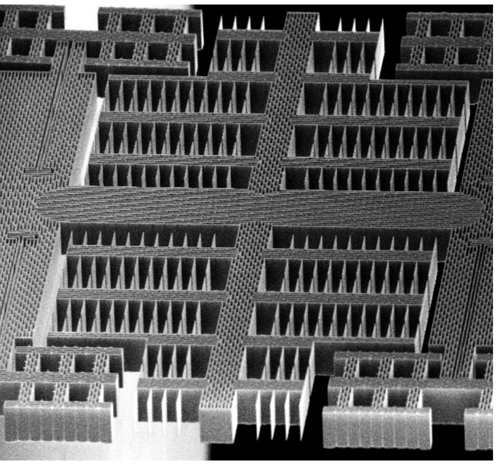
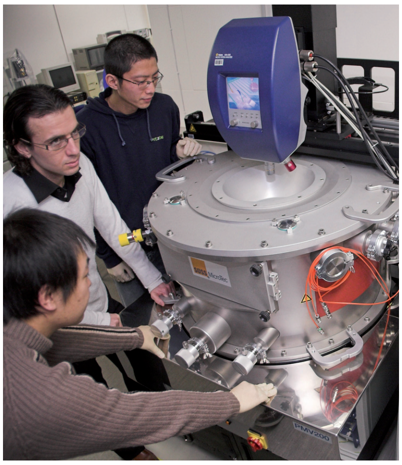
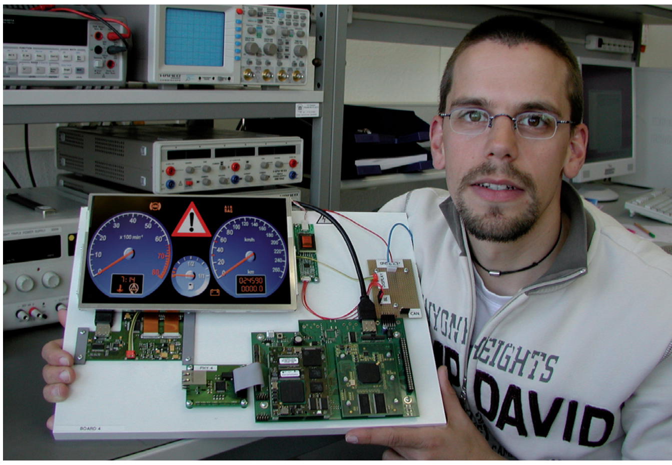
Center for Microtechnologies

Faculty for Electrical Engineering and Information Technology
Chemnitz University of Technology







ZfM
Zentrum für
Mikrotechnologien

CHEMNITZ UNIVERSITY
OF TECHNOLOGY
1836-2011
175 Years

Annual Report
2011 / 2012

Contents

Center for Microtechnologies

The Center for Microtechnologies (ZfM), founded in 1991, belongs to the department of Electrical Engineering and Information Technology of the Chemnitz University of Technology (CUT). It is the basis for education, research and developments in the fields of micro and nanoelectronics, micro mechanics and microsystem technologies in close cooperation with various chairs of different CUT departments.

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

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

- Chair Microtechnology – Prof. Dr. Thomas Gessner
- Chair Microsystems and Precision Engineering – Prof. Dr. Jan Mehner
- Chair Circuit and System Design – Prof. Dr. Ulrich Heinkel
- Chair Electronic Devices of Micro and Nano Technique – Prof. Dr. John Thomas Horstmann
- Chair Electrical Measurement and Sensor Technology – Prof. Dr. Olfa Kanoun
- Chair Power Electronics and Electromagnetic Compatibility – Prof. Dr. Josef Lutz
- Chair Materials and Reliability of Microsystems – Prof. Dr. Bernhard Wunderle.

Additionally two departments belong to the ZfM, the department Lithograpy/Etch/Mask as well as the department Layer Deposition. The ZfM facilities include 1000 m^2 of clean rooms, whereby 300 m^2 of them belong to cleanroom class ISO 4. Modern equipment was installed for processing of 4 inch, 6 inch and 8 inch wafers.

