost polymer-based actuators.

As molecular based medicine and genomic research becomes more and more mature, in-vitro diagnostic approaches gain increasing interest in the field of medical health care. Another trend focuses on bringing medical diagnostics closer to the patient and carrying out even complex biomedical analyses at the 'point-of-care'.

Integrated systems for in-vitro diagnostics are of great interest for both markets. Within a joint research project of eight institutes of the Fraunhofer-Gesellschaft, a technology platform has been developed which aims at providing the technological basis for an accelerated launch of new in-vitro diagnostic products (www.ivd-plattform.fraunhofer.de). Within this project, a complete microfluidic cartridge for in-vitro diagnostics has been developed at Fraunhofer ENAS. Due to its modular concept, the microfluidic platform is able to work both with optical and electrochemical biosensors. The cartridges incorporate liquid reagents and integrated micropumps. As they are completely self-contained, the cartridges are able to run bio assays in a fully automated way.

Nanocomposite materials offer certain advantages over classical inorganic materials such as easy processing and nearly unlimited design of components. Additionally typical included nanoeffects (e.g. quantum confinement) enhance the system performance substantially or provide completely new functionalities. But a big challenge is to bring nanoparticles, nanorods or nanowires in contact to the micro and macro world. To overcome these difficulties we favour different approaches such as use of special conditioned composits (interfaces, orientation of inclusions) or self-assembling technologies. In current projects humidity and magnetic positioning sensors are being developed by means of nanocomposites. First results look very promising and it seems that the big advantage of composites, namely the separate conditioning of inorganic (nano)inclusions and the organic matrix, lead to cost efficient sensitive sensors with simultaneously high reliability and sensor lifetime.

Furthermore nanocomposites can serve as excellent basis for the development of thermoelectric generators with relatively large areas. Classical thermoelectric materials show very low conversion efficiencies because of the fact that electrical and thermal conductivity are coupled. With nanocomposite materials these parameters can be tuned and optimized independently. In current work we investigate and qualify different organic and nanocomposite materials for the use in thermoelectric generators for energy autarkic microsystems. Exemplary for the activities in the field of microoptics is the development and validation of infrared MEMS spectrometers. Such a miniaturized spectrometer has been developed together with the Company Colour Control Farbmesstechnik GmbH Chemnitz. The systems can be configured for different wavelength bands and hence used in various applications. To the fields of application of this spectrometer belong, for example, food studies, environmental monitoring, medical diagnostics, metrology, or the physical forensic analysis.

For all microsystems appropriate electronics for data processing and control, respectively, is developed and manufactured. Thereby the key features of the electronics are, among others, noise reduction and energy efficiency.

MEMS/NEMS Design

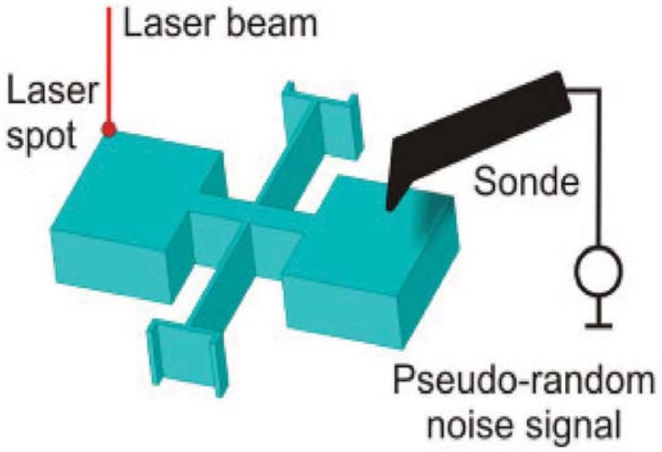
Modern modeling and simulation technologies are essential to design innovative products in micro and nano system technologies (MEMS/NEMS). The development of such systems requires an understanding of different physical interactions. Numerous commercial and customized software tools are employed for design, analyzing and optimizing complex microsystems. They are used to analyze interactions of various physical effects in micro and nano systems. Coupled field analysis enables accurate, real-world simulations of MEMS devices such as electrostatic comb drives, squeeze film damping, thermo-mechanical induced packaging stress and piezoelectric transducer behavior, to name a few. The scientists have comprehensive experience in the development of varied MEMS devices like accelerometers, inclinometers, gyroscopes, micro mirrors, radio frequency MEMS switches and micro fluidic devices.

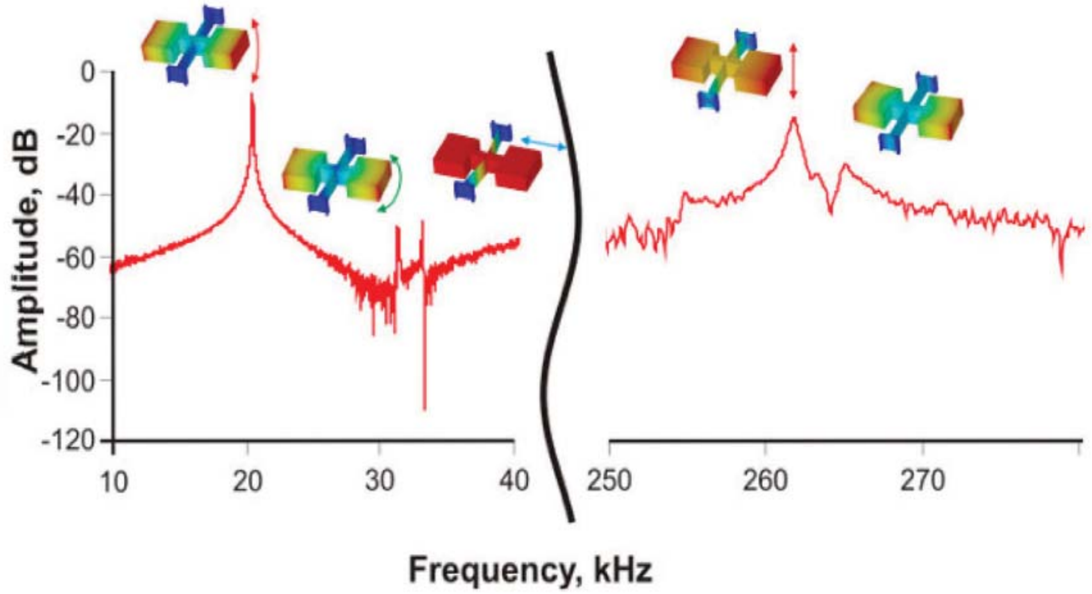
The competencies concern modeling and simulation solutions in MEMS design, mask layout and combination of numerical simulations with experimental methods. The main MEMS simulation activities are structural analysis, electrostatics and magnetostatics, low-frequency electrics and magnetics, circuit coupling, acoustic structural coupling, electrostatic-structural coupling, fluid-structural coupling capability to calculate damping effects on device response, micro fluidics and piezoelectric calculations. The scientists have an extensive knowledge in MEMS technology and work closely together with technologists to develop process flows and properly design.

Service:
* MEMS/NEMS design and optimization on device and system level
* mask design
* support in MEMS technology development

The research is focused on:
* MEMS design and optimization methods on device and system level
* development of MEMS applications
* basic research in multiscale modeling methods for nano devices (PhD student)

Examples for the current research activities are the project "Design for reliability" (This project is focused on advanced techniques for indirect stress monitoring in MEMS manufacturing process based on test-structures. It utilizes a data fusion process that combines numerically calculated and experimentally determined data to estimate stress variation) and the project "IMU-MOCAP" (This project deals with the inertial motion, orientation and position capturing based on miniaturized MEMS inertial sensors. The department is specialized in design and development of a two axis MEMS gyroscope).





Measurement, Test and Characterization

The test and characterization group offers the development and utilization of test technologies, test strategies and the accomplishment of measurements.

The measurement of spatial parameters and mechanical stress is one of the biggest challenges in micro electro mechanical system (MEMS) test. Monitoring these parameters during the manufacturing process offers the possibility to react more quickly to process variations. Furthermore chips that do not meet the specifications can be selected even before the cost intensive packaging process has started. Often the production technology is very complex. A large number of sensors and other devices is fabricated in a wafer batch process. The biggest effort in manufacturing of MEMS is being caused by packaging and interconnection technologies, which also generate the major part of the costs of a device. Assuming a certain yield, a number of defective chips in addition to error-free ones will be assembled. To sort out these faulty devices before the packaging process can essentially reduce the costs of the entire MEMS product. Prerequisites are fast and reliable methods for wafer level testing of one hundred percent of the fabricated chips. These include the measurement of resonant frequencies, the determination and visualization of vibration mode shapes, as well as the identification of spatial parameters by combining measurement data with results from finite element analysis. Furthermore equipment and expertise for conducting surface, capacitance, insulation and resistance tests of MEMS are available.

In addition to conventional measurement technologies, the characterization of RF MEMS requires expertise in the microwave range and special test setups that can generate and detect RF signals. For precise measurements of devices with a high Q factor such as MEMS varactors, the parasitics must be eliminated. This is achieved by direct feed-in of the RF signals at the device under test using coaxial RF probes with an appropriate pitch (150 µm to 1250 µm), as well as comparative measurements (calibration) on known standards. Non-standard configurations are calibrated by using so-called “imperfectly known on-wafer standards”, which are typically manufactured in association with the device under test. The operation of RF MEMS requires a controlled application of DC bias voltages, for which a software controlled four channel high voltage DC source is available. All measurements can be conducted on wafer, chip or circuit level. The multifunctional wafer prober enables a combined analysis of RF performance and mechanical characteristics (dynamic response and structural deformation) by using scanning laser Doppler interferometry or white light interferometry.

MEMS Packaging and Waferbonding

Today micro and nano systems (MEMS/NEMS) are integrated in almost every high tech or smart product. While the MEMS/NEMS themselves have matured significantly over the last decade to become commonplace products, packaging of these tiny sensitive components and systems has not been addressed thoroughly. Hence the packaging plays a significant role for the manufacturing costs at least. We develop solutions for exactly these packaging problems starting with zero level packaging on wafer level up to module or board level packaging. Different concepts are being worked on that imply the covering of the micro mechanical structure by using different bonding methods first and the interconnection and wiring of electrical signals as well. One main goal of our work is the development of packaging methods for any micro machined structures with low temperature approaches, which provides a hermetic protection of these structures against environmental conditions.

At Fraunhofer ENAS wafer bonding technologies like anodic or silicon direct bonding, eutectic bonding, metal thermo compression bonding, glass frit bonding, adhesive bonding and laser assisted bonding are applied to package sensor and actuator components as well as electronics at wafer level. One important point is the modification of the bonding partner's surface regarding the applied bonding technology. Actual research work is focused on decreasing the bond temperature below 400°C. A second emphasis is the nano scaled structuring of bonding interfaces like needles or pins. By forming and contacting densely allocated metal pins, it is possible to join micro devices at temperatures around 150°C. Furthermore nano scaled reactive multi layers were investigated for bonding especially to keep the heat away from the substrates. Through a very fast exothermic and self propagating reaction after initialization only bond interfaces were influenced by the soldering heat.
3D integration is of major interest for several applications in fields of microelectronics and MEMS technology especially for further miniaturization. Hereby chips are stacked vertically with electrical contacts through the silicon to minimize electrical path lengths and thus enhance the electrical and thermal performance as well as to minimize the chip size as well as parasitic capacitances. The fabrication technology comprises processes such as wafer thinning, Through-Silicon-Via (TSV) drilling/etching, TSV filling and wafer bonding. Together with our Back-End of Line department these 3D-integration technologies could be performed completely.

Surface modification and preparation respectively, dicing of different substrate materials as well as chip and wire bonding are main topics of our daily work. For chip bonding processes techniques like eutectic bonding or adhesive bonding and bonding layers like epoxies, ceramic adhesives or pastes as well as solders (Si/Au, Sn, Pb free) could be used. Also wire bonding equipment for ultrasonic bonding, thermo compression bonding and thermo sonic bonding is available. Several bond wires made of gold, copper, and aluminium with wire diameters between 32 µm and 250 µm and both ball/wedge and wedge/wedge contacts depending on the material could be processed. Therewith different kinds of lead frames, electronic packages and ceramic substrates as well as special formed substrates can be handled for prototype development.

At least it is possible to characterize and evaluate all the bonding results with the well known blade, micro chevron, and hermeticity tests as well as with optical (VIS, IR), ultra sonic, scanning electron and atomic force microscopy. Either as single technology step or as complex process flow every packaging work and characterization could be offered as service.

INTEGRATION OF AUTARKIC SENSORS FOR ENGINES CONDITION MONITORING

Alexander Weiß, Duc Bach, Reinhard Schubert, Thomas Otto, Thomas Gessner

Introduction

Current industrial trends in mechanical engineering and plant manufacturing address engines condition monitoring mainly to minimizing system failures. Appropriate machine elements therefore are seals since they can be found in nearly every machine. At this point, informations such as impermeability, temperature of the sealing lip or wastage of the seal, are important reliability parameters. Measuring these parameters preventive ensures a trouble-free working of the machine, and avoids cost-intensive down time or failures. The implementation of sensors, electronics for signal conditioning, wireless signal transmission (necessary due to rotating parts) and self-sustaining power supply allows an autonomous and efficient operation of those for various applications. Two different approaches of such seals (Simmering® with optical sealing function detection on air side, Radiamatic HTSII with sputtered platinum layer for wastage and temperature control) were developed in a jointly cooperation with Freudenberg Dichtungs- und Schwingungstechnik GmbH & Co. KG, Weinheim and Fraunhofer IZM, Berlin. In this paper the sensor system with optical sealing function detection is described in detail.

Sensors

The optical sensor system consists of an absorption system for the leakage which is placed behind the sealing (see [1]). During normal operation mode, the sealed media is not in contact with this absorption system. If damage or wear causes sealing function loss, permeated liquids are absorbed by the porous medium. Then the medium changes its optical characteristic (e.g. color, contrast, reflection), which is detected by an Infrared Reflective Interrupter.

Electronics

Main challenges while electronics design are high robustness and large scale integration, since the outer dimensions should not exceed r_i=20mm and r_a=30mm. Taking harsh environmental conditions in case of operation (gear) into account following requirements had to be fulfilled:

* temperature range: -40 to 100°C
* resistant against temperature cycles
* chemical resistance
* estimated lifetime: 10 years

An universal electronic layout thereby allowed us to implement various functions, e.g. rectification of the input voltage, rotation speed measurement, acquisition and interpretation of the sensor readings (wastage, temperature) as well as wireless transmission of the output data. Thereby internal wireless communication is achieved using synchronous serial data bus system (SPI).
Processed sensor parameters are transmitted every 3 seconds to an internal that is connected via cable to an external customer interface.

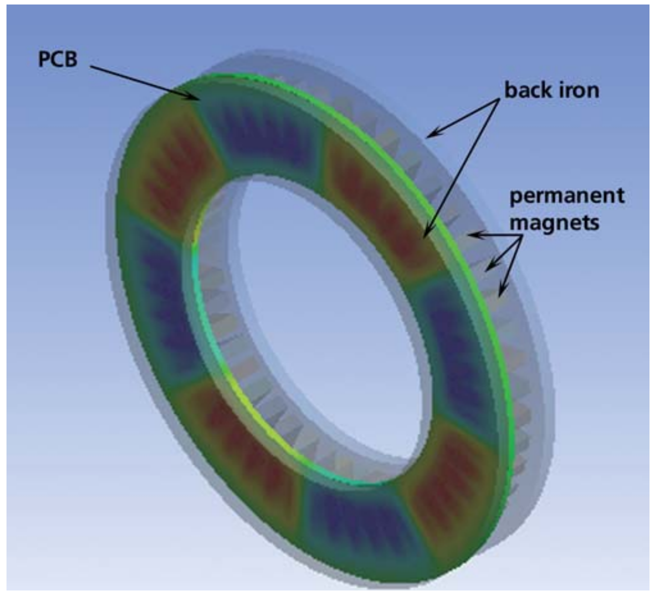


FIG. 2

Power Supply

Major requirements for supplying sensors and electronics autonomously with energy are the aspired power output over time and the operating temperature range. In case of dynamic measurements certainly signal transmission should be simultaneous. The effective power output for sequential

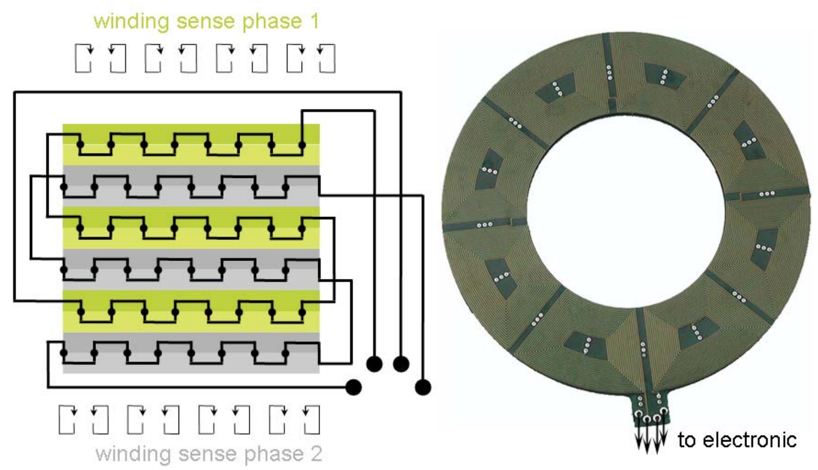


FIG. 3

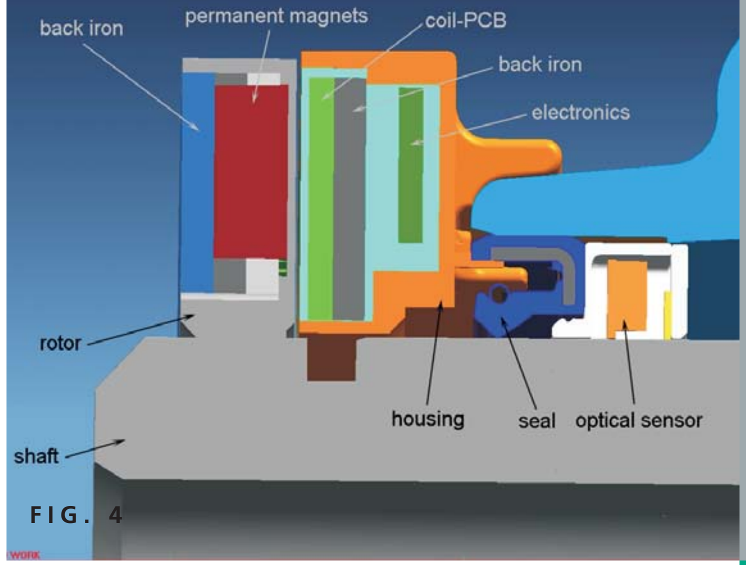


FIG. 4

FIG. 1

mode (1s measuring and 1s signal transmission) would be 100 mW permanent or alternatively approx. 170 mW every 3 seconds at 1000 rpm (supply voltage 3.3 V). Owing the high power output and the additional need for measuring the drive speed of the rotating shaft, the realized power supply matches an axial flux generator with a PCB as coil carrier. This type of generator is especially well suited for slim applications, since the cross section of the air gap compared with a radial flux generator is larger. In addition the ease of assembly is a further major advantage.

In general the axial flux generator consists of two main parts. On the one hand a rotor composed of 48 inversely arranged (number of pole pairs = 4) NdFeB-magnets (B_r=1.4 T; H_c=1140 kA/m) and a back iron (St37) for field forming and on the other hand stator consisting of the Coil-PCB (FR4) and another back iron.

By using ANSYS Multiphysics software, average flux density (Fig. 2) has been simulated for calculating the number of windings.

$$U_w = N \times \frac{\Delta j}{\Delta t} = N \times \frac{\Delta(B \times A)}{\Delta t} \qquad (1)$$

$$U_w = B \times p \times (r_a^2 - r_i^2) \times 2 \times N \times n \qquad (2)$$

For optimal impedance matching the internal resistance of the Coil-PCB was designed to be 100 Ω. Figure 3 shows a photograph of the PCB consisting of 850 windings for 2 phases and a principle drawing. Due to the field density, adjoined windings were wound in opposite direction.

System integration

Electrical contacting of the Coil-PCB, electronics and the optical sensor can be reached simply with contact pins. All electronic parts are encapsulated in a housing, which additionally assures trouble-free operation of the seal especially since it has to be lubricated permanently. The rotating part of the power supply is made of laser-beam cut brass and is mounted on the shaft by drive fit. Figure 4 shows a schematic drawing of the assembled system.

Conclusion

In this paper a seal with integrated sealing function detection, temperature measurement and rotation speed measurement is presented. Wireless transmission of the sensor data inside the gearbox by using conventional 2.4 GHz transceivers (IEEE 802.15.4 (Zigbee)) is achieved. The required supply voltage is generated by an axial flux generator at 1000 rpm.