The ZfM carries out basic research, practical joint projects and direct research & development orders for the industry in the following fields:

- Basic technologies and components for microsystems and nanosystems (sensors, actuators, arrays, back-end of line)
- Design of components and systems
- Nanotechnologies, nano components and ultrathin functional layers

Within the last years a very strong cooperation has been established with the Fraunhofer Institute for Electronic Nano Systems ENAS and the other partners within the Smart Systems Campus Chemnitz.

Please visit our homepage:

http://www.zfm.tu-chemnitz.de/

President of the Board
Prof. Dr. Thomas Gessner

Deputy of the President
Dr. Karla Hiller

Chair Microtechnology

Contact: **Prof. Dr. Thomas Gessner**

Phone: **+49 (0)371 531-33130**

Email: **thomas.gessner@zfm.tu-chemnitz.de**

Main working fields:

- Development of new materials and processes for metallization systems in micro and nanoelectronics
- Simulation and modeling of equipment and processes for micro and nanoelectronics as well as nano materials and nano structures
- Development of nanotechnologies, nano components and ultra-thin functional films
- Development of plasma processes for photovoltaics
- Development of technologies and components for microsystems and nanosystems (sensors, actuators and arrays)
- Processes and technology for integration of electronics and micro as well as nanosystem components
- Prototype fabrication of sensors, actuators and arrays
- Processing services for customer applications

Special attention is paid to Si-based MEMS technologies:

- Bulk technology
- High aspect ratio technologies, e.g. air gap insulated microstructures (AIM technology)
- Encapsulation by wafer bonding
- Encapsulation by thin film technology

Several high aspect ratio MEMS technologies, such as the patented AIM technology or the BDRIE (Bonding and Deep RIE) technology, have been established in order to fabricate high precision inertial sensors, e.g. acceleration, vibration and inclination sensors as well as gyroscopes. Furthermore, RF switches and RF resonators are presently under development. The performance of such sensors and actuators using the capacitive working principle is highly influenced by the capacitance gradient due to an electrode movement. However, fabrication restrictions limit the minimum size of the spacing between the electrodes. The reduction of the trench width after patterning of the microstructures down to the sub-µm-range can overcome these restrictions and hereby contribute to higher sensitivity of inertial sensors, decrease of the switching time for RF switches, increase the tuning range of varactors and decrease the motional impedance for RF resonators.

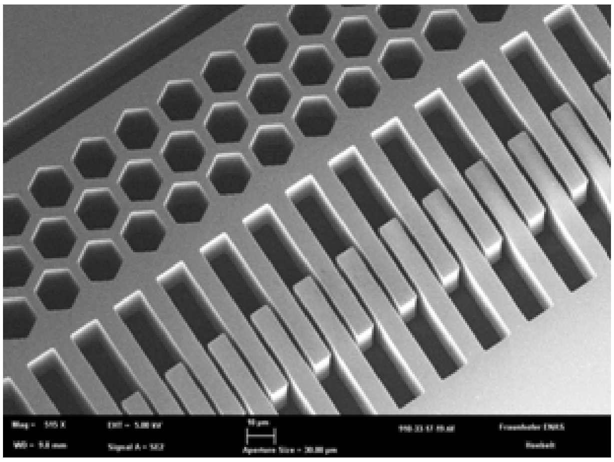


Fig. 1: SEM photograph of the gyro comb drive electrodes.

Several high aspect ratio MEMS technologies, such as the patented AIM technology or the BDRIE (Bonding and Deep RIE) technology, have been established in order to fabricate high precision inertial sensors, e.g. acceleration, vibration and inclination sensors, as well as RF switches and RF resonators. High precision z-axis MEMS gyroscpoes are presently under development in co-operation with Fraunhofer ENAS and EDC Chemnitz. The robust design has been fabricated utilizing the BDRIE technology in combination with zero-level vacuum packaging by glass-Si Anodic bonding, with getter material inside the cavity (see fig. 1 and 2). Thus, the sensors benefit from capacitor gaps with aspect ratio > 50 and quality factors of more than 100,000 and provide high sensitivity (angle random walk < 5°/√h) and BIAS stability (< 10°/h).