References

[1] Schreiner, M.: Infrared Reflective Interrupter for Sealing Function Detection. OPTO&IRS² Conferences 2008 Proceedings, AMA Service GmbH, pp. 115-120.

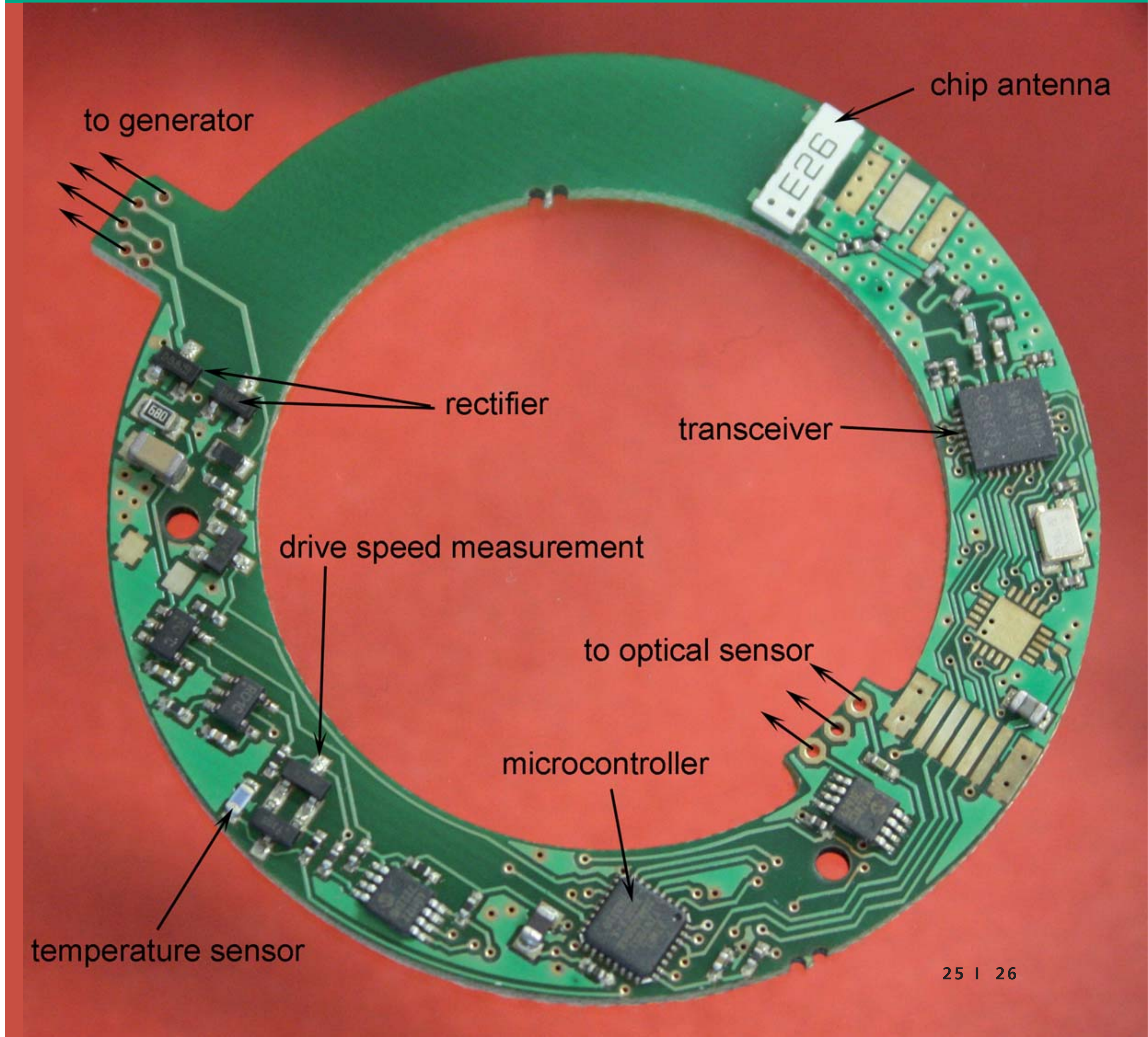
Legend

Fig. 1: Photograph of assembled electronics

Fig. 2: Flux simulation of axial generator

Fig. 3: Photograph of Coil-PCB

Fig. 4: Schematic drawing of integrated system



DEVELOPMENTS TRENDS IN THE FIELD OF WAFER BONDING TECHNOLOGIES

Maik Wiemer, Jörg Frömel, Chenping Jia*, Thomas Gessner
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One well established technology for the fabrication of 3D devices in microelectronics and micro system technology is wafer bonding. Several technologies like direct and anodic bonding without intermediate layer or wafer bonding processes with intermediate layers like low melting frit glasses, eutectic materials, polymers as well as thermo compression bonding approaches were developed during the last years and are nowadays extensively used in industrial applications. Important aspects during the process control are the substrate requirement, treatments for the modification of material surfaces, various bonding parameters and their process integration as well as the reliability. Figure 1 shows a rough classification of wafer bond techniques.

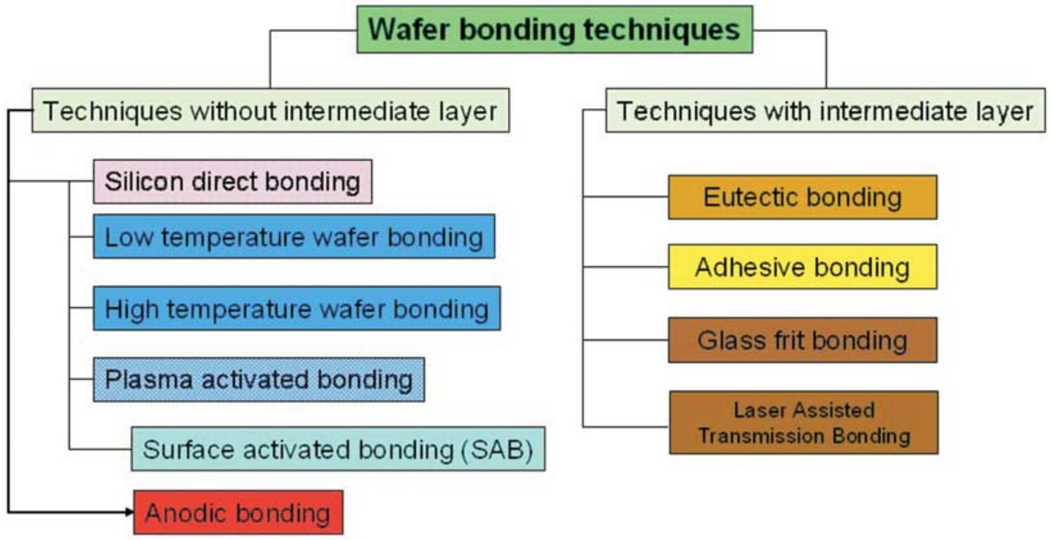

FIG. 1

The development trends in the field of wafer bonding are focused on low temperature bonding with temperatures below 400°C for metallic and nonmetallic layers, on the use of bonding for integration of mechanical, optical, electronic and fluidic components into applications for microelectronics and micro mechanics and on the bonding of different material to form new types of material stacks. That's why new developments will address aspects like bonding with plasma pretreatment, use of nanostructures for bonding, metal to metal bonding, integration of new materials to form special SOI substrates and new materials to optimize bond conditions.
Main aspects for the reliability of wafer bonded devices are the yield after bonding, the bond strength and the hermeticity as well as the suitability for the packaging processes (e.g. moulding). The main method to evaluate the bond strength is the micro chevron test. This test requires special designed test samples and is destructive. For anodic bonding between transparent glass and silicon a non destructive bond strength test structure can be used. The hermiticity can be tested by using resonant structure inside of the cavities which change the quality factor of the structure in dependence on the pressure inside of the cavity.

Two relatively new bond techniques will be introduced. These are the direct bonding between Ti-Si and a selectively usable laser assisted transmission bonding.

Recently, thermo-compression bonding that uses metal as intermediate layer has raised much interest [1]. A relatively new technique in this field is the Ti-Si bonding. Because metals have good conductivity, the same layer of metal that is used as bonding frame, can also be used as wires and electrodes, so that electrical-connections and packaging can be realized in the same process step. That is why the Ti-Si bonding technology was used for the fabrication of capacitive ultrasonic transducer.

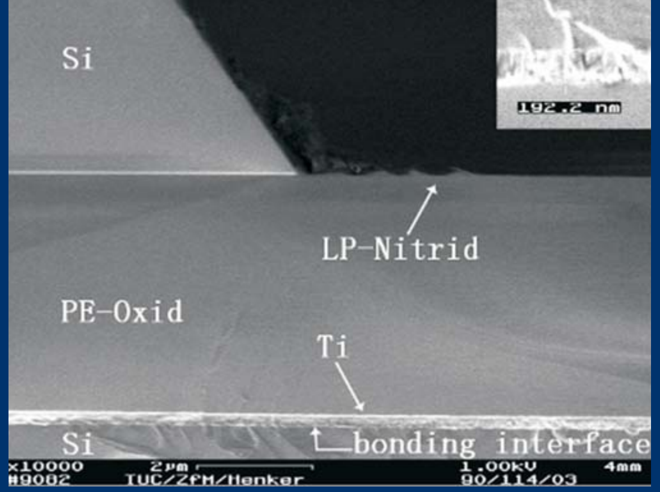

FIG. 2

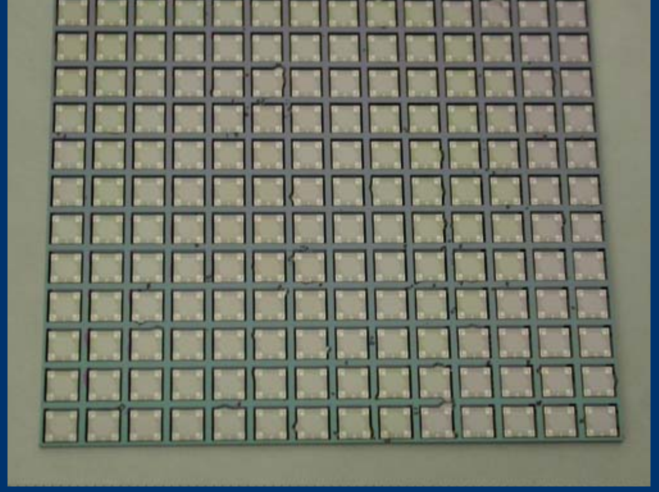

FIG. 3

For the fabrication process single side polished 4-inch (100)-type Si wafers are used. First, 500nm thermal-oxide is grown on the wafer. Next, 600nm Al and 4um PE-SiO$_2$ are deposited and patterned to form conductors and dielectric insulation. After that, 200nm Ti is sputtered on the wafer surface.
This layer is then patterned into bonding frames through lithography process. In following step, the wafer is contacted and bonded with a counter silicon wafer. Depending on the thickness of the embedded Al wires, an optional CMP step may be used to planarize the wafer surface, so that flat and smooth contact regions can be formed, which significantly improves the bonding quality. Actual bonding process is carried out in a wafer bonder in vacuum, with 3kN down force applied. After bonding, the wafer stack is annealed at 400°C for 2 hours to increase the bonding strength. Figure 2 shows the cross-sectional SEM of an ultrasonic transducer, which is fabricated with the help of this method. Figure 3 shows the successfully realized transducer array ready for wire-bonding and testing. The results show that Ti-Si thermal compression bonding is suitable for non-flat bonding surfaces. It can relax the roughness tolerance of bondable surface to 1~2 nm.

A second bonding technique which can be used selectively, without heating of the whole substrate, is the laser-assisted transmission silicon to silicon bonding [2]. This process is a joining method based on the transmission heating of the interface of the sample pair to be joined and also based on the thermo-chemical principles of silicon direct bonding. With laser-assisted transmission bonding, the laser radiation is transmitted through the upper sample and absorbed by the lower sample. Thereby the laser radiation is converted into heat energy. The bonding zone at the interface is heated so the chemical reactions can be induced. A metallic interlayer with a thickness of 50 - 100 nm is coated on one of the samples and the sample pair with the interlayer shows an absorbing capacity of approx. 25%. Blank silicon samples and, in addition, thermally oxidized silicon samples (oxide layer thickness 1500 nm) and silicon nitride coated silicon samples (layer thickness 200 nm) are combined with blank silicon samples. The achieved bond results (Fig. 4) show in general the applicability of lasers combined with the transmission joining technique for the bonding of silicon and silicon.

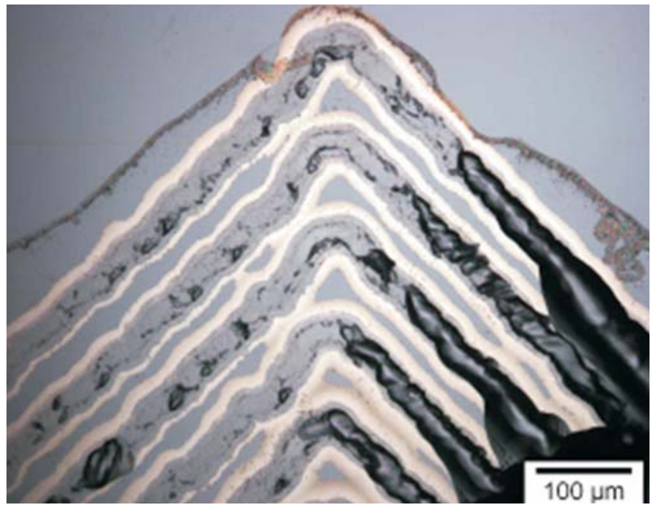

FIG. 4

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[1] Yu, J. etc.: Low Temperature Titanium-Based Wafer-Bonding Ti/Si, Ti/SiO$_2$, and Ti/Ti. Journal of the Electrochemical Society, 154(1), pp. 20-25, 2007.

[2] Sari, F.; Wiemer, M.; Bagdahn, J.: Laser assisted transmission bonding. Conference on waferbonding for MEMS technologies and wafer level integration 2007, Halle.

Legend

Fig. 1: classification of wafer bond techniques
Fig. 2: Ti-Si bonding interface
Fig. 3: ultrasonic transducer array
Fig. 4: silicon sample after micro chevron test

DEPARTMENT MICRO MATERIALS CENTER CHEMNITZ

Head of the department: Prof. Dr. Bernd Michel

Competences

- mechanical and thermal reliability (microreliability, nanoreliability)
- lifetime analysis and reliability optimization
- fracture research and crack avoidance strategies
- micro and nano materials testing and characterization
- microDAC, nanoDAC, and related local deformation analysis
- nanotom computer tomography for reliability analysis
- reliability simulation, FEA analysis, molecular modelling, etc.
- microsecurity – security research using micro and nano technologies
- reliability analysis for solar energy applications
- thermal reliability and cooling strategies for microsystems
- reliability of medical systems
- reliability of automotive electronics and aeronautics
- clean technology reliability, safety, and security assistance systems
- long-term reliability and accelerated testing of materials and components
- complex interactions (humidity, thermal, mechanical, vibrations, electro-magnetic, etc.)

The primary research field of the Micro Materials Center Chemnitz (MMCC) is the thermo-mechanical reliability analysis and evaluation of failure and lifetime of micro and nano components and systems, e.g. for automotive, semiconductor, aeronautic and aerospace, medical, solar-energetic, security and several other fields of high-tech applications.

Microsecurity is one of the new fields of the department's activities.
All problems related to "thermal misfit" ("thermal mismatch") effects can be simulated, studied experimentally and also optimized with respect to lifetime and costs.

The simulations are based on most modern calculation methods (e.g. fully parametrized Finite Element Analysis combined with DOE optimization tools (DOE – Design of Experiment)). Any kind of complicated field interaction can additionally be taken into account in the reliability and lifetime analysis, e.g. mechanical, thermal, electrical, magnetic, diffusion, radiations, humidity, vibrations etc..

Advanced experimental techniques are available and have been used for numerous experimental verifications for contracts with industry and research projects in Europe and worldwide.
The following experimental methods are coupled with the simulations (selection):

- grey value correlation techniques based on digital image correlation method (DIC), e.g. microDAC, fibDAC, AFM DAC, etc.
- thermo-mechanical testing and DMA, TMA, and related materials testing
- cyclic tests coupled with vibrations, humidity, temperature, etc.
- fracture and crack analysis and crack avoidance experiments
- nanotom computer tomography analysis for reliability estimation
- x-ray stress and selfstress analysis
- micromoire, laser scanning, FIB and EBSD analysis
- lock-in thermography and electro-thermal testing and characterization methods
- acousto-microscopy coupled with thermal and mechanical testing tools
- accelerated testing combined with lifetime concepts and reliability estimation
- video-metallographic investigations
- micro Raman and nano Raman micro deformation analysis combined with other experiments and with simulation
- nano indentation experiments combined with reliability and lifetime prognosis
- vibration analysis (e.g. laser vibrometry) combined with reliability calculations

In a mine near Chemnitz, the department Micro Materials Center also operates a longlife reliability lab for high-tech electronics, sensor and MEMS testing (prescribed mechanical, thermal and humidity environment, accelerated testing).
The Lab is part of the European KeyLab on Micro- and Nanoreliability in the framework of EUCEMAN – the European Center for Micro- and Nanoreliability (see www.euceman.com).

Outstanding internationally recognizes results have been achieved in thermo-mechanical simulation of packaging and interconnection technologies for chip based systems (semiconductor electronics, automotive selectronics and sensorics, aeronautic applications).

The experience of MMCC in the field of solder reliability and life-time estimations of solder interconnects has found worldwide reputation too. Outstanding papers on important international conferences, workshops and meetings in London, Paris, Singapore, Vienna, Berlin, San Diego, Boston, Oxford and others in the last year confirm the acceptance of the reliability approach of MMCC.

The newly established activities in the field of "Microsecurity" and "Nanosecurity" have become an interesting field of applications for modern micro and nano technologies. Methods of digital image correlation techniques, x-ray diagnostics by means of energy-dispersive analysis have been developed together with various SMEs and companies to develop new security assistance systems using modern microtechnologies and advanced methods of local field analysis in direct combinations.
Advanced methods of local deformation analysis are a mayor experience in MMC, e.g.

- deformation analysis by means of x-ray diffraction and EBSD
- microDAC and nanoDAC local strain analysis with various techniques (e.g. FIB, AFM, SEM, etc.)
- deformation and selfstress analysis by Focus Ion Beam technique
- micromoire deformation analysis
- nanotomographic field estimations
- acoustic AFM (AFAM) deformation analysis
- lock-in thermografic and deformation analysis
- strain field analysis in cyclic chambers of many kinds (humidity, etc.)
- acoustic stress, strain and delamination analysis
- classical methods of deformation and fracture analysis
- humidity sensitive SPM/AFM testing technique

In the field of simulation for reliability of automotive components in the frame of collaboration with companies Bosch, Toyota, Conti, VW, BMW, Daimler et al interesting results have been obtained for various applications. Together with companies as AMD, Infineon, NXP, SUN, EADS, SONY, Thales, IBM et al. interesting results for reliability assessment for various micro and nano systems have been obtained. The simulations have been directly coupled with the experimental techniques mentioned above mainly based on local deformation and temperature field analysis.

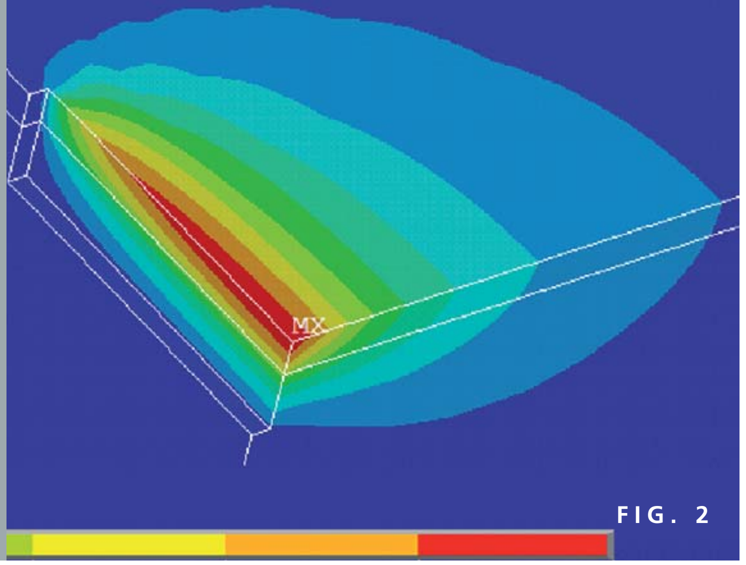


FIG. 2

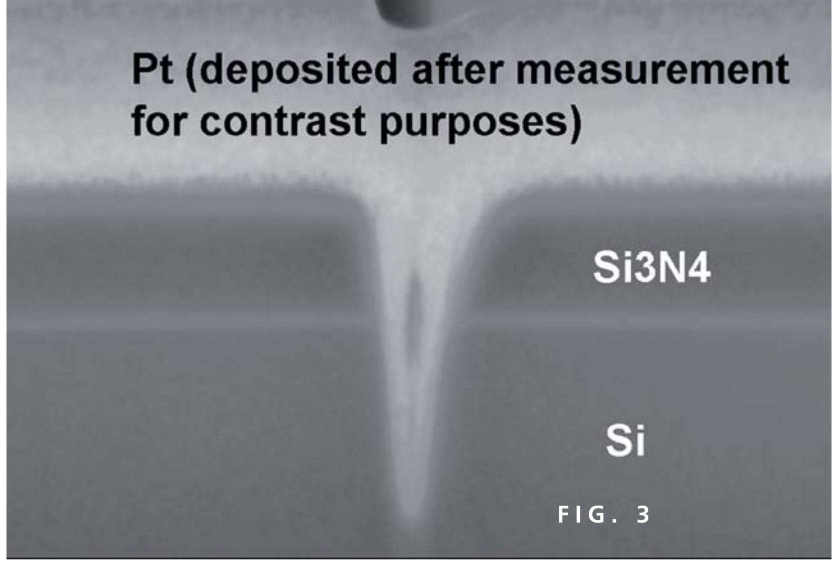


FIG. 3

CRACK- AND DAMAGE EVALUATION IN LOW-K BEOL STRUCTURES UNDER CHIP PACKAGE ASPECTS

Jürgen Auersperg, Dietmar Vogel, Bernd Michel

The electronic industry drive for miniaturization and increasing functional integration forces the development of feature sizes down to the nanometer range. Moreover, harsh environmental conditions and new porous or nano-particle filled materials introduced on both chip and package level (in particular low-k and ultra low-k materials in Back-end of line (BEOL) layers of advanced CMOS technologies) cause new challenges for reliability analysis and prediction.

New activities have been started in this context combining experimental and numerical methods towards optimized fracture resistance of those structures under chip package interaction aspects. Integral bulk and interface fracture concepts, VCCT and cohesive zone models in multi-scale and multi-failure modeling approaches with several kinds of imperfections have been applied.

As important preconditions for high-quality simulations, nanoindentation AFM, FIB and EBSD provide the desired properties, while FIB-based trench techniques using deformation analyses by grayscale correlation and numerical simulations provide the intrinsic stresses especially of thin films in BEOL layers.

The approach takes several aspects into account:

1. Multi-scale modeling utilizing substructuring and submodeling techniques within the "conventional" finite element method, as well as the consideration of the close neighborhood of structural dimensions in design and morphology of newly developed materials in BEOL layers of advanced Cu/Low-k 90, 45…32 nm CMOS technologies (grain sizes, size-dependent material properties). This is of greatest interest for new developments in CMOS downscaling technologies from actually 45 nm to 22 nm structures and requires to further progress the application of advanced molecular dynamics methodologies together with hybrid approaches, coupling it with finite element methods. Ways appropriate in this context are the direct coupling via homogenization in unit cells as well as the extraction of material properties.

2. Multiple failure mode evaluation for overload prevention and thermo-mechanical fatigue evaluation of inelastic and viscoplastic materials and bimaterial interfaces – modified Coffin-Manson-approaches, adapted Paris-Erdogan-approaches evaluating the damage propagation as well as the life time.

3. FEA-based Design of Experiments (DoE) and optimization with respect to multiple simultaneously existing failure modes. This demands for parameterized models, allowing the variation of designs, interconnect technologies, geometry parameters, material properties and manufacturing conditions (cure conditions, thermal treatment control and sequential build up) and model preparations for failure evaluations (CZM- und VCCT-elements, damage models, J-integral contours).

4. Residual stresses in the back-end layer stack caused by the different manufacturing processes have an essential impact on damage behaviour, because they superpose functional and environmental loads. Their determination with a spatial resolution necessarily for typical BEOL structure sizes is a critical issue. A determination of residual stresses by means of finite element simulations is problematic due to the large amount of process steps to be considered. Well established measurement methods either do not exhibit the necessary spatial resolution or show other limitations. That is why new stress measurement methods with high spatial resolution are developed at the Fraunhofer ENAS: Among them are nano-scale stress relief techniques (fibDAC), nanoRaman and electron backscattering (EBSD) based approaches. E.g., the fibDAC makes use of tiny trenches placed with a focused ion beam equipment at the position of stress measurement. Digital image correlation algorithms applied to SEM micrographs captured before and after ion milling allow to conclude on stresses released.

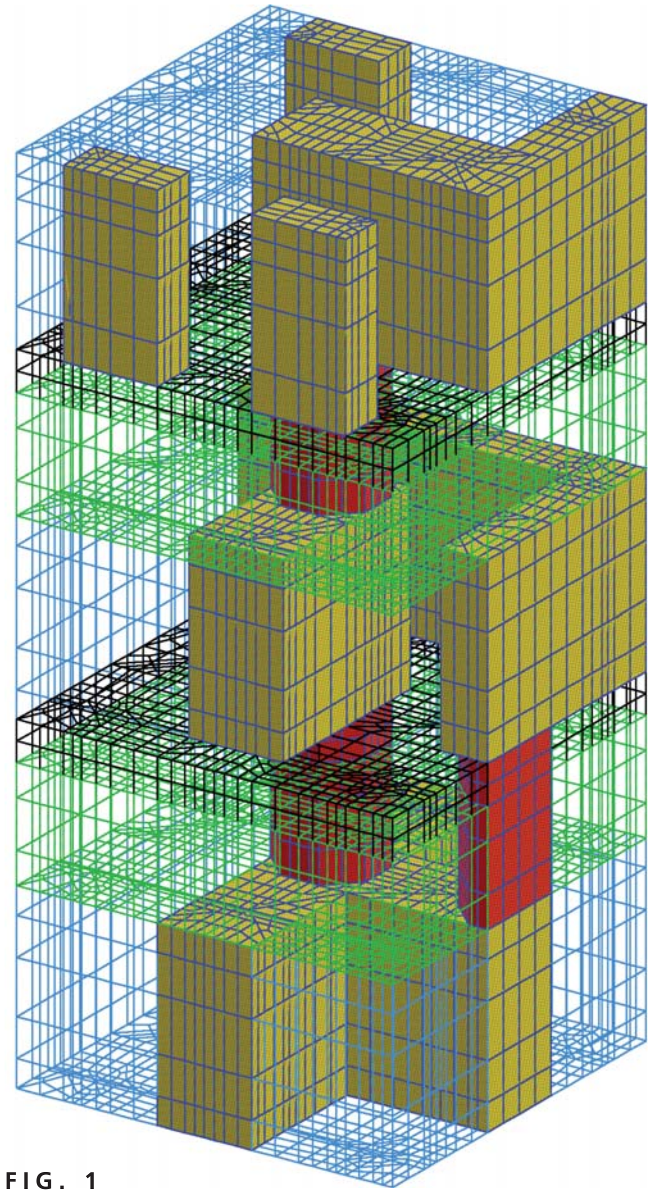


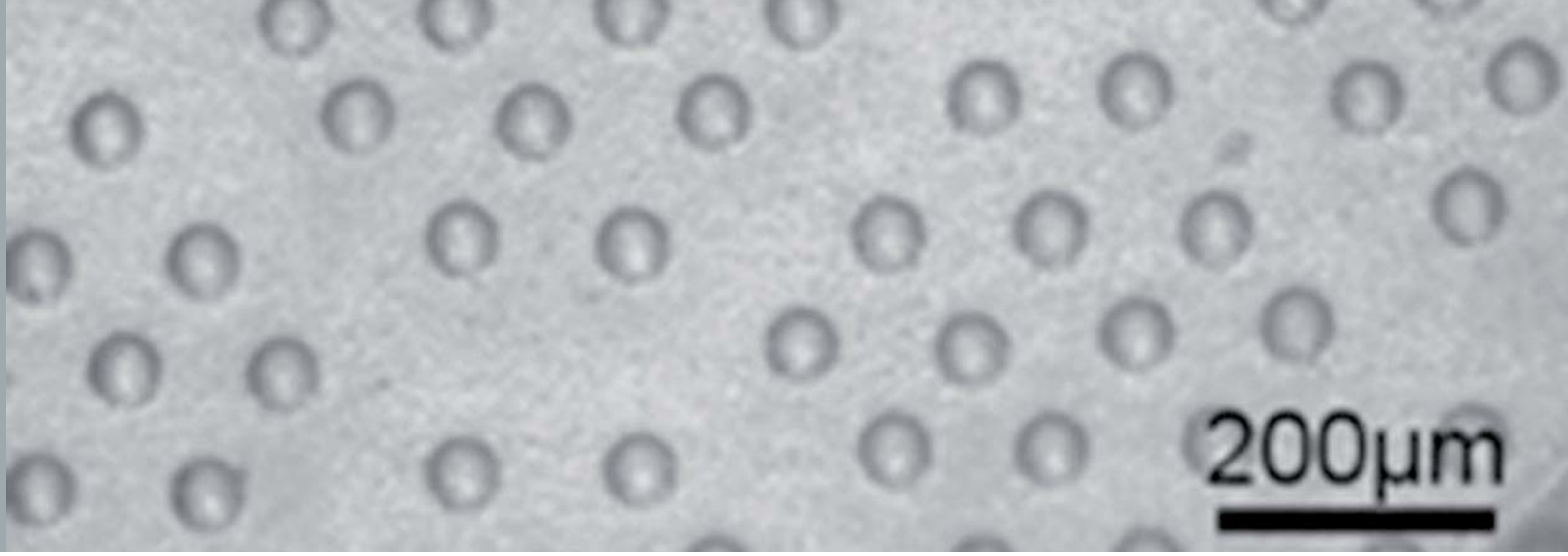
FIG. 1

Legend

Fig. 1: Local FE model – detail of a BEOL structure

Fig. 2: Measured deformations nearby trenches are compared with finite element simulations in order to extract residual stresses.

Fig. 3: Trenches milled by focused ion beam equipment cause measurable local stress relief



DEPARTMENT PRINTED FUNCTIONALITIES

Head of the department: Prof. Dr. Reinhard Baumann

The department Printed Functionalities focuses on printing technologies for the manufacture of printed products which do not solely address the human visual sense. These printed 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.

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 applied by using special effect finishing processes. Special vanishing techniques enable the printer to apply haptic elements to his products. Using special inks containing micro-encapsulated odorous substances even the human sense of odor 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 foil or sheet metal. The print quality is satisfactory 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 imagewise coating technology to deposit functional materials only at the right position on an appropriate substrate.
Which means printing is an additive technology in contrast to subtractive technologies, characterized by coating the substrate with a continuous material film initially and remove the material imagewise 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, 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.

We expect a growing number of printed functionalities which in many applications will be supplemented by silicon-based micro and nano systems which are likewise developed in the Fraunhofer ENAS labs.

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.

In the Fraunhofer ENAS department Printed Functionalities we cope with these challenges. We employ traditional and digital printing technologies to manufacture these 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 industrial and academic partners.

Competences:

- printed functionalities: conductivity, semi-conductivity, insulation, energy accumulation, catalysis, light based energy conversion
- printed smart objects with integrated micro and nano systems
- device prototyping and industrialization of their manufacturing
- characterization of inks, functional layers, components and systems

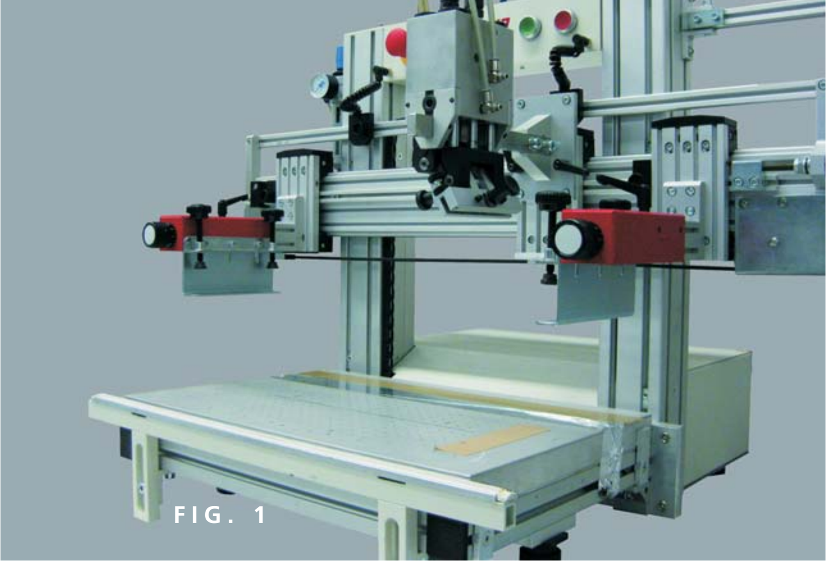


FIG. 1

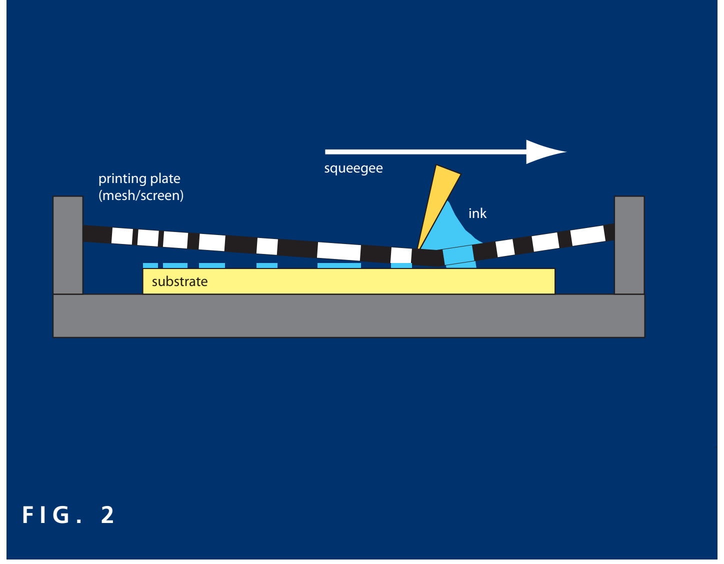


FIG. 2

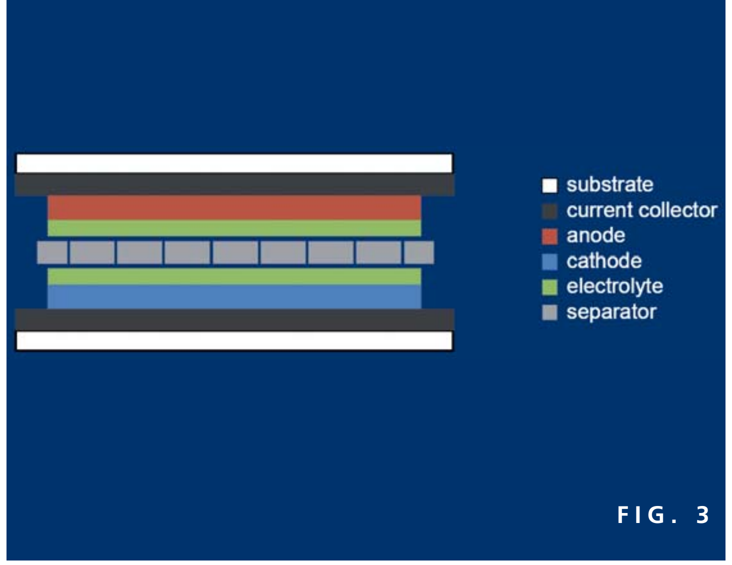


FIG. 3

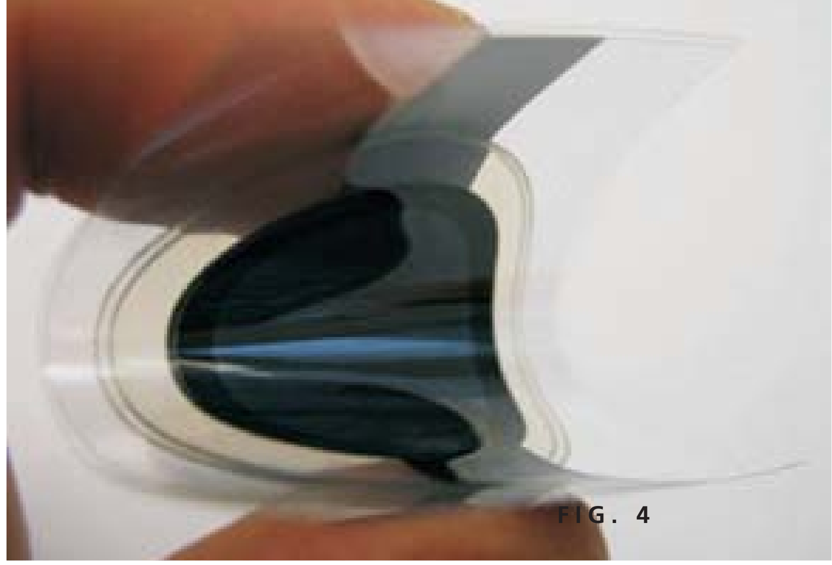


FIG. 4

LAB-SCALE OF BATTERY MANUFACTURING BASED ON PRINTING TECHNOLOGIES

Reinhard Baumann

Abstract

Parallel with the number of distributed autonomous electrical devices and components the demands for adapted electrical power sources will increase considerably. Especially smart systems require a tailored energy source which meets the appropriate amount of energy stored and the required shape to be integrated. These energy sources can be manufactured efficiently using printing technologies. In this paper we report on an approach to manufacture primary batteries employing printing technologies. We describe the setup of the battery, the print process and the characterization of the batteries manufactured on the lab-scale.

Introduction

Today electronic applications have become ubiquitous and will be found in all areas of the daily life [1]. This requires matching energy sources with high flexibility in regard to thickness, geometrical shape, voltage, capacity and weight. Applying the appropriate functional materials to flexible substrates will open new opportunities to integrate e.g. batteries into ductile products. A remarkable gain in productivity can be achieved if the functional materials are processed by printing technologies integrated in the product manufacturing line. Printing technologies are characterized by versatile flexible substrates (paper, plastic foil, textiles …), high throughput, high application accuracy and cost efficiency based on its additive nature. These technologies allow the imagewise application of appropriate functional materials, which have to be formulated as printing inks.

We report on approaches to manufacture batteries employing printing technologies to get ready to meet future demands regarding the autonomy of electronic devices. These might be e.g. intelligent chip and sensor cards, medical patches and plasters for transdermal medication and vital signs monitoring, as well as lab on chip analysis devices. The combination with other thin and flexible modules is intended whereby flexible displays and solar cells may be manufactured in a compatible manner and combined where required.

Manufacturing

The lab-manufacturing of primary and secondary batteries was accomplished by using semiautomatic sheet-to-sheet screen printing and blading processes using a table top screen printer Alraun AT 301, Fig. 1. Among other printing technologies screen printing allows the application of relatively thick layers and enables the printing of a wide variety of materials using specially formulated inks [2]. Thus, the screen printing of metal grain based electrode materials seems to be reasonable. The principle of screen printing is shown in Figure 2.

For the battery system the different battery components were applied layer by layer onto a flexible plastic substrate. The primary battery under discussion is a zinc-manganese system. As a first step the current collectors were printed onto a 50 µm thick PET (polyethylene-terephthalate) foil. After drying the first layer the positive and negative electrode material was printed onto the current collectors. The electrodes consist of manganese dioxide (positive) and zinc-based (negative) inks which were dried after their application. Subsequently both, positive and negative electrodes were coated with an electrolyte (based on zinc chloride) using a doctor blade.
In the finishing step the batteries were encapsulated with high-performance adhesive tape (3M) using a proprietary assembling technique. The design scheme is shown in Figure 3.

Results

The printed primary batteries are very thin and lightweight. A battery with a nominal voltage of 1.5 V has a thickness less than 0.6 mm and weights 0.75 g. Because the batteries are printed onto plastic foils they have the advantage of being flexible (Fig. 4) and the potential to be manufactured in a roll-to-roll printing process. Due to the characteristics of the involved materials the battery system is considered to be environmentally friendly.
Batteries are being characterized by their capacity and discharge characteristics. The data measured for a laboratory sample is given in Table 1 and Figure 5.

Characteristics of the Zn-MnO$_2$ battery	
Nominal voltage	1.5 V
Nominal capacity	2 mAh/cm²
Discharge current	10 µA

Tab. 1: characteristics of Zn-MnO$_2$ battery

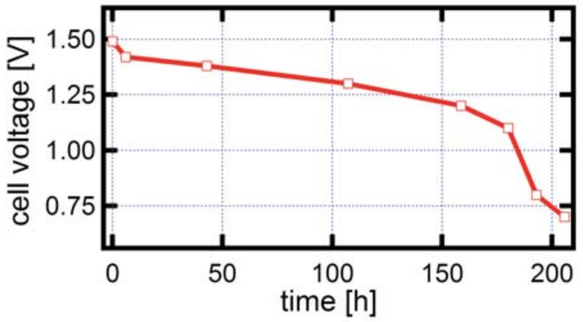


FIG. 5

A discharge curve of a printed primary battery is shown in Figure 5.