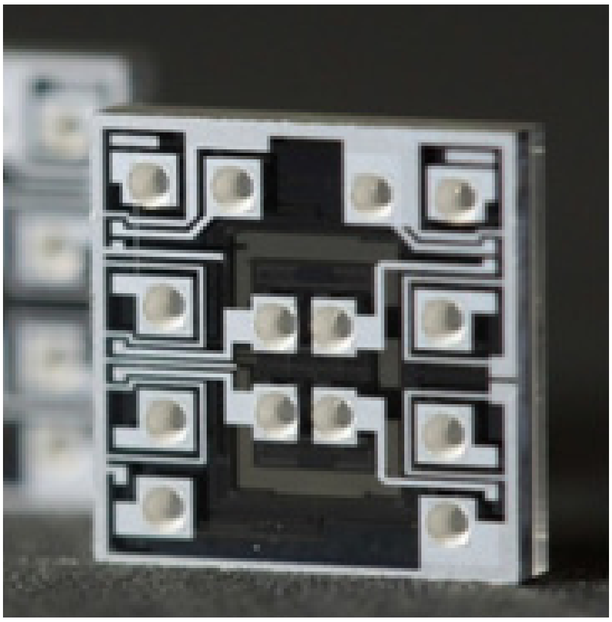


Fig. 2: MEMS gyro chip.

Micromachined Fabry-Perot filters for the NIR range (3…5 µm) for spectral analysis of gases have been fabricated for several years. Recently, in joint projects with Fraunhofer ENAS, InfraTec Dresden and Jenoptik LOC, further improvement could be demonstrated, e.g. extension of the measuring range to the 5…8 µm and the 8…11 µm window and achievement of dual band characteristics by integration of new optical materials. Presently the focus is put on establishing a robust technology for a new design with two moveable reflector carriers and smaller chip size on 6” wafers. Besides distributed bragg layers, the integration of nanostructures fabricated by nanoimprinting is under investigation.

Special attention is paid to thin films ranging from several nanometers to a couple of microns in thickness. They are used as active and functional layers in micro electronic devices, as intermediate layers for packaging processes or protective coatings for micro machines or even as functional films in optical components like gratings or interferometers.

Selected publications:

Nowack, M.; Reuter, D.; Bertz, A.; Kuechler, M.; Aurich, T.; Dittrich, C.; Gessner, T.**: A Novel Three-Axis AIM Vibration Sensor for High Accuracy Condition Monitoring**. IEEE Sensors 2010 Conference, Waikoloa (USA), 2010, Nov 1-4; Proceedings, pp 879-884 (ISBN 978-1-4244-8168-2).

Kurth, S.; Leidich, S.; Bertz, A.; Nowack, M.; Kaufmann, C.; Faust, W.; Gessner, T.; Akira, A.; Ikeda, K.**: Reliability enhancement of Ohmic RF MEMS switches**. Proc. SPIE, Vol. 7928-11 (2011), SPIE Photonics West, San Francisco, USA, Jan 22-27, 2011.

Meinig, M.; Kurth, S.; Hiller, K.; Neumann, N.; Ebermann, M.; Gittler, E.; Gessner, T.**: Tunable mid-infrared filter based on Fabry-Pérot interferometer with two movable reflectors**. Proc. of SPIE, Vol. 7930-18 (2011).

Waechtler, T.**: Thin Films of Copper Oxide and Copper Grown by Atomic Layer Deposition for Applications in Metallization Systems of Microelectronic Devices**. published by Universitätsverlag Chemnitz, 2010 (ISBN 978-3-941003-17-0).

Hofmann, L.; Braeuer, J.; Baum, M.; Schulz, S.E.; Gessner, T.**: Electrochemical deposition of reactive nanoscale metallization systems for low temperature bonding in 3D integration**. AMC, Baltimore (USA), Oct 13-15, 2009; Proceeding of the Advanced Metallization Conference 2009, pp 241-251 (ISBN 987-1-60511-218-3).

Hofmann, L.; Ecke, R.; Schulz, S.E.; Gessner, T.**: Pulse Reverse Electroplating for TSV Filling in 3D Integration**. Smart Systems Integration, Como (Italy), 2010, Mar 23-24; Proceedings (ISBN 978-3-8007-3081-0).