Conclusions

The reported approach constitutes the basis for future developments towards a roll-to-roll fabrication of printed batteries although today some of the material application steps still have to be transformed into printing techniques. This opens new routes to integrate battery manufacturing into mass production of smart systems such as printed smart products. Thus, an assembly of printed batteries and devices, e.g. sensors, data loggers or RFID applications will be possible in the near future. Next steps in research will be further performance enhancements of the batteries by improving the appropriate materials and their interaction.

References

[1] Dennler, G. et al.: A self-rechargeable and flexible polymer solar battery. in: Solar Energy, H. 8, 2007, p. 947-957.

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

Legend
Fig. 1: Screen printer Alraun AT 301
Fig. 2: Principle of screen printing
Fig. 3: Design scheme of printed battery
Fig. 4: Printed primary battery with a nominal voltage of 1.5 V (Photo: Roman Timm)
Fig. 5: Battery discharge curve

DEPARTMENT BACK-END OF LINE

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

Short Portrait

The Back-end of line (BEOL) in semiconductor processing and micro / nanoelectronics comprises the processing steps from contact level through to complete processing of the wafer prior to electrical testing, in other words, the entire interconnect system, including passivation.

The department BEOL works in close collaboration with the Center for Microtechnologies (ZfM) at the Chemnitz University of Technology on developing materials, processes and technologies for interconnect systems as well as on modeling and simulation of processes, equipment and interconnect systems. Application areas are micro and nano electronics, MEMS/NEMS, and 3D-integration. In the field of 3D-integration a strong collaboration with the Fraunhofer IZM departments "Si-Technology and Vertical System Integration" and "High Density Interconnect & Wafer Level Packaging" exists. The main competences and long-term experiences of the department BEOL are in the fields of:

* low-k and ULK dielectrics
* metallization for micro and nano electronics
* metallization for 3D-integration
* airgaps for low parasitic capacitances in nano interconnect systems
* process and equipment simulation and modeling
* simulation and modeling of interconnect materials and systerms
* planarization and surface modification for BEOL and MEMS/NEMS fabrication

Special emphasis is placed on integrating low-k and porous ultra-low-k materials with material properties that require a modified integration pattern into copper damascene interconnect systems adapted to the respective material. For successful integration of those materials especially etching and cleaning techniques, low down force barrier and copper CMP, k-restore processes after patterning and diffusion barrier compatibility 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 continue to be developed, currently in particular airgaps. Here, not only the potential for manufacturing airgap structures is investigated, but also their electrical, thermal and mechanical impact on the interconnect system. Two approaches for wet etch removal of the sacrificial SiO_2 have been developed, called "Spacer" and "Mask" approach. Process step and technology development and optimization are accompanied by electrical, mechanical and thermal modeling and simulation of airgap containing interconnect systems.

3D-integration requires to metallize mostly 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) different geometries can be addressed for 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 gained knowledge and experience of the simulations are made available for our customers and partners to optimize process parameters and equipment.

Trends

Ongoing downscaling has led to numerous diversifications of the interconnects systems over the past decade, depending largely on the product concerned. While transistors operate faster as their dimensions shrink, interconnects increasingly limit this gain in speed. The resistance-capacitance product (RC product) of the interconnect system rises with reduced dimensions, and thus also the signal delay. Suitable materials can contribute to a resistance and capacitance decrease and therefore compensate for the performance loss in the interconnect system. The past decade was affected by the introduction of copper technology and low-k dielectrics. Further innovations and challenges are expected in the following years from the employment of porous ultra low-k dielectrics and the accompanying new processes required, such as atomic layer deposition (ALD) for ultra-thin films. By further scaling copper interconnects, increasing line via and resistance will appear to be dramatic facing sub 30 nm dimensions. Intensive efforts in material and interface engineering as well as modeling and simulation of nano interconnects will be necessary to address this issue. Future devices will implement nano structures like Carbon Nanotubes (CNT), which is addressed by fundamental research in this area.

Furthermore, the trend to explore the third dimension will require adaptation of existing interconnect technologies, e.g. to Through-Silicon-Via metallization, and development of advanced processes like CVD barriers and seed layers for very high aspect ratios. 3D-integration will play a major role in further increasing integration density by chip stacking as well as building smart multifunctional systems combining different technologies.
Fraunhofer ENAS as a competent partner is ready to address these challenges.

Competences

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

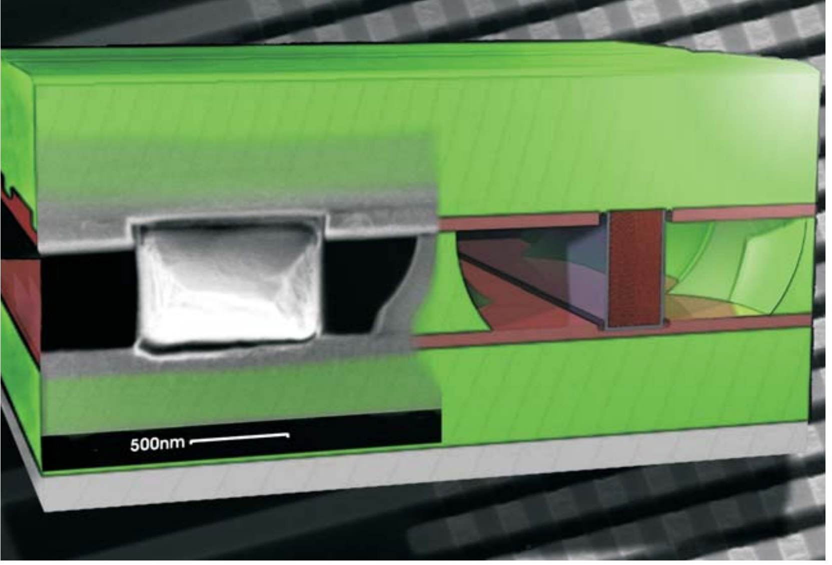
* low-k dielectrics
* metallization for micro and nano electronics
* metallization for 3D-integration
* airgaps for low parasitic capacitances in nano interconnect systems
* process and equipment simulation and modeling
* simulation and modeling of interconnect materials and systems
* planarization and surface modification for BEOL and MEMS/NEMS fabrication

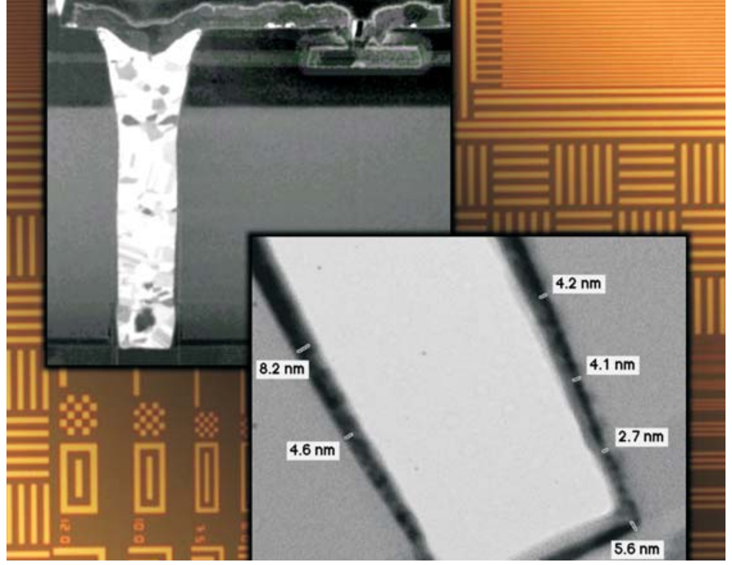
Services

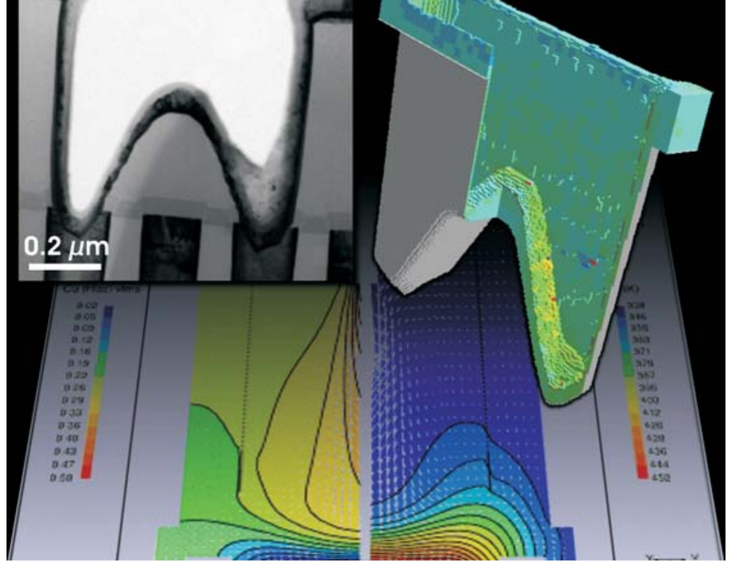
We offer the following services:

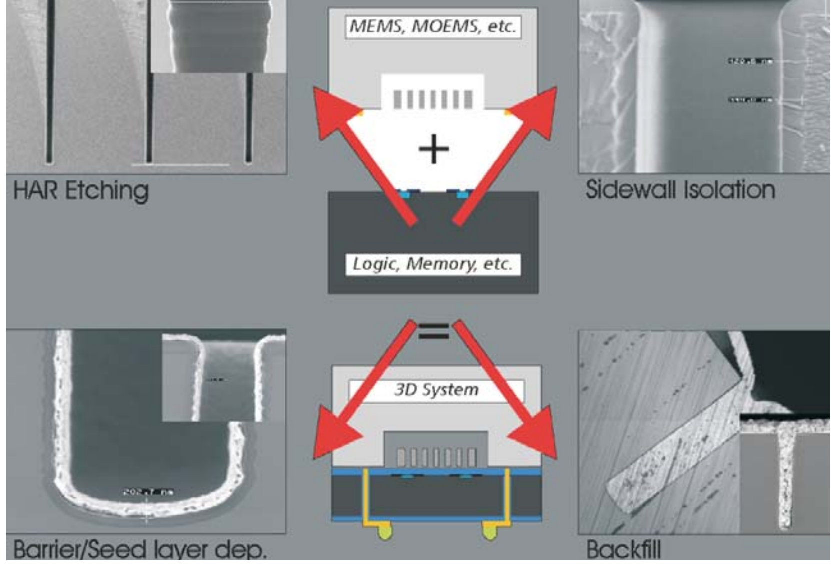
* wafer processing (deposition, patterning, planarization)
* thin film measurement and characterization
* R&D service for processes and technology development
* in-situ process diagnostics
* modeling and simulation of processes and equipment
* modeling and simulation of interconnect materials and systems

related to the fields described above.









On-chip Interconnects

Airgap Structures:

Within the European Integrated Project PULLNANO the work of the Center for Microtechnologies ZfM and Fraunhofer ENAS focussed on feasibility studies for the integration of air gap structures starting with relaxed pattern dimensions. Lifetime measurements have been carried out on airgap structures according to the sacrificial layer approach, developed at the ZfM and Fraunhofer ENAS. The sacrificial layer SiO_2 is removed by buffered hydro acid solution (BHF). A comparison of airgaps and Cu/SiO_2 integration without sacrificial etch showed comparable results in electromigration failure rates and no significant difference.

Investigations of the mechanical behaviour of airgap structures (using up-to-date node geometries) by FEM simulation during the encapsulation of airgaps (CVD film deposition), exposure to air and CMP treatment have shown distinct loads to cantilever films and interfaces of the interconnect system.

Nevertheless, compared to critical yield stress and interfacial adhesion strength, these loads are non-critical and give no remark for any interface delamination or collapse of the cantilever films.

Low-k Integration:

In the field of low-k materials and low-k processing a strong collaboration existis with AMD/GLOBALFOUNDRIES and partly with Air Products in the frame of the projects PRIMER, VERBINDEN/KUWANO and PULLSAR. Improvements in optical, mechanical, electrical and structural properties of porous SiCOH low-k dielectrics (k-value 2.2 - 2.5) resulting from optimized deposition and curing conditions have been analyzed. An fluorocarbon based etch process and a SiCOH compatible resist strip process using reducing chemistry with a minimal process induced damage of via and trench sidewalls have been developed for porous SiCOH and for dense SiCOH dielectrics. Using in situ diagnostic methods, e.g. guadrupole mass spectrometry, optical emission spectroscopy, laser absorption spectroscopy and a langmuir probe, the etch reaction, the formation of a surface polymer film and the damage of the low-k material by ions, radicals and UV radiation have been analyzed more intensively.

Wet chemical cleaning processes for etch residue removal have been investigated regarding wetting conditions, low-k- and Cu/CoWP-compatibility. It was found that low surface energy solutions are needed to efficiently wet and remove low-energetic residues. Most of the commercially available cleaning solutions provided by Air Products showed good compatibility to low-k dielectrics and copper.

The restoration of low-k dielectrics damaged by plasma processes (ashing and etching) by using silylation in combination with UV-curing has been investigated (project PRIMER, cooperation with Leibniz Institute of Surface Modification IOM, Leipzig). The selection of the UV-wavelengths for curing was found to be critical, because high energy radiation additionally introduced a network destruction of the treated low-k material.

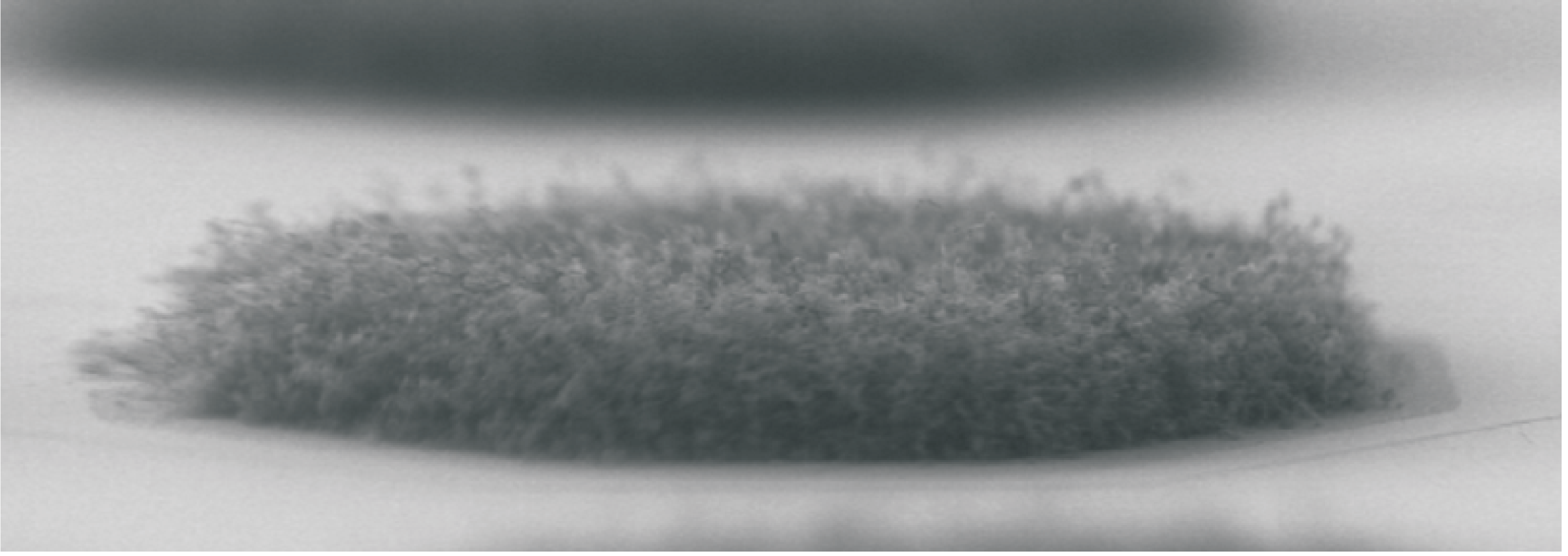
Simulation and Modeling

In the frame of the 3-year R&D project SIMKON, multi-scale modeling of CMP has been performed in cooperation with Qimonda in Dresden. Main focus of research was modeling of fundamental interactions between pad, slurry, and wafer based on physical simulations of elasticity, roughness, and conditioning of the pad. In cooperation with AMD/GLOBALFOUNDRIES in Dresden, several investigations have been carried out regarding the scalability of PVD films and reliability parameters in the fabrication of present and future metallization systems. Multi-scale modeling of copper seed layer deposition by advanced PVD was carried out and the influence of process conditions and geometrical properties of via and trench structures on overhang formation, bottom and sidewall coverage has been studied using the simulation environment T2. The simulation tool has been developed further for the application to reactive PVD of Ta(N) based barriers. Necessary extensions are the implementation of models for the calculation of plasma properties such as composition, ionization of the constituents, and fluxes of ions to target and wafer, and for the description of particle-surface interactions at target, wafer, and reactor walls. Models for film growth and composition had to be implemented, too. The extended tool was applied to simulate the influence of nitrogen flow rate on deposition rate and uniformity. The consideration of the reliability of interconnect systems is focused on the understanding of dielectric breakdown and of the course of leakage current during the time before. Several models have been developed with the objective to investigate process-induced influences -
As copper line dimensions approach the electron mean free path the size effect becomes a major challenge for the continuous device scaling. Therefore, the electronic transport properties of nano-scaled interconnects as well as of gold and copper quantum point contacts have been investigated using the density functional based tight binding method. The electrical resistivity of copper interconnects with barrier and cap layers has been calculated by solving the Boltzmann transport equation for various transport mechanisms including electron-phonon scattering.

Metallization for 3D interconnects

Vertical (3D) system integration aims to achieve shorter signal paths, package size reduction and cost minimization by stacking chips of different kind. The involved key technologies are wafer thinning, wafer bonding and the fabrication of Through-Silicon-Vias (TSV). The latter comprises the etching of the vias and the backfill with conductive material. Due to the fact that these TSVs mostly have high aspect ratios (AR) there is a need for advanced metallization concepts. In general there are two ideas of TSV backfill. The conductive material could either be deposited by Chemical Vapor Deposition (CVD). This is done in case of via diameters smaller than 5 µm. For larger vias Electrochemical Deposition (ECD) is used for via backfill. Hereby CVD is used to deposit the required seed layer and for the deposition of a diffusion barrier between the via sidewall and the conductive material. With increasing AR the metallization of the TSVs is getting more challenging. For CVD this means worsening of the via step coverage of barrier and seed layers. A uniform seed layer in return is counted among the import factors for failure free backfill with ECD. Other impacts on backfill through ECD are the ECD chemistry the plating parameters, the pre treatment of the vias as well as the via geometry.

At Fraunhofer ENAS those processes for TSV fabrication are under investigation, e.g. in the project Smartsense.
Process optimization regarding step coverage is done for TiN barrier and Cu seed layer deposition with (MO)CVD. For TSV's with AR=4 a TiN-barrier step coverage of 74% could be reached. For Cu seed layers the achieved step coverage is 90% for AR=20. Moreover investigations regarding TSV backfill with Cu-ECD are carried out for different via geometries. The via backfill is examined for varying process parameters (current density, mass flow, chemistry). Vias with AR=9 have only small seams and vias with AR=4 show only small voids at the via bottom after deposition. Void free deposition is under further investigation.



Nanostructures, Nanomaterials

In the field of nano structures and nano materials, the PhD students at Fraunhofer ENAS and ZfM work on development of a copper atomic layer deposition (ALD) process and the integration of carbon nanotubes (CNT) in interconnect systems and/or NEMS. This work is basically done in the frame of the International Research Training Group (IRTG) "Materials and Concepts for Advanced Interconnects".
For deposition of very thin Cu films we use thermal ALD between 110 - 155°C from $[(^nBu_3P)_2Cu(acac)]$ and wet O_2 for growing oxidic copper films. To apply the ALD films as seed layers in subsequent electroplating processes, several reduction processes are currently under investigation. The most promising results so far were obtained used formic acid vapour at temperatures between 100 and 120°C, offering the benefit of avoiding agglomeration of the very thin ALD films. First investigations to ECD were carried out using 8 nm Cu ALD seed layer onto 100 nm Ru films. There are no differences in the process compared to 8 nm PVD Cu seed onto Ru film. However the growing process is significant better than on blanket Ru films.