Chair Microsystems and Precision Engineering

Contact: **Prof. Dr. Jan Mehner**

Phone: **+49 (0)371 531-24430**

Email: **jan.mehner@etit.tu-chemnitz.de**

The Chair of Microsystems and Precision Engineering is mainly focused on design, experimental characterization and application of micro-electro-mechanical systems (MEMS). Innovative techniques are investigated in order to link mechanics, optics, electrical engineering and electronics for highly integrated smart systems. Medical and precision engineering are completing the working field

Main working fields:

- Modeling and simulation of physical domains and their interactions
- Experimental characterization and measurement methodologies
- Sensor and actuator development
- Wireless communication and energy scavenging

Microsystems are key components of complex heterogeneous devices such as automotive products, industrial automation and consumer applications. Academic research and education is strongly related to partners from industry and research institutes (e.g. Fraunhofer Institutes, IPHT Jena, Freescale...).

One of the most advanced topics in the field of design is the challenge to establish fast and precise behavioral models for microsystems. Parametric reduced order modeling (ROM) technique, Fig. 1, is the most promising approach to this. The parametric ROM macromodels capture the complex nonlinear dynamics inherent in MEMS due to highly nonlinear electrostatic forces, residual stresses, stress stiffening and supports multiple electrode systems and mechanical contact phenomena. Geometrical nonlinearities, such as stress stiffening, can be taken into account if the modal stiffness is computed from the second derivatives of the strain energy with respect to modal coordinates. The ROM technique based on the mode superposition method is a very efficient technique for fast transient simulation of MEMS components in order to export macromodels for external system simulators.

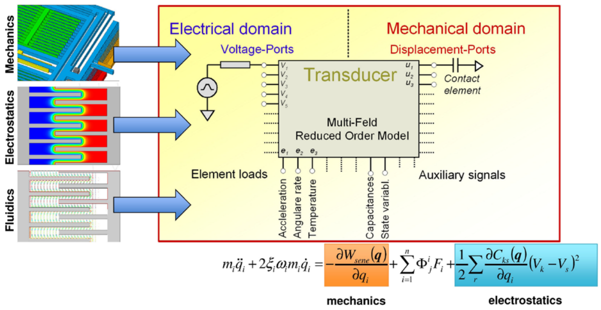


Fig. 1: Reduced order modeling for microsystems design.

This advanced design technique is successfully used for instance for the design of the vibrational sensor shown in Fig. 2.

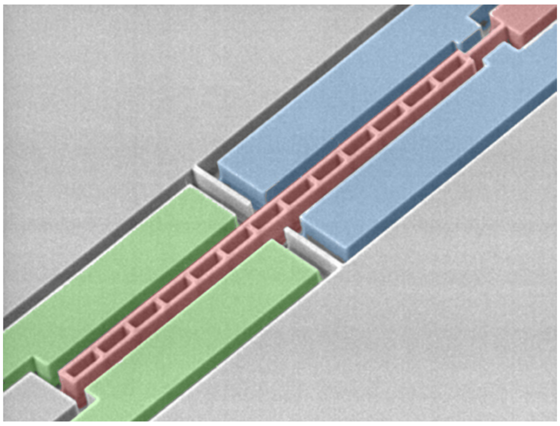


Fig. 2: Zoomed and colored view of a vibration sensor for machine noise detection

The Chair of Microsystems and Precision Engineering is equipped with a state of the art characterization lab containing an atomic force microscope (AFM), autofocus topography, dynamics measurement system and different types of interferometrical measurement systems. Fig. 3 shows the currently most advanced tool which is a PVM-200 Vacuum Wafer Prober equipped with a Micro System Analyzer MSA 500 enabling dynamic and topographic characterization of MEMS at adjustable vacuum and thermal interference. The MSA uses laser doppler vibrometry with scanning laser beam and stroboscopic illumination for out-of-plane and in-plane motion analysis respectively. White light interferometry allows topographic measurements in vacuum conditions.

Fig. 3: PVM-200 vacuum wafer prober and microsystem analyzer.

One of the current medical related projects is the research on a pressure measurement catheter for the human esophagus with high resolution regarding pressure and position. Fig. 4 shows the working principle of this fiber bragg grating (FBG) based sensing system. A wideband light source is selectively reflected by an array FBGs with stepped reflection wavelength. In case of the presented pressure sensor catheter the FBGs are sensitive to pressure and the characteristic wavelengths can be allocated to the place of applied pressure. The advantages are the absence of electrical components, the feasibility of long time measurements, the non-bulky interrogation systems which allow the manometry in rather natural situations and the homogeneous surface which enables easy cleaning and disinfection.