For the integration of CNTs, two approaches are pursued, the direct CNT growth by chemical vapour deposition (CVD) in interconnect systems and the dielectrophoresis of CNTs for NEMS. For CNT growth by CVD we work with different metallic catalyst systems (single metallic like Ni or Co as well as bimetallic catalysts) and different precursor gases, e.g. ethylene or acethylene. The predominant aim is to grow vertical and densely packed CNT-arrays at low temperatures with acceptable structural integrity. In the project CoNTemp (together with Fraunhofer IZM Berlin) we realized CNT bumps, which were flip chip bonded to a NiAu bump. These CNT-metal bumps were electrical conductive with a contact resistivity of 2.2 'Ω and also stable under thermal cycling test.

The dielectrophoresis is more suitable for CNT integration in NEMS. High quality CNTs, selected into the required properties, were selectively deposited and aligned at low temperatures. The work is focused on CNT dispersions using different dispersing agents and cleaning and drying procedures.

INTEGRATION OF POROUS LOW-K DIELECTRICS FOR NANOELECTRONICS

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In recent years SiO_2 as interlevel dielectric has been replaced by ultra low-k materials to fabricate high performance integrated circuits with less cross talk and low power consumption. The industrial focus is on CVD-SiCOH materials which consist of a $SiO_{4/2}$-matrix with 10-15% of hydrophobic CH_3 groups. The incorporation of organic species decreases polarizability and moisture uptake, which leads to a much lower k-value compared to SiO_2. To achieve dielectric constants below 2.7 porosity is introduced. Typically porous SiCOH films have a porosity of 30-50% with an average pore size of 2-2.5nm [1].

Integrating porous SiCOH dielectrics faces a lot of challenges, especially looking at more and more decreasing feature sizes in nanoelectronics. At Fraunhofer ENAS the department BEOL intensively focuses on research and development of low-k compatible and damage free plasma etching and strip processes, wet chemical etch residue removal and restoration processes for damaged low-k dielectrics. In this field of research Fraunhofer ENAS successfully cooperates with Center for Microtechnologies ZfM of the Chemnitz University of Technology and the industrial partners AMD (now GLOBALFOUNDRIES) and Air Products.

Patterning of porous SiCOH materials: Optimization of low-damage plasma processes by in situ plasma diagnostics

The patterning of porous SiCOH dielectrics is usually done by reactive ion etching (RIE) using a CF-containing etch chemistry. Figure 1 shows the mechanisms occurring in the reactor during trench and via etching, with the low-k material before etching in Figure 1a and the reactive chemical etching in Figure 1c. During etching the Si-O-Si bonds of the SiCOH material are broken due to reaction with fluorine species, and volatile SiF_x reaction products are formed. Using a fluorocarbon etch chemistry, especially the formation of CF_2 fragments leads to the deposition of a CF-containing polymer at the bottom and sidewall of the features, Fig. 1d. Long-chain molecules, which are the precursor for polymer deposition at the SiCOH surface, are already formed in the gas phase by the reaction $C_xF_y(CF_2)_n + CF_2 \rightarrow C_xF_y(CF_2)_{n+1}$ [2]. By changing the C/F ratio in the process gas the process can be tuned to achieve an etching reaction or polymerization. This can be realized by using additives, e.g. H_2, O_2 or CO, and changing the plasma dissociation.
The most critical mechanism during plasma etching is the degradation of the low-k material by ion bombardment, free radicals and UV radiation within the plasma. Si-C bonds are oxidized and removed, which leads to a carbon depletion in the upper most layers (Fig. 1c) and the porous low-k becomes dense at the surface. These plasma damage effects lead to an increasing k-value. Especially unprotected feature sidewalls are affected by the damage mechanism and a substantial SiO_2-like damaged layer can be formed. By deposition of SiC and a HF-dip the damaged zone can be quantitatively investigated by SEM cross sections, Fig. 2. For a CF_4 etching process the thickness of the damaged p-SiCOH layer was found to be 20-25 nm. The plasma damage mechanisms are not completely understood till now and non-damaging etching processes are still under development. At Fraunhofer ENAS

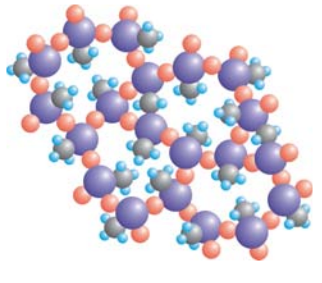

FIG. 1A

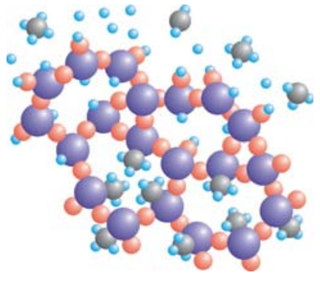

FIG. 1B

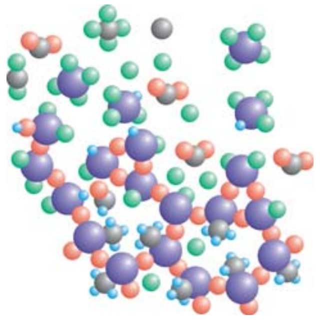

FIG. 1C

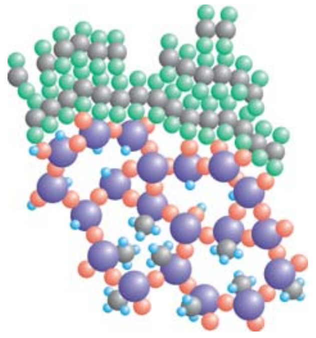

FIG. 1D

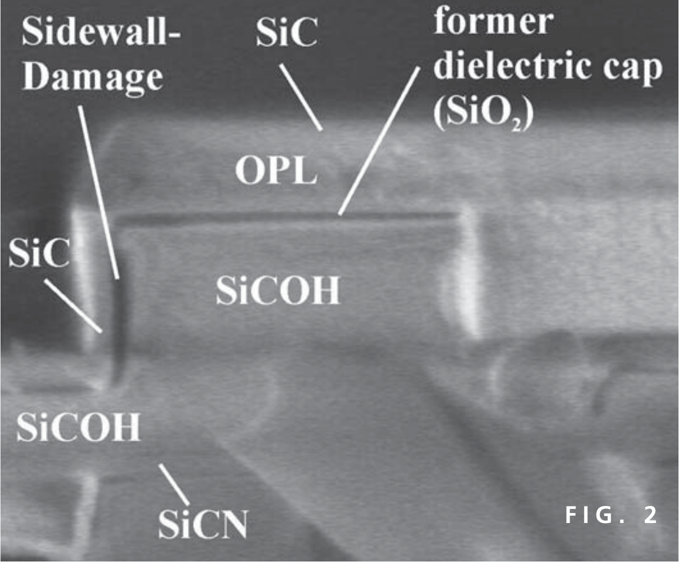

FIG. 2

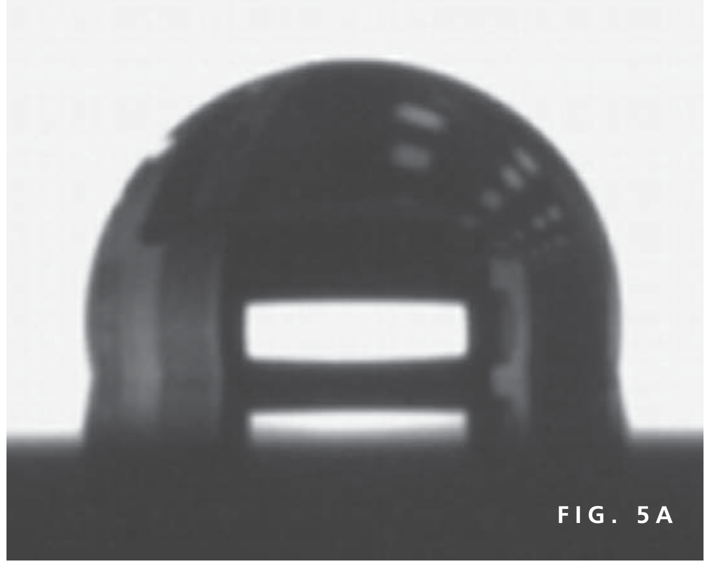

FIG. 5A

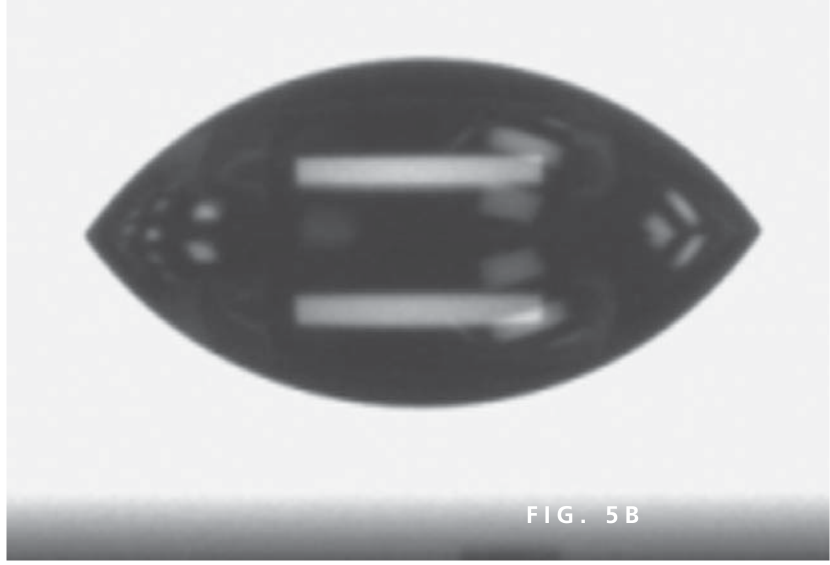

FIG. 5B

high performance in situ analytics are used to investigate and identify the damaging mechanisms during plasma etching. A differentially pumped quadrupole mass spectrometer is able to measure the concentration of fragments within the process gas and can detect reaction products by analyzing the residual gas, Fig. 3. This gives a qualitative view on plasma dissociation and the polymerizing reactions within the process gas. Optical emission spectroscopy directly allows the detection of the C/F-ratio inside the plasma by analyzing the F- and C_2-peaks (swan bands) qualitatively, Fig. 4. The spatial electron concentration and the electron temperature can be analyzed by a Langmuir probe. An auspicious approach is the use of laser adsorption spectroscopy, which is tested at present. By this method the concentration of species inside the plasma can be detected exactly. By correlating the results of in situ analytics and process data the plasma damage mechanisms occurring while patterning porous low-k dielectrics will be better understood in the future.

Analysis of process induced surface modifications on porous SiCOH materials by surface energy determination

Surface energies are not only the key to determine the wetting behaviour of solids and liquids, but can also be used to get an idea about process induced surface modifications on solid surfaces, Fig. 5a and b. The surface energy of a solid can not be measured directly, but using the experimental method of Owens et al. [4] the energies can be determined by contact angle measurements. This method delivers the dispersive part of the surface energy, which exists in all materials, e.g. due to van der Waals forces, and the polar part induced by permanent dipoles. Adding both energy contributions gives the total surface energy.

Besides the optimization of wet cleaning processes [5] the determination of the energetic character of a solid surface was used to understand process induced surface modifications, e.g. the influence of plasma etching processes on porous low-k materials. A porous CVD-SiCOH material has been investigated regarding its energetic character after deposition and after being etched using a CF_4 plasma process with varying content of Ar or C_4F_8.

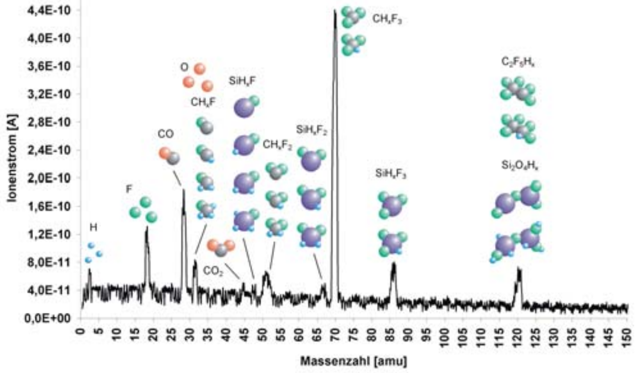

FIG. 3

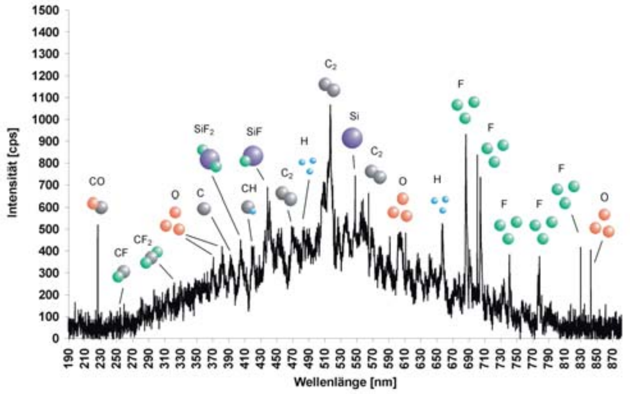

FIG. 4

Figure 6 shows the polar and dispersive energy contributions of the p-SiCOH surface. The pristine film has a low surface energy of less than 30mN/m and almost no polar energy part. After etching in CF_4 without any additives the total energy value increased rapidly up to 47mN/m with a strong polar energy part. Adding Argon does not remarkably change the surface conditions. The material keeps its higher surface energy and the polar energy contribution. By adding C_4F_8 the surface conditions change clearly compared to the Argon-Process. The material also shows a polar energy part, but this contribution is much smaller and therefore the total surface energy value decreased. Increasing the C_4F_8 flow also increased the dispersive energy part and for a flow of 6 and 8 sccm C_4F_8 the total energy value is as low as for the untreated sample. The increasing dispersive contribution and the low surface energy indicate the formation of a CF-containing polymer film on the low-k surface by adding C_4F_8 [5]. Adding argon forms polar groups on the low-k surface. On the one hand this may be a benefit because of the better wettability of the surface, but on the other hand this may also advance moisture uptake and therefore an increase of the k-value. The influence of the etch process parameters on the surface energy and its polar and dispersive part is an important criterion during the integration of porous SiCOH films in nanoelectronics. With regard to the surface energies etch processes and post etch wet clean methods can be matched better in the future.

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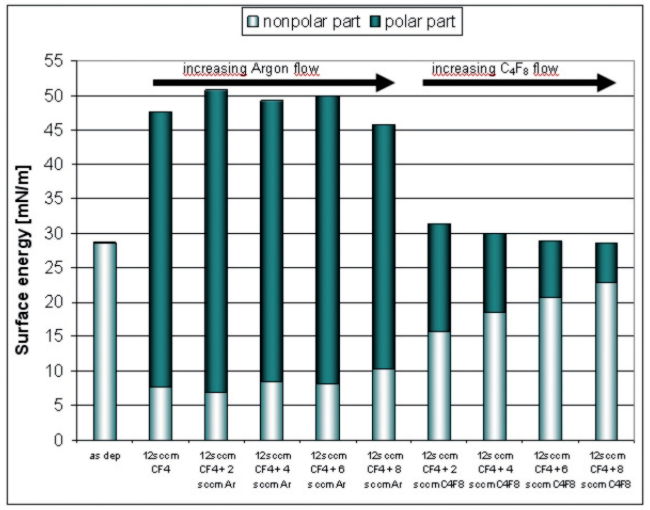


FIG. 6

Legend

Fig. 1: Etching mechanisms occurring at patterning of porous low-k dielectrics by a CF_4 plasma process: left to right: a) original condition b) low-k-damage by the loss of CH_3 groups, densification and incorporation of H, c) etch reaction, d) formation of a CF-polymer at the low-k surface

Fig. 2: Analysis of the sidewall damage by SiC-deposition and HF-dip

Fig. 3: Detection of different species of the etch reaction by mass spectrometry

Fig. 4: Detection of different species of the etch reaction by optical emission spectroscopy

Fig. 5: a) Water on a pristine p-SiCOH material: the contact angle is higher than 90° and the surface is not wetted by the liquid, b) Water on a p-SiCOH material after a plasma etching process: the contact angle is much lower than for the untreated material and the etching process may have introduced polar bonds at the surface

Fig. 6: Surface energy values of a porous SiCOH dielectric: the pristine film is very low energetic with almost no polar part. Etching with addition of Argon introduces a strong polar contribution and increases the surface energy while adding C_4F_8 may deposit a low-energetic polymer film.

DEPARTMENT ADVANCED SYSTEM ENGINEERING

Head of the department: Dr. Christian Hedayat

Short Portrait

The department of Advanced System Engineering (ASE) focuses its research and development domains on the design, the simulation and the characterization of micro and nano electronic systems with more than ten years of experience in the field of system integration and electromagnetic reliability. The department ASE works in close collaboration with the University of Paderborn on developing simulation methodologies for complex micro and nano electronic systems as well as for specific wireless devices such as RFID systems. The main topic of research is the characterization of electronic complex systems by modeling, simulating and measuring the parasitic electromagnetic effects in order to assess the electromagnetic compatibility of the studied systems as well as the signal and clock integrity at high frequencies, 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:

* mobile wireless smart sensor systems
* RFID antennas and circuits
* advanced modeling and analysis of EMC and SI-effects
* EMC/EMR of micro and nano electronic 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

Methods for the measurement and calculation of electromagnetic fields and circuit simulations at an analogue level are employed to analyze the transmission behaviour of micro and nano electronic systems (crosstalk, reflection, changing of the nominal signal shape, ESD noise path tracing) in the time and frequency domain.
Furthermore RFID antennas and systems are developed for the use in harsh conditions and environments.
The application areas EMR and model driven design are the specialty of ASE. 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) and PARIFLEX (BMBF).

ASE closely cooperates with the University of Paderborn (Faculty of Electrical Engineering, Computer Science and Mathematics) and the Leibniz University Hannover (Institute of Electromagnetic Theory) within the competence network future EMC/RF-modeling and simulation methodologies.

Trends

Within complex modern micro and nano electronic devices, system level top-down and bottom-up black box modeling concepts, analogue circuit and hybrid system simulation methods, electromagnetic field analysis capabilities (including parasitic effects like crosstalk, reflection, attenuation and distortion) together with suitable measurement techniques are necessary to predict and to guarantee the reliability of the power supply system as well as the integrity of high-speed transmitting signals. For these trends the ASE group uses the most recent modeling and simulation approaches and employs adequate programming languages and tools.
This SI-analysis is carried out and workflow procedures as well as tool integration are developed for HDP/HDI designs.
In addition, ESD-overstress oriented analysis methodologies were developed for a better implementation within customer-specific design environments.

Based on its high-performance measurement equipments including an innovative self-developed Near-Field Scanning System, various microelectronic systems and components can be optimally characterised with respect to EMC/SI/RF increasing constraints.

Besides the efficient simulation and design of advanced hybrid 3D micro-packaged systems, a solid know-how is developed in the area of mixed-signal IC modeling and design methodologies for reliable clock synthesising systems (such as Phase Locked Loops).

The ASE design activities concentrate not only on HDP/HDI industrial electronic systems for telecommunications, radar and automotive applications, but also on the challenging new area of wireless autonomous sensor and RFID systems with a specific focus on optimized antenna designs and energy management strategies.

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

Competences

The main competences of the department ASE are:

* mobile wireless smart sensor systems
* RFID antennas and circuits
* advanced modeling and analysis of EMC and SI-effects
* EMC/EMR of micro and nano electronic 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 2 port measurement (40 Mz – 26 GHz)
* vector network analysers for 4 port measurement (40 Mz – 50 GHz)
* RF-probing station for on wafer measurements (300 µm pitch size, 40 GHz)
* 3D-Near-Field Scanner (high resolution, 9 kHz – 26.5 GHz)
* vector network analysers for 2 port measurement (300 kHz – 8.6 GHz)
* spectrum analyser (9 kHz – 26.5 GHz)
* EMC analyser (9 kHz – 2.9 GHz)
* power meter with power sensors (100 kHz – 4.2 GHz, -30 dBm to +20 dBm)
* digital oscilloscope (up to 500 MHz, 2.5 GSa/s)
* communication signal analyser with 20 GHz TDR/sampling heads
* RF signal generator (up to 3.2 GHz, analogue modulations)
* RF pre-amplifier (9 kHz – 1.3 GHz, G = 28 dB)
* power amplifiers (10 kHz – 1 GHz, 30 W).

Black Box Modeling of Linear and Nonlinear Systems

Due to the decreasing size and the increasing complexity of modern electrical circuits and constantly rising frequencies, the simulation of these devices becomes a more and more time-critical aspect in the design of HDI/HDP systems. In order to reduce the cost-intensive simulation time, there is a demand for fast, simple but precise and reliable models to perform efficient system level simulations for electromagnetic compatibility (EMC) and signal integrity (SI) characterization. Electrical and transistor-level simulations, which cover all physical effects, are usually very accurate but often suffer from a very large computational effort. The long simulation time of HDI/HDP systems is a needless delay in the development process. Therefore in the department ASE of the Fraunhofer ENAS, a mathematical approach is used to describe the systems' behaviour. Linear systems can be modeled by means of vector fitting based on rational transfer functions and their complexity can be reduced by Model Order Reduction algorithms. In the case of nonlinear devices, the modeling is more challenging. Due to their very good interpolation properties an approach based on Normalized Radial Basis Function Nets (NRBF) with Gaussian centres is chosen to tackle this problem. With a time domain simulation or measurement of the nonlinear system at hand, which covers all necessary and relevant system states, it is possible to adjust the predefined model structure to reconstruct the part of interest of the system dynamics. For this the extended Kalman filter has been proven to be well suited for the determination of the nonlinear model parameters, Fig. 1. Next to the different ports of the circuit, physical parameters, such as the temperature, often have to be considered. Therefore, the NRBF models are enhanced to reproduce the influences of these electrical and physical parameters, Fig. 2.

In order to use these mathematical macro-models in different environments, it is convenient to use the SPICE format, which can be imported by most commercial design tools on the market. With the aid of these efficient models the simulation time of nonlinear systems often can be reduced significantly. Naturally, the actual speed-up factor depends on the complexity of the related system.

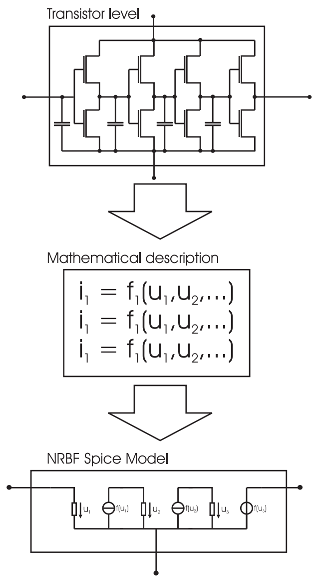


FIG. 1

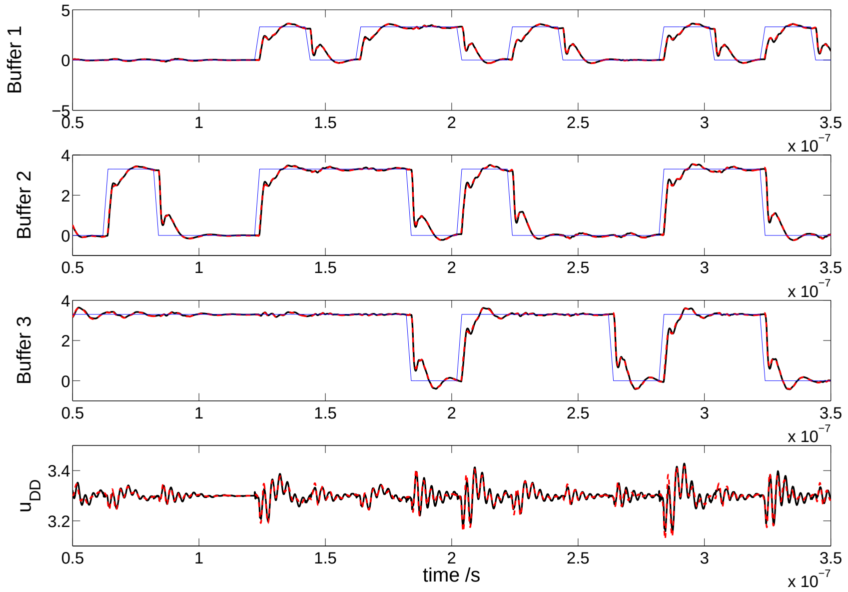


FIG. 2

The development of a vector fitting C++ library has been done in close cooperation with the industrial partner ZUKEN who is going to implement it within their EDA-Tool CR-5000 Lightning.

Near-Field Scanning

There are growing challenges in the prevention of electromagnetic compatibility (EMC) problems within modern electronic products carrying mixed analogue-digital signals. Progressive miniaturisation, complexity and reductions in the operating voltages of electronic products increase the risk of malfunctions due to the higher sensitivity for ambient noise as well as parasitic field couplings between "aggressive" and "sensitive" subcomponents located very closely to each other. Various measurement techniques are required for the behavioural analysis of an actual microelectronic system unlike its model in terms of radiated and conducted emission characteristics, Fig. 3. Finally, the measured data should verify the EMC compliant design of the system. In addition to the radiation investigation, the Near-Field Scanner is also able to inject electromagnetic interferences with well defined field strength, position and direction, spatially limited in the test object. This makes efficient reliability investigations possible. An electromagnetic near-field scanner primarily developed for the testing of antennas may be used for the characterisation of possible electromagnetic interference (EMI) sources included in passive and active radiating objects such as mixed analogue-digital signal boards. The distinctiveness and the most attractive features of this contact-less measurement technique are the spatial localisation and the frequency characterization of EMI sources. This powerful special characteristic provides the capability for quick corrections of design mistakes at the root of the problem. Additionally, a classical antenna near-field scanner has been adopted and optimised to satisfy demands of EMC test applications to establish specific design considerations for a vector EMI scanner system.

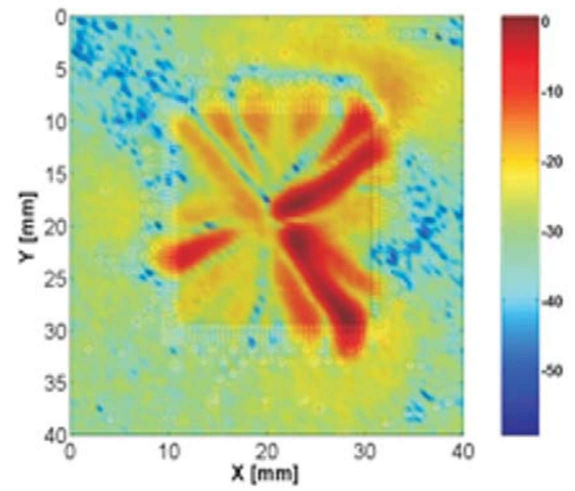


FIG. 3

Commercially available typical EMI scanner systems include the precise robotic positioning of a probe accompanied by a scanning automation and data visualization software. An implemented option for the overlaying of the probe signal distribution with the object's photograph or the 3D model of its structure enables the interpretation of the scanning results. The electrical performance of the scanners is mainly specified by third-party probes and signal receivers. Since only scalar receivers are supported, the post-processing possibilities of the measured data are typically limited to the relative mapping of the electric charge and the current densities (hot-spot localization). Furthermore, arbitrary three dimensional test objects cannot be gathered automatically. A very close positioning of the probe over the test object is necessary for a good sensitivity for small probes and a high spatial resolution. Typically, the influences of the positioning system on the measurements are mostly not considered. These last points and the capability to measure complex field components are the basic conditions for the characterization of the nowadays smaller and more complex electronic systems.

The construction of a scanner robot to position a near-field probe is driven by challenging requirements and determines the ultimate limits of measurement accuracy results, Fig. 4. High positioning precision should be maintained over a large geometrical dynamic range from micrometer to dozens of centimetres. This depends on the dimensions of the DUT that is to be investigated and the spatial density of its interconnections and components. The positioning errors degrade the results of the post-processing considerably, since these errors occur due to the solving of integral equations with spatial variables. For example, it can be shown that the standard deviation of a positioning error of 4.7 µm for the monopole probe restricts the spatial resolution of the probe compensated fields to 0.5 mm!

The system has a positioning accuracy of 1µm in all directions for a maximum allowed dimension of the DUT of 500 mm x 800 mm x 500 mm (x, y, z). The positioning system is mounted on a granite basement with an mass of approximately 600 kg. This is essential for the absorption of subsonic noise. The upper hemisphere of the positioning system is metal free, in order to avoid scattering, field distortion and reflection. The portal is made of plastic with a low permittivity. The portal carries the pivotable near field probe fixture and the optical contour scanning system, which consists of two line laser systems and a CCD-camera. Unlike conventional scanners, the DUT will move under the stationary probe. This concept avoids mechanical oscillations in the probe that occur when the probe is moved over the DUT.

Before the eventual near field measurement starts, the contour of the DUT must be gathered by an optical triangulation system. The row data of this contour must be post processed to compensate for errors, such as speckling, mirroring, absorption, optical distortion, etc. Based on this scanned contour, the system checks whether all measurement positions can be reached without a collision with the probe.

The 2 channel signal receiver can detect amplitude and phase. The broad frequency range spans from DC up to 6 GHz, with a dynamic range of -140 dBm to 20 dBm. The noise figure is below 4 dB. The receiving technique is based on RF down converting and highly precise digitising in time domain. Each sub-spectrum (IF) has a bandwidth of 36 MHz and can be measured with a maximum record length of 500 ms.

The development of the advanced near field scanner is being realised in close cooperation with the industrial partners Continental and Infineon. In addition to the first implemented system at Fraunhofer ENAS, Continental also built the same scanning system in Nuremberg for the scanning of automotive devices.

Legend

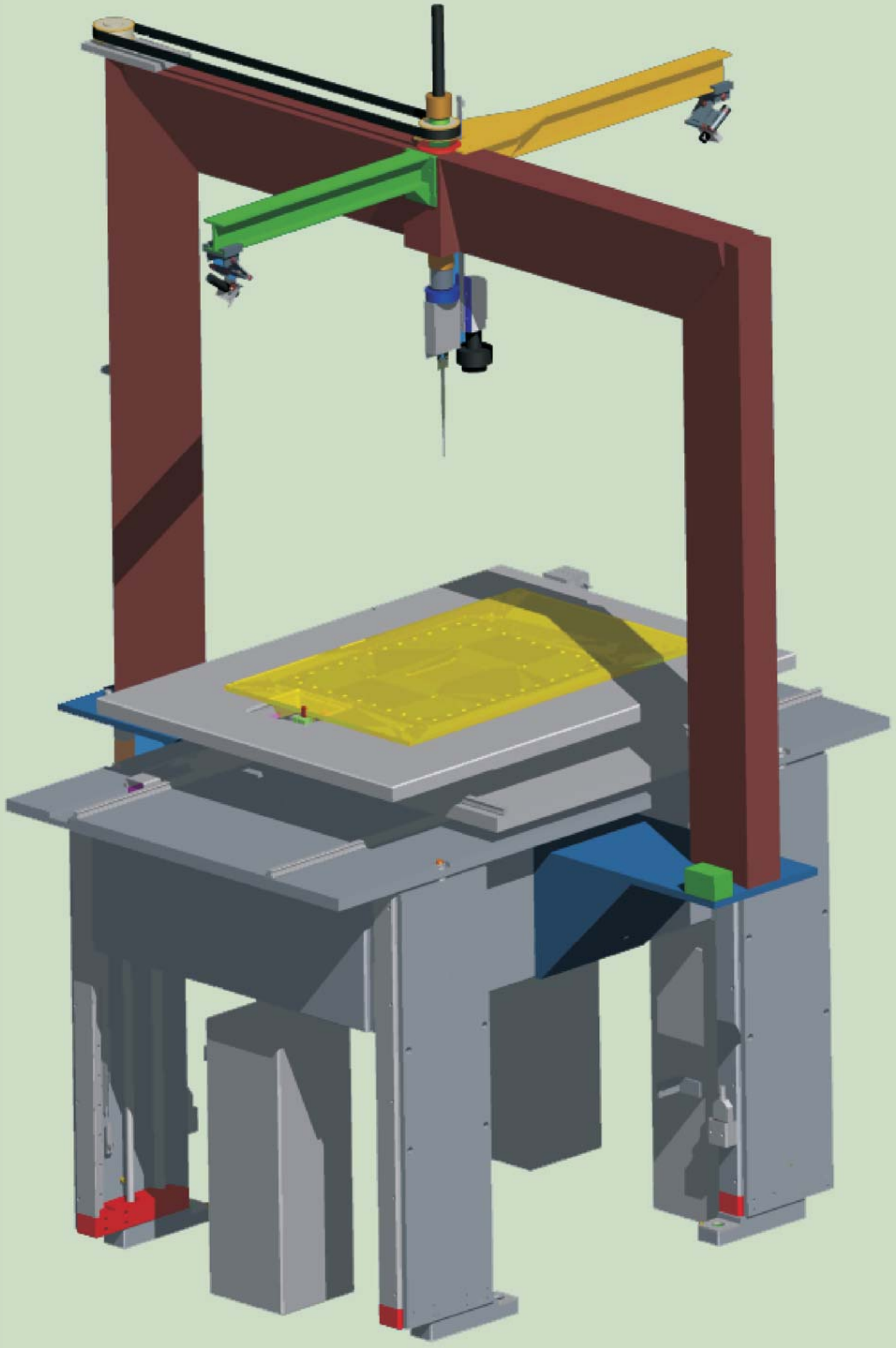
Fig. 1: black box modeling-procedure of a non-linear electronic system

Fig. 2: original simulations and non-linear BBM predictions fit very precisely

Fig. 3: tangential electric field of a microcontroller

Fig. 4: high precise Near-Field Scanner

FIG. 4



COOPERATION

FRAUNHOFER ENAS - COOPERATION WITH NATIONAL AND INTERNATIONAL UNIVERSITIES

National cooperation

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

The departments Multi Device Integration and Back-End of Line closely cooperate with the Center for Microtechnologies (ZfM). With the Center for Microtechnogies, its clean rooms and technological equipment, the faculty of Electrical Engineering & Information Technology possess a special scientific operating unit. It is the bases for the production of prototypes and pilot-run series, for the development of technologies and materials as well as for the training of students, trainees and young researches in step with research and actual practise.

Together with the ZfM the Fraunhofer ENAS carries out research and development in the fields micro and nano electronics, micro mechanics and micro systems 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 nano electronics
* design of components and systems,
* nano technologies, 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.

A relatively new research topic of the smart systems integration are the printed functionalities, which are just well established at the Institute for Print and Media Technique 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.

In December 2008 the department heads Dr. Thomas Otto and Dr. Stefan E. Schulz have been appointed as honorary professors of the faculty of Electrical Engineering and Information Technology of the Chemnitz University of Technology.

The department of Advanced System Engineering located in Paderborn continues to develop the close cooperation with the University of Paderborn, the Leibniz University of Hannover and the University of Erlangen building up a competence network of modeling, simulation and measuring for EMC and RF compliant system designs and integration.

International cooperation

The cooperation between the Fraunhofer Research Institution for Electronic Nano Systems ENAS and the Center for Microtechnologies ZfM is just one example for close collaboration. Close contact is maintained with numerous other universities and research institutes via participation in projects and European technology platforms. In Asia, long-term cooperations exist with Tohoku University, Sendai and Fudan University, Shanghai, and the Shanghai Jiao Tong University. Two examples will be given.

The cooperation of both institutes with the Tohoku University Sendai in Japan is a very successful one. The principal investigator Prof. Thomas Gessner got a own WPI research group belonging to the big complex material and system integration 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 nano structures using self organizing and self assembling.

Within the international graduate school “Materials and Concepts for Advanced Interconnects“ work engineers specialised in electrical engineering and micro electronics, material sciences as well as physicists and chemists together on the development of 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 nano electronics. It supports and requests an interdisciplinary and cross-cultural communication and cooperation. Participants at this 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 Research Institution for Electronic Nano Systems ENAS.
Together with its French partners of the University of Grenoble and the CEA-LETI, the department of Advanced System Engineering develops a know-how in the area of low cost wireless smart sensor systems (like SAW-detectors). One other aspect of the European engagement of the ASE with the Ecole des Mines in Gardanne and the University of Leuven is driven around the development of an innovative Near-Filed Scanner.

COOPERATION WITH UNIVERSITIES AND RESEARCH INSTITUTES (SELECTION)

Brandenburgische Technische Universität, Cottbus, Germany

CEA-LETI, Grenoble, France
CEA-Liten Grenoble, France
Chongqing University, Chongqing, China

École Nationale Supérieure des Mines de St-Étienne, Gardanne, France
ETH Zurich, Switzerland

Forschungszentrum Rossendorf, Germany
Fraunhofer CNT, Dresden, Germany
Fraunhofer IAP, Golm, Germany
Fraunhofer IBMT, Potsdam, Germany
Fraunhofer IISB, Erlangen, Germany
Fraunhofer ISIT, Itzehoe, Germany
Fraunhofer IWM, Halle, Germany
Fraunhofer IWS, Dresden, Germany
Fraunhofer IZM, Berlin and Munich, Germany
Fresenius, Germany
Friedrich-Alexander-Universität Erlangen-Nürnberg, Germany
Friedrich-Schiller-Universität, Jena, Germany
Fudan University, Shanghai, China

Hochschule Mittweida, Laserapplikationszentrum, Germany

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

Johannes Kepler Universität, Linz, Austria
Joseph Fourier University, Grenoble, France

Konkuk University, Chungju, Korea

Leibniz IFW, Dresden, Germany
Leibniz IHP, Frankfurt/Oder, Germany
Leibniz INP, Greifswald, Germany
Leibniz IOM, Leipzig, Germany
Leibniz Universität, Hannover, Germany

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

Royal Institute of Technology, Stockholm, Sweden

Shanghai Jiao Tong University, Shanghai, China

Tohoku University, Sendai, Japan
TSINGHUA University, Beijing, China
TU Dresden, Germany

University of California, Berkley, USA
University of Nevada, Reno, USA
University of Nice-Sophia Antipolis, France
University of Paderborn, Paderborn, Germany
University Paris Diderot, France
University of Tokyo, Research Center for Advanced Science & Technology (RCAST), Tokyo, Japan

VTT Technical Research Centre, Finland

Westsächsische Hochschule Zwickau (FH), Zwickau, Germany

Xiamen University, Xiamen, China

FRAUNHOFER ENAS AND THE INTERNATIONAL RESEARCH TRAINING GROUP IRTG

"Materials and Concepts for Advanced Metallization"

At a Glance

Since April 1st, 2006, the International Research Training Group (Internationales Graduiertenkolleg 1215) "Materials and Concepts for Advanced Interconnects", jointly sponsored by the German Research Foundation (DFG) and the Chinese Ministry of Education, has been established for 4.5 years between the following institutions:

- Chemnitz University of Technology
  - Institute of Physics
  - Institute of Chemistry
  - Center for Microtechnologies
- Fraunhofer Research Institution for Electronical Nano Systems ENAS
- Fraunhofer Institute for Microintegration and Reliability IZM
- Technical University Berlin
- Fudan University, Shanghai
- Shanghai Jiao Tong University

This International Research Training Group (IRTG) is the first of its kind at Chemnitz University of Technology. It is lead by Prof. Ran Liu of Fudan University as the coordinator on the Chinese side and Prof. Thomas Gessner on the German side. A graduate school like this offers brilliant young PhD students the unique opportunity to complete their PhD work within 2.5 to 3 years in a multidisciplinary environment. Up to 14 PhD students of the German and 20 of the Chinese partner institutions, as well as a post-doctoral researcher at the Center for Microtechnologies are involved in the current program. The different individual backgrounds of the project partners bring together electrical and microelectronics engineers, materials scientists, physicists, and chemists. In particular, the IRTG is working to develop novel materials and processes as well as new concepts for connecting the devices within integrated microelectronic circuits. Smaller contributions are being made in the field of device packaging and silicides for device fabrication. In this sense, the IRTG project is helping to solve problems currently encountered on the way to nanoelectronics.

Therefore, the research program of the IRTG concentrates on both applied and fundamental aspects, and treats the mid- and long-term issues of microelectronics metallization. Atomic layer deposition (ALD) of metals, new precursors for metal-organic chemical vapor deposition (MOCVD), ultra low-k dielectrics and their mechanical and optical characterization together with inspection techniques on the nanoscale are considered. New and innovative concepts for future microelectronics such as carbon nanotube interconnects or molecular electronics along with silicides to form links to front-end of line processes are of interest, as well as the evaluation of manufacturing-worthy advanced materials. Moreover, the research program addresses reliability and packaging issues of micro devices. Highlighting links between fundamental materials properties, their characteristics on the nanoscale, technological aspects of materials and their applications to microelectronic devices is the main objective of the program.

Nevertheless, the principal idea of the IRTG is four-fold: The research program defines the framework of the activities and the topics of the PhD theses. This is accompanied by a specially tailored study program including lectures, seminars and laboratory courses to provide comprehensive special knowledge in the field of the IRTG. The third part of the program comprises annual schools held either in China or Germany, bringing together all participants of the IRTG and leading to vivid discussions during the presentation of the research results. Moreover, an exchange period of 3 to 6 months for every PhD student at one of the foreign partner institutions is another essential component. Besides special knowledge in the scientific field, these activities will provide intercultural competencies that cannot easily be gained otherwise.

Eight of 15 positions (14 PhD and 1 postdoc position) have been assigned to female researchers. Such high percentage of women can only rarely be obtained in the fields of engineering and natural science.

Current Activities

Summer School 2008

A summer school is held every year which is alternately organized by German or Chinese partners. In 2008 the summer school was organized by the Center for Microtechnologies and was combined with the conference "Materials for Advanced Metallization 2008" (MAM 2008). The MAM 2008 took place from March 2nd to March 5th in Dresden. All PhD students from German and Chinese side had been called for abstract submission. 12 contributions were accepted, 11 for poster presentations and 1 talk. Most of the professors and tutors and all PhD students attended the MAM 2008 and had the opportunity to come in discussion with researchers from Europe, America and Asia. The work of the IRTG awaked general interest during the conference.

After the MAM 2008, from March 6th to 7th, the PhD student workshop took place also in Dresden, where the PhD students presented the progress of their work. There were lively discussions and helpful suggestions for the further work.

The Workshop was flanked by a cultural and culinary program. We attended the 4th Chamber Concert on Schloss Albrechtsberg with compositions from Ludwig van Beethoven, Robert Fuchs and Antonín Dvořák. Furthermore, there was the opportunity to visit for oneself the "Frauenkirche" during the event "Open Church".

Exchange program

Four Chinese PhD students and one German PhD student made use from the exchanging program last year. During this time, the fellows worked and studied at one of the foreign partner institutions in China or Germany.

From the German side, one PhD student started a three-month stay at Fudan University Shanghai. The work results of this exchange were presented in a joint contribution on the MAM 2009 in Grenoble, France. The Chinese PhD students, two from Fudan University and two from Shanghai Jiao Tong University, attended our lectures in the study program as well as social and cultural events.

For further information please visit our webpage:
http://www.zfm.tu-chemnitz.de/irtg/

FRAUNHOFER ENAS AND THE WORLD PREMIER INTERNATIONAL RESEARCH CENTER

Advanced Institute of Materials Research (WPI-AIMR) at the Tohoku University in Sendai

In the year 2007 the Japanese Ministry of Education, Culture, Sports, Science and Technology, MEXT, established the program “World Premier International Research Center (WPI) Initiative.” The WPI Program, as it is called for short, provides concentrated support for projects to establish and operate research centers that have at their core a group of very high-level investigators. These centers are to create a research environment of a sufficiently high standard to give them a highly visible presence within the global scientific community-that is to create a vibrant environment that will be of strong incentive to frontline researchers around the world to want to come and work at these centers. Four of such research centers have been created. One of them is the Advanced Institute of Materials Research (WPI-AIMR) at the Tohoku University in Sendai headed by Prof. Yamamoto. WPI-AIMR has adopted a unique method of appointing the world’s leading researchers as research leaders, or what is termed Principle Investigators (PI). Currently there are 29 PIs. Although most of them belong exclusively to WPI-AIMR, two of them also belong to other domestic institutions and 10 of them are located at research centers outside Japan. PIs possess comprehensive authority over their research and are allowed to make proposals to the Center Director on hiring new researchers necessary to carry out their research. Prof. Thomas Gessner, Director of Fraunhofer ENAS, has been selected as one of PIs.

WPI-AIMR consists of four research groups. The four research groups, or Thrusts, implement joint projects and aim at creating breakthrough research through fusion research. Although it is important, as a matter of course, for them to deepen their studies in each specific area or research field to produce cutting-edge results, discoveries of totally new phenomena and the creation of completely original ideas is more often generated from the fusion between different fields. It is thought that cluster structure exists through glue and interface science and atomic and molecular manipulation are the fundamental academia, which are developed into useful materials by MEMS and NEMS for example.

Since November 2008 the research group of Prof. Thomas Gessner at the Tohoku University takes shape. At that time Dr. Yu-Ching Lin has been employed as Assistant Professor to start the actual research work. Prof. Lin has been working at the Tohoku University before to obtain her PhD degree in the field of engineering.

Just before moving to the WPI-AIMR she was working in Germany at the Fraunhofer ENAS for almost a year. Because of that it is expected that she can form a strong relation between the topics researched in Chemnitz and her future work in Sendai within a close cooperation. Her field of work at the time in Fraunhofer ENAS was to investigate bonding technologies for the packaging of MEMS devices, especially the gold-silicon eutectic bonding. In the research group at the Tohoku University this work should be continued, but with focus on new nano structured materials and integration technologies that can not be used at the Fraunhofer ENAS because of the contamination sensitive near production equipment environment. Since the main focus of the WPI-AIMR is the development and investigation of new materials with world class physicist and chemists it is expected that collaboration within the institute will stimulate the research work inside the group of Prof. Gessner. Already now a strong cooperation between the Gessner Lab and the Esashi Lab, both working in the field of MEMS/NEMS devices takes place. So the members of Gessner Lab are working in the same facilities as staff of Prof. Esashi. As a starting point multilayered nano scale materials that exhibit a self propagating exothermic reaction behavior for the purpose of very localized heating for semiconductor bonding with low thermal budget will be researched. Especially the creation of new kind of 3D-interlayer structures is of interest.

It is planned to increase the size of the research group of Prof. Gessner next year by hiring additional post doctors that will work in Sendai under the guidance of Prof. Lin to broaden and deepen the research work.

LONGTIME COOPERATION WITH GEMAC – AN INTERVIEW WITH DR. CLAUS DITTRICH

Marketing studies announce continuous growing total revenue for products based on micro system technologies. In the region of Chemnitz more than 40 companies have established business in this field. The Fraunhofer Research Institution for Electronic Nano Systems ENAS and the GEMAC - Gesellschaft für Mikroelektronikanwendung Chemnitz mbH have signed a cooperation contract in 2008. We spoke with Dr. Claus Dittrich, the managing director of the GEMAC, about his experiences with cooperative projects.

ENAS: Dr. Dittrich, the GEMAC and the Fraunhofer ENAS have developed a long-term relationship of trust. What are the reasons for a SME to cooperate with Fraunhofer-Gesellschaft?

Dr. Dittrich: The GEMAC has continuously grown since their foundation in 1992. The requirements on micro systems as well as the requests and expectations of our customers are growing rapidly, too. If a SME wants to get a leading position within a special field in the market it is obviously necessary to get competent support. For that reason we just cooperate in the field of micro electro mechanical systems for a long time with the Fraunhofer ENAS, the former branch Chemnitz of Fraunhofer IZM as well as the Center for Microtechnologies of the Chemnitz University of Technology. The last 17 years are characterised by a successful technology and knowledge transfer – especially in the field of inclination and acceleration sensors. Consequently, a cooperation contract has been signed last year. We benefit from the very good technical basis of Fraunhofer ENAS as well as from the knowledge of the staff. We have successfully placed a family of inclination sensors at the market and we are working on a new generation of micro mechanic inclination sensors based on AIM (airgap insulating microstructure) technology right now.

ENAS: What services of Fraunhofer ENAS does your company use?

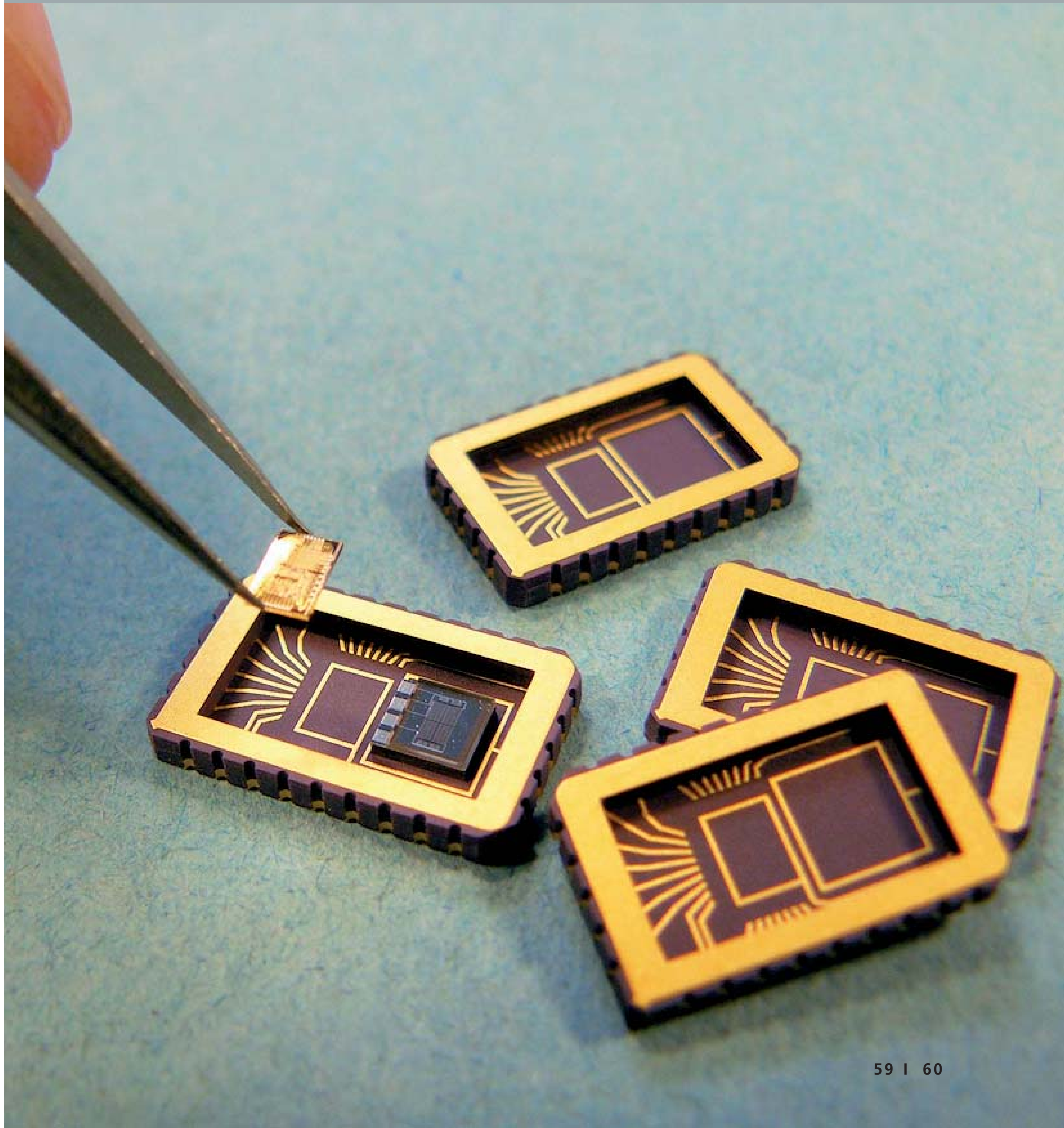
Dr. Dittrich: We use different services. Fraunhofer ENAS together with the Center for Microtechnologies have the opportunity to produce micro electro mechanical systems in their facilities. On the other hand they support us with simulations of the components and with test in order to improve our products. The staff of Fraunhofer ENAS has a specific knowledge, which allows them to solve problems in a profound and scientific manner. Together with the application oriented knowledge of our staff, that means with the engineers of GEMAC, we are able to develop first-class products. These first class products lead on the other hand to the fact that we have a good standing at our customers.

ENAS: What has worked really well, what needs improvements?

Dr. Dittrich: As an entrepreneur you would like to have the next generation of products or a new product ready just the day before yesterday in order to present it to your customers. But I am an engineer, too, and I know of course, that haste makes waste. Furthermore, I can tell you that we have successfully implemented and transferred all common sensor developments up to now. We are very satisfied with the cooperation. GEMAC's total revenue related to inclination and acceleration sensors has been continuously growing. Currently our new project, a vibration sensor for high speed spindles, is in the test phase at our customer and seems to satisfy him very well.

About Dr. Claus Dittrich:
Dr. Claus Dittrich studied electrical engineering at the Dresden University of Technology and received his doctor's degree from the Chemnitz University of Technology. Nearly 20 years he was with GEFREMA GmbH the former research center of machine tool manufacturing Chemnitz. He is the managing director of GEMAC - Gesellschaft für Mikroelektronikanwendung Chemnitz mbH since the foundation in 1992. The GEMAC developed very well. Starting with 30 employees in 1992, today 80 people work for GEMAC, of which 38 are certified engineers.

About GEMAC:
GEMAC is a renowned provider of individual research, development and production services in the fields of measurement and sensor systems. We offer our clients complete tailor-made solutions, i. e. both sensor and ASIC-design as well as electronic boards and development and construction of own products.
We sell our products regionally and internationally to be used in machine and automotive construction as well as in medical science and automation technology.



COOPERATION WITH INDUSTRY (SELECTION)

3D-Micromac AG, Chemnitz, Germany

ACREO, Kista, Sweden
Advanced Micro Devices (AMD), Sunnyvale, USA and Dresden, Germany
Air Products and Chemicals, Inc., Carlsbad (CA) and Allentown (PA), USA
Alenia Aeronautics, Casoria, Italy
AMTEC GmbH, Chemnitz, Germany
Applied Materials, Santa Clara, USA and Dresden, Germany
Arentz Optibelt, Höxter, 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
Clean Tech Campus GmbH, Chemnitz, Germany
Colour Control Farbmeßtechnik GmbH, Chemnitz, Germany
Continental AG, Germany
CST AG, Darmstadt, Germany

Drägerwerk AG & Co. KGaA, Lübeck
Diehl Hydrometer, Arnsbach, Germany

EADS Deutschland GmbH, Corporate Research Center Germany, Deptartment Microsystems, München, Germany
Elmos Semiconductor AG, Dortmund, Deutschland
Endress und Hauser AG & Co. KG, Germany
Envia M GmbH, Halle, Deutschland
EPCOS AG, Germany
Exalos AG, Schlieren, Schweiz

FACRI , Research Institute, Xi´an, China
FHR Anlagenbau GmbH, Ottendorf-Okrilla, Germany
First Sensor Technology GmbH, Berlin, Germany
Freiberger Compound Materials GmbH, Freiberg, Germany
Frottana Textil GmbH & Co. KG, Großschönau, Germany
FSG Automotive GmbH, Oelsnitz, Germany

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

Hella, Lippstadt, Germany
Helenic Aerospace Industry S.A., Schimatari, Greece

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

Jenoptik-LOT GmbH, Gera , Germany

KSG Keiterplatten GmbH, Gornsdorf, Germany
LITEF GmbH, Freiburg, Germany
LG Electronics, Korea

MELEXIS, Bevaix, Switzerland
memsfab GmbH, Chemnitz, Germany
Microelectronic Packaging Dresden GmbH, Dresden, Deutschland
Microtech GmbH, Gefell, Germany
Multitape GmbH, Büren-Ahden, Germany

Nano Jura, Besançon, France
neoplas control GmbH, Greifswald, Germany
NXP (founded by Philips), Eindhoven, The Netherlands, and Hamburg, Germany

Ocè B.V., Venlo, The Netherlands

Panasonic Plasma Display Labaratory, Inc., Highland, New York, USA
Physikalisch-Technische Bundesanstalt Braunschweig (PTB), Germany
Philips Applied Technologies, Eindhoven, The Netherlands

Ricoh Company, Ltd., Yokohama, Japan
Roth & Rau Oberflächentechnik GmbH, Wüstenbrand, Germany
RWE AG, Essen, 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
SF Automotive GmbH, Freiberg, Germany
Siegert TFT GmbH, Hermsdorf, Germany
SolviCore GmbH & Co. KG, Hanau, Germany
Solardynamik GmbH, Berlin, Germany
Sony Corp., Semiconductor Business Unit, Japan
ST Microelectronics, Crolles, France
Surrey NanoSystems Ltd, Newhaven/Guildford, U.K.
Suss Microtec AG Vaihingen, Munich and Sacka, Germany
Dr. Teschauer AG, Chemnitz, Germany
Thales-Avionics, Valence and Orsay, France
Toyota, Japan
Turboméca, Bordes, France

X-FAB Semiconductor Foundries AG, Erfurt and Dresden, Germany

Vowalun GmbH, Treuen, Germany
VW Oelsnitz, Germany

ZMD AG, Dresden, Germany

EVENTS

EVENTS IN 2008

SMART SYSTEMS INTEGRATION 2008, Barcelona

The second SMART SYSTEMS INTEGRATION, European Conference & Exhibition on Integration Issues of Miniaturized Systems – MEMS, MOEMS, ICs and Electronic Components, took place on April 9th to 10th, 2008, in Barcelona, Spain. The SMART SYSTEMS INTEGRATION conference is part of the activities of EPoSS- the European Technology Platform for Smart Systems Integration. In the conference program there was a session track complied by EPoSS.

More than 300 participants from European countries, Japan, China, Taiwan and Israel attended the conference, organized by Mesago and Fraunhofer IZM. Moreover 35 exhibitors: from ten countries showed their products and services.

In his welcome presentation the chairman of the conference Prof. Thomas Gessner pointed out: "The European distribution gave the evidence that smart systems integration is a big issue especially in Germany, Belgium, France, Netherlands, Italy, Great Britain and Spain."

Smart system integration forms systems out of components which are able to gain information from the environment, to process it electronically, to communicate signals and data to the outside world. Customers require energy-autonomous systems with new increasingly complex functionalities, higher quality, lower cost and long term reliability. The integration of nano materials and printed functionalities in such systems lead to new challenges and requires new approaches in terms of design, testability and reliability as well.

The SMART SYSTEMS INTEGRATION Conference 2008 showed a snap shot of the European research work on this field. Experts and scientists from industry and research institutes addressed and discussed various aspects of smart systems integration starting from technology and reliability, via development of components and materials up to best practise examples. This includes special aspects of integration for automotive, aerospace, logistics, life science, RF and bio applications.

MAM 2008, Dresden

The conference "MAM 2008 - Materials for Advanced Metallization" took place from March 2nd to 5th, 2008, in Dresden. The 2008 conference was mainly organized by the staff of the Center for Mictrotechnologies of the Chemnitz University of Technology and the branch Chemnitz of Fraunhofer IZM (since July 1st, 2008, Fraunhofer ENAS). Head of the organizing committee and Co-Chair of the 2008 conference was the head of the department BEoL of Fraunhofer ENAS, Prof. Stefan E. Schulz.

Altogether 35 lectures and 50 posters were presented in seven topical oral sessions and one poster session with nine topical fields. Nine invited talks were given by experts from Europe, North America and Asia.

This workshop was the 17th in a series devoted to materials research, materials properties and interactions. Starting as workshop on refractory metals and silicides in the 80s, moving to materials for advanced metallization in 1995, the 2008 year's workshop included a number of new and challenging topics in the field of materials and structures for advanced micro and nano electronics.

The objective of the workshop was to provide a forum for open discussions between science and industrial application. It was dedicated to materials scientists, process and integration engineers.

Topics included both fundamental and applied research, as well as issues related to introduction into manufacturing. With the progressive scaling down of device dimensions and the simultaneous demands for more functionality, the challenges have become tremendous. New and extensive materials research is needed to further follow IC scaling as well as to develop new devices on the nano scale. Therefore this workshop focussed on material issues in traditional metallization and interconnect schemes, advanced interconnect options and new approaches for nano electronics.

Steering Commitee of SMART SYSTEMS INTEGRATION 2008 European Conference & Exhibition (from left to right): Wolfgang Gessner (VDIV-DE-IT, Berlin, Germany), Thomas Gessner (Fraunhofer ENAS, Chemnitz, Germany), Klaus Schymanietz, (EADS, Germany and EPoSS), Guenter Lugert (Siemens, Germany), Pietro Perlo (Fiat Research Center (CRF), Italy), Sebastian Lange (VDIVDE-IT, Berlin, Germany), Carles Cané (Centro Nacional de Microelectrónica (CNM-IMB), Spain), Reinhard Neul (Robert Bosch GmbH, Germany)

Chongqing Forum

The Sino-German-Italian workshop in environmental monitoring by means of microsystems has been organized by the Chongqing University, the branch Chemnitz of Fraunhofer IZM (now Fraunhofer ENAS) and the Center for Applied Research in Micro and Nano Engineering Pisa (Italy) on April 18th in the Chongqing Exhibition Center.

Sino-German-Italian Hi-tech Forum in Environment Monitoring System" aimed at enhancing publicity of environmental protection ideas, and discussed in detail the issue of MEMS technology application in the aspects of environmental monitoring, environmental protection and social development. The goal was to promote further understanding and cooperation among Germany, Italy and China in relevant fields. Meanwhile, it could provide a better communication platform for Chongqing's MEMS research institutes and the departments of environmental monitoring to communicate with domestic and international institutions and businesses. It is significant for Chongqing to develop MEMS technology and industry, and accelerate the progress of environmental monitoring technology and industrial upgrading and enhance their competitiveness in the market.

Special focus was given to the presentation of common projects. So the Chongqing University and the Fraunhofer ENAS presented their micro mirror spectrometers which can be used for environmental monitoring. Moreover an introduction was given to Smart Systems Integration and the Smart Systems Campus Chemnitz.

MINAPIM 2008 in Manaus

The MINAPIM 2008 was held in the Suframa´s auditorium September 11th to 13th. During these 3 days four sessions related to Microsystems and two sessions related to nanotechnology took place.

The Microsystems sessions were:
* networking and trends
* microsystems for sustainability,
* microsystems fabrication and
* special applications

The nanotechnology program was related to the Nanoforumeula consortium which joint the Europeans and Latino American researchers.

The MINAPIM will be held every year in different Brazilian cities. It is supported by Deutsche Messe in Brazil.
The MINAPIM 2008 was organized by SUFRAMA and the Ministry of Development Industry and Foreign Trade of Brazil. Co-Organizer was the Fraunhofer ENAS (Chemnitz Branch of Fraunhofer IZM).

Topping out Ceremony of Fraunhofer ENAS on September 18th, 2008

On September 18th, 2008, the Fraunhofer Research Institution for Electronic Nano Systems ENAS celebrated the completion of outline construction on its new laboratory and office building on the Smart Systems Campus in Chemnitz, Saxony. After the laying of the foundation stone for the start-up building in May and the opening of the new physics building at the Chemnitz University of Technology in April 2008, it was now time to celebrate topping-out of the new institute building for Fraunhofer ENAS.

After ten months of construction, Prof. Thomas Gessner, Director of Fraunhofer ENAS, and Prof. Hans Nickl, the project architect, thanked the planners and construction staff for their quick and problem-free completion of the first half of the construction project. Excavation work had begun in autumn of 2007 and work on the structure at the beginning of 2008. Prof. Gessner looked forward to being able to move in soon: "Today's topping-out ceremony means that we are within sight of the end of the provisional accommodation which many facility staff have had to use because of our rapid growth."

4th Fraunhofer-Gesellschaft Symposium in Sendai

The Fraunhofer ENAS participated at the 4th Fraunhofer-Gesellschaft Symposium on December 2008 in Sendai.
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 system integration of micro electronics and micro system technologies. This event has attracted scientists and researchers from all over Germany and Japan.

Within this symposium the director of Fraunhofer ENAS Prof. Thomas Gessner gave a talk "Towards micro and nano technology for integrated systems". The assistant professor Yu-Ching Lin has presented an overview about the cooperation between Tohoku University, Sendai, and Fraunhofer ENAS in the field of wafer level integration.

The day before this Fraunhofer-Symposium the "Micro-Nano Hetero System Integration in Sendai (MHSI ‚08)" took place. It is a part of the „Sendai International Forum 2008". There "Activities of Fraunhofer for the Integrated Microsystems" have been presented by Prof. Gessner as well.

We are very pleased about this collaboration between the Fraunhofer-Gesellschaft, the city of Sendai, the MEMS Park Consortium, MEMS Core Ltd. and the Sendai Intelligent Knowledge Cluster.

A joint showroom, resulting from the collaboration in Sendai, displays product samples and development examples from Fraunhofer institutes and Tohoku exhibitors. With the realized layout of the showroom a concept could be implemented that makes it possible to present all important information and specification of the sample without the help of a human being.

FRAUNHOFER ENAS AT TRADE FAIRS

In 2008 Fraunhofer ENAS (and the former Chemnitz branch of Fraunhofer IZM) presented its manifold activities at 16 tradeshows in Germany and abroad.

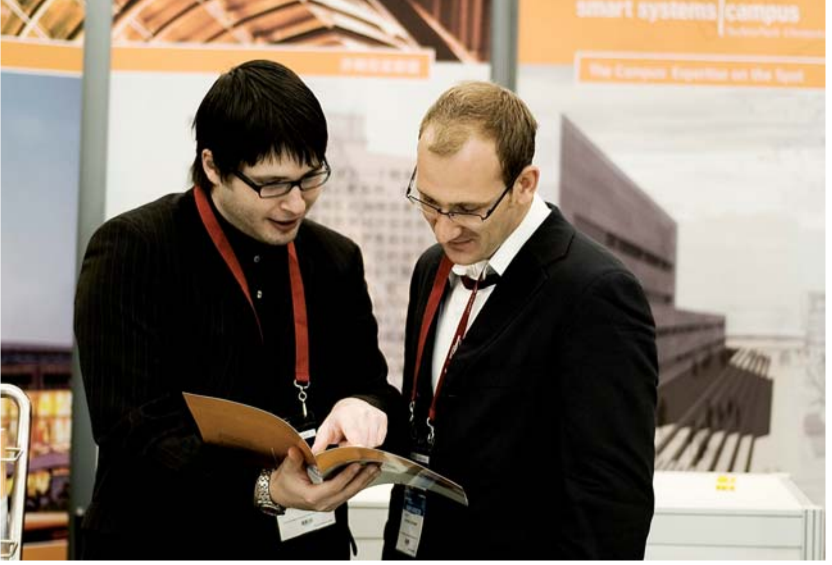
The year started with the nano tech in Tokyo, Japan. During this fair the partners of the Smart Systems Campus Chemnitz, among them the Fraunhofer ENAS (as former branch of Fraunhofer IZM) presented their activities in the field of nano technologies. Special emphasis was given to nano imprinting, nano composites as well as MEMS (micro electro mechanical system) and NEMS (nano electro mechanical system) packaging. During this first visit at the nano tech in Tokyo first contacts to the nanotechnology cluster Osaka have been established.

The partners of the Smart Systems Campus Chemnitz presented commonly their activities also at the:

* SEMICON China, Shanghai, China
* SMART SYSTEMS INTEGRATION, Barcelona, Spain
* Chongqing High Tech Fair, Chongqing, China
* SIT, Chemnitz, Germany
* Exhibition Micromachine/MEMS, Tokyo, Japan

The branch Chemnitz of the Fraunhofer Institute for Reliability and Microintegration IZM presented micro and nano technologies at the SEMICON China 2008 from March 18th to 20th, 2008. In 2008 the scientists from Chemnitz have shown exhibits and research results of applied nano technologies. They presented nano structured bonding surfaces developed by electroplating as well as PVD processes on wafer level. Additional the researchers in Chemnitz have introduced first research results of manufacturing and selective deposition of carbon nano tubes for electronic interconnects. Moreover novel nano composites with enhanced dielectric properties and piezoelectric polymers for low-cost sensors and actuators have been shown. The magnetic properties enable these polymers to be applied for micro fluidic actuators. For instance such system components could be used in miniaturized water coolers for computers and workstations, point-of-care devices for in-vitro diagnostic applications, PCR chips or filter devices for whole blood filtering.

In April the Chemnitz branch of Fraunhofer IZM had an own booth at the HANNOVER MESSE 2008 at the Product Market Micro, Nano & Materials of IVAM.
Laser applications for MEMS and NEMS have been in the focus of the presentation this year. At the Microtechnology exhibition in Hannover, the Chemnitz branch of Fraunhofer IZM has shown developments of laser structured polymers, semiconductors and metals but also micro scaled optical actuators for precise laser beam deflection. Actual developments like high precision laser trimming of MEMS and laser patterning of micro structured polymer slides for fluidic applications were also presented. Furthermore the use of laser techniques for MEMS Packaging and wafer bonding as well as first samples of micro optical devices for medical applications was intensively demonstrated.



FRAUNHOFER ENAS (BRANCH CHEMNITZ OF FRAUNHOFER IZM) TRADE FAIRS IN 2008

February		
	nano tech 2008 International Nanotechnology Exhibition & Conference	Tokyo, Japan
	NRW Nano-Konferenz 2008	Dortmund, Germany
March		
	SEMICON China 2008	Shanghai, China
	LASER World of Photonics China	Shanghai, China
	Silicon Saxony Day	Dresden, Germany
April		
	SMART SYSTEMS INTEGRATION 2008 European Conference & Exhibition	Barcelona, Spain
	China Chongqing Hi-Tech Fair	Chongqing, China
	HANNOVER MESSE, Microtechnology	Hannover, Germany
May		
	SENSOR+TEST 2008 The Measurement Fair	Nuermberg, Germany
June		
	SIT 2008 Sächsische Industrie- und Technologiemesse	Chemnitz, Germany
	ACTUATOR 2008	Bremen, Germany
July		
	Exhibition Micromachine/MEMS 2008	Tokyo, Japan
September		
	MINAPIM 2008	Manaus, Brazil
	MICRONORA 2008	Besançon, France
October		
	SEMICON Europe	Stuttgart, Germany
	Mercopar 2008	Caxias, Brazil

In May at the Sensor+Test 2008 the Chemnitz branch of Fraunhofer IZM presented the micro machined Fabry-Perot filter. During this fair the researchers Dr. Karla Hiller, Dr. Steffen Kurth and Dr. Norbert Neumann (InfraTec GmbH Dresden) have been awarded with the Sensor Innovation Award of AMA Fachverband für Sensorik e.V..

In June the miniaturized spectrometer and the inclination sensors (mounted in a model of an airbus) have been demonstrated at the local fair SIT 2008 especially on the booth of the Smart Systems Campus Chemnitz. Special attention was given to the cooperation with 3D-Micromac AG, the first company which builds an own building within the business area of this campus.

Within the summer break the scientists of Fraunhofer ENAS have presented their developments on the Exhibition Micromachine/MEMS in July in Tokyo. Both spectrometer, the Fabry-Perot interferometer which was commonly developed with InfraTec GmbH Dresden and the miniaturized MIR/NIR spectrometer commonly developed with Colour Control GmbH, have been demonstrated. Moreover other MEMS products and technologies like micro coils for NMR spectroscopy, imprinting technologies, laser trimming of mirrors, printed functionalities have been shown. Special attention was paid to MEMS/NEMS packaging. First time the principles of wafer bonding have been shown by means of a digital picture frame.

The final stop in the 2008 trade show circuit were the SEMICON Europe in Stuttgart and the Mercopar in Caxias, Brazil. At the Semicon in Stuttgart especially the services of the department Back-end of Line have been presented.

FACTS & FIGURES

FRAUNHOFER ENAS IN FACTS
- FRAUNHOFER ENAS IN ZAHLEN

human resources development:

Due to the increase of turnover, the staff level of Fraunhofer ENAS (former branch Chemnitz of Fraunhofer IZM) increased in 2008. Overall, 14 employes joined the team, bringing the total staff at Fraunhofer ENAS in Chemnitz and Paderborn to 63 at the end of 2008.

The research institution 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 10 interns, undergraduates and students assistants were working.
The latter are proving to be a growing source for up-and-coming new scientists and technicians.

financial status, equipment and laboratory investment:

Within 2008 the turnover of the Fraunhofer ENAS was 5.2 million Euro. External proceeds accounted for 87 % of the operating budget. At total 4.5 million euros was procured externally.
Contracts from German and international industry and trade associations reached just 3.4 million Euro, or in other words 65 % of the total turnover.
Equipment investment of 0.65 million Euro was realized in 2008.

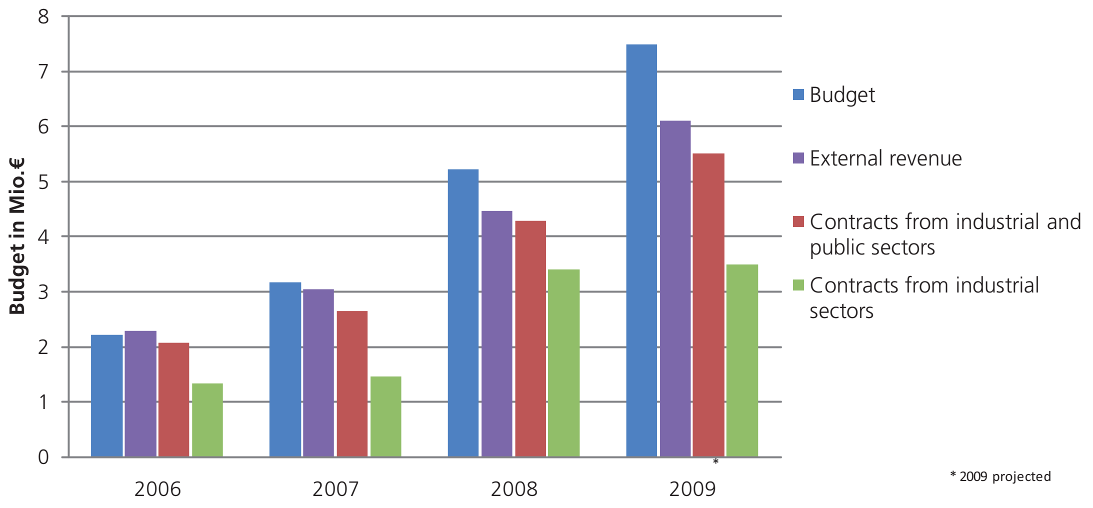
Personalentwicklung:

Basierend auf der Steigerung der Erträge erhöhte sich der Personalbestand der Fraunhofer ENAS in 2008. Es wurden 14 Mitarbeiterinnen und Mitarbeiter eingestellt, sodass 63 Personen an den Standorten der Fraunhofer ENAS in Chemnitz und Paderborn zum Ende 2008 beschäftigt waren.

Zusätzlich bietet die Einrichtung Studentinnen und Studenten die Möglichkeit, ihr Studium mit praktischer wissenschaftlicher Arbeit in den Büros und Laboratorien der Fraunhofer ENAS zu kombinieren. Im Jahresdurchschnitt wurden 10 Praktikanten, Diplomanden und studentische Hilfskräfte betreut. Dieser Mitarbeiterstamm erweist sich in wachsendem Maße als Quelle für den Nachwuchs von Wissenschaftlern und Technikern.

Finanzielle Situation, Geräteinvestition:

Im Jahr 2008 erreichte der Umsatz der Fraunhofer ENAS in Summe 5,2 Millionen Euro. Der Anteil der externen Erträge betrug 87 % des Betriebshaushaltes. Insgesamt wurden 4,5 Millionen Euro extern eingeworben.
Die Aufträge aus deutschen und internationalen Industrieunternehmen erreichte eine Summe von 3,4 Millionen Euro, was einem Umsatzanteil von ca. 65 % entspricht.
Die Geräteinvestitionen im vergangenen Jahr betrugen 0,65 Millionen Euro.



* 2009 projected

THE NEW BUILDING FOR FRAUNHOFER ENAS - BAUGESCHEHEN DER FRAUNHOFER ENAS

After the ceromony held to lay the foundation stone for the new building in November 2007, the construction of the building of Fraunhofer ENAS has made substantial progress. The shell of the building has been finished in August 2008. The completion of interior started just in Mai 2008. The building will be finished in May 2009.

On September 18th 2008, on the occasion of the topping-out ceremony, the director of Fraunhofer ENAS Prof. Thomas Gessner and the architect Prof. Hans Nickl thanked the planners and construction workers for the fast and smooth first stage of construction.

The building will contain 31 offices and 20 laboratories for 100 employees, a caferteria, an artrium and three oases in order to secure a convenient working atmosphere. The energy efficiency at and within the building was an important issue during planning process. The building will have very low power consumption. By means of an earth heat exchanger and the usage of water coming from a 62 m deep spring the building is temperature controlled.

This construction is being funded by the European Fund for Regional Development, the Federal Ministry for Education and Research (BMBF) and the regional government of Saxony. The building will be part of the Smart Systems Campus Chemnitz, to which belong the newly constructed Institute of Physics, the new clean room facilities of the Center for Microtechnologies of the Chemnitz University of Technology, a start-up building for new entrepreneurs and a business park nearby. The approach “Smart Systems Integration” will be given special consideration in the further development.

Nachdem im November 2007 der Grundstein für den Bau eines Gebäudes gelegt wurde, hat dieser in 2008 große Fortschritte gemacht. Der Rohbau wurde im August 2008 fertig gestellt. Bereits im Mai 2008 begann der Innenausbau. Die Fertigstellung ist für Mai 2009 geplant.

Am 18.09.2008, anläßlich des Richtfestes, dankten Prof. Dr. Thomas Geßner, Leiter der Fraunhofer ENAS, und Prof. Hans Nickl, Projektarchitekt, den Planern und Bauleuten für die schnelle und reibungslose Umsetzung der ersten Hälfte des Bauprojektes.

Das neue Institutsgebäude wird neben 31 Büro- und 20 Laborräumen für insgesamt 100 Mitarbeiter und einer Cafeteria auch einen Innenhof und drei Freiterrassen für eine angenehme Arbeitsatmosphäre bieten. Ein wichtiger Aspekt bei der Planung war die Energieeffizienz am und im Gebäude. Mit einem Erdwärmetauscher und der Nutzung von Wasser aus einem 62 m tiefen Brunnen zur Gebäudetemperierung steht der Neubau für einen niedrigen Energieverbrauch.

Die Baumaßnahme wird aus Mitteln des Europäischen Fonds für regionale Entwicklung, des Bundesministeriums für Bildung und Forschung (BMBF) und des Landes Sachsen finanziert. Das neue Gebäude wird Teil des Smart Systems Campus Chemnitz, zu dem der Neubau des Instituts für Physik, der neue Reinraum des Zentrums für Mikrotechnologien der Technischen Universität Chemnitz, ein Start-Up Gebäude für Existenzgründer und ein Gewerbegebiet gehören. Dem Ansatz „Smart Systems Integration“ wird beim weiteren Ausbau besonderes Augenmerk gewidmet.

AWARDS 2008

Sensor Innovation Award 2008

Dr. Karla Hiller (Center for Microtechnologies ZfM and Fraunhofer ENAS), Dr. Steffen Kurth (Fraunhofer ENAS) and Dr. Norbert Neumann (InfraTec GmbH Dresden) got the sensor innovation award 2008 of the AMA Fachverband für Sensorik e.V. during the trade fair Sensor+Test 2008 in Nuermberg. The winner team consisting of partners from basic and applied research as well as industry got the award for the development of a "spectral tunable infrared detector based on micromechanical Fabry-Perot filter element". With this development first time the Fabry-Perot interferometer principle has been used to realize a tunable, micromechanical infrared filter. The consequent optimization of the arrangement and of the processes has led to a powerful module with excellent spectral resolution and high optical quality. It can be applied for detection of gases, liquids and solids with characteristic spectral absorption, for instance in process measurement, medicine, environment sensing, quality control and safety.

The awarded infrared detector is just sold by Laser Components. Based on follow-up projects the system will be further developed and transferred into application together with industrial partners.

NXP Semiconductors Best Paper Award

On the 9th International Conference on Electronic Packaging Technology & High Density Packaging (ICEPT-HDP 2008), which took place in Shanghai, China from August 28th to 31st, 2008, Dr. Rainer Dudek achieved the NXP Semiconductors Best Paper Award for his article "FEA Based Reliability Prediction for Different Sn-Based Solders Subjected to Fast Shear and Fatigue Loadings".

Co-Authors of this paper are Dr. E. Kaulfersch, S. Rzepka, M. Röllig and Prof. B. Michel.

MEMBERSHIPS (SELECTION)

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
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
Conference on Safety and Security Systems in Europe	Prof. B. Michel	head of the conference committee
EPoSS (European Platt form of Smart Systems Integration)	Prof. T. Gessner	member of the steering group
European Center for Micro- and Nanoreliability (EUCEMAN)	Prof. B. Michel	president
EURELNET	Prof. B. Michel	member of executive board
European Security Research and Innovation Forum (ESRIF)	Prof. B. Michel	representant of Germany
German Science Foundation	Prof. T. Gessner	referee
International Young Scientists Conference Printing Future Days	Prof. R. Baumann	general chair
Materials for Advanced Metallization MAM	Prof. S.E. Schulz	member of scientific program committee
microsystems Technology Journal	Prof. B. Michel	editor in chief
Organics Electronics Association (oe-a)	Prof. R. Baumann	member of the board
Senatsausschuss Evaluierung der Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz (WGL)	Prof. T. Gessner	member
Smart Systems Integration Conference	Prof. T. Gessner	conference chair
Smart Systems Integration Conference	Prof. T. Otto, Prof. B. Michel, Dr. C. Hedayat, Dr. K. Hiller	member of program committee
US-MRS-Conference "Advanced Metallization Conference" AMC	Prof. S.E. Schulz	member of the executive committee

PHD IN 2008

PhD: Knut Schulze
topic: „Beiträge zur Technologieentwicklung für die Erzeugung von Airgap - Strukturen in Metallisierungssystemen in integrierten Schaltkreisen“
institution: Chemnitz University of Technology

PhD: Danny Reuter
topic: „Entwicklung einer Dünnschichtverkappungstechnologie für oberflächennahe Mikrostrukturen“
institution: Chemnitz University of Technology

PhD: Werner John
topic: „Charakteristische Parameter von Leitungsstrukturen auf quasi-planaren Substraten“
institution: BTU Cottbus

PhD: Mohamed Taki
topic: “Identification an Simulation of Critical Interconnect Paths with Respect to Transient Noise on PCB-Level“
institution: University of Paderborn

PhD: Ljubica Radic-Weissenfeld
topic: “Model Order Reduction of Linear Systems with Applications to Signal Processing and EMC“
institution: Leibniz University Hannover

Phd: Uzzal Binit Bala
topic: “Hybrid Numerical Modelling an Simulation of Electrostatic Force Microscope“
institution: Leibniz University Hannover

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Department Back End of Line (Prof. Dr. S.E. Schulz)

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