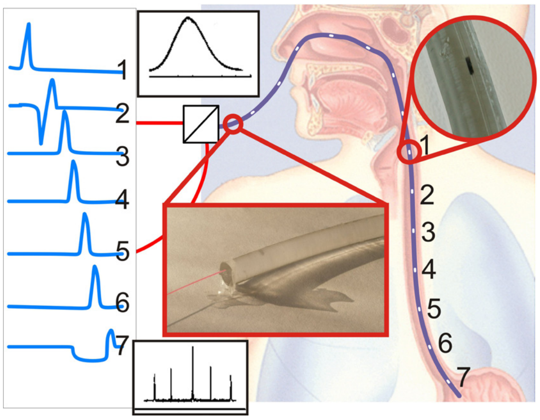


Fig. 4: Working principle of a medical pressure sensor catheter for esophageal diagnosis.

Other current research projects:

- Development of a parametric ROM technique for precise and fast simulation of microsystems
- Design and characterization of microsystems for acoustic emission and vibration detection
- Development of test structures based characterization technique for the extraction of critical technological parameters for microsystems on wafer level
- Development of vibrational energy harvester
- Pressure Sensor for human bladder

Selected Publications:

Dienel, M.; Naumann, M.; Sorger, A.; Tenholte, D.; Voigt, S.; Mehner, J.: **On the influence of vacuum on the design and characterization of MEMS**. Vacuum, Special Issue: Sensors, Vol. 86, Issue 5, 2012 Jan 5, pp. 536-546.

Kolchuzhin, V.; Naumann, M.; Mehner, J.: **Recent developments in reduced order modeling based on mode superposition technique**. 12th International Conference on Thermal, Mechanical and Multi-Physics Simulation and Experiments in, Linz (Austria), 2011 Apr 18-20, Proceedings, pp. 1-6 (ISBN 978-1-4577-0107-8).

Naumann, M.; Lin, D.; Mehner, J.; McNeil, A.; Miller, T.: **Design evaluation of shock induced failure mechanisms of MEMS by correlation of numerical and experimental results**. Transducers 2011 - 16th International Conference on Solid-State Sensors, Actuators and Microsystems , Beijing (China), 2011 Jun 5-9, IEEE, 2891 - 2894 (978-1-4577-0157-3).

Voigt, S.; Rothhardt, M. ; Becker, M. ; Lüpke, T. ; Thieroff, C. ; Teubner, A. ; Mehner, J.: **Homogeneous catheter for esophagus high-resolution manometry using fiber Bragg gratings, SPIE Photonics West, Proc**. SPIE 7559, 75590B (2010).

Mehner, J.; Kolchuzhin, V.; Schmadlak, I.; Hauck, T.; Li, G.; Lin, D.; Miller, T. F.: **The influence of packaging technologies on the performance of inertial MEMS sensors**. Proceedings of 15. Intern. Conf. on Solid State Sensors, Actuators and Microsystems, Transducers' 09, (2009) pp. 1885-1888.

Naumann, M.; Koury, D.; Lin, D.; Oi, H.; Miller, T.F.; Mehner, J.: **Characterisation of sticking effects by surface micromachined test structures**. Chemnitzer Fachtagung Mikrosystemtechnik, Tagungsband, (2009). S. 103-107.

Chair Circuit and System Design

Contact: **Prof. Dr. Ulrich Heinkel**

Phone: **+49 (0)371 531-24310**

Email: **ulrich.heinkel@etit.tu-chemnitz.de**

Main working fields:

- Design of ASICs (Application Specific Integrated Circuits) and FPGAs (Field Programmable Gate Arrays)
- Design of heterogeneous systems (MEMS) in cooperation with the Chairs of the Center for Microtechnologies
- Formal specification/verification and simulation methodologies for digital, analogue and heterogeneous systems with VHDL, VHDL-AMS, SystemC, SystemC-AMS, SystemVerilog, PSL
- Efficient communication (Car2X, application of wireless networks ad-hoc networks, network management, bandwidth reduction with digital image processing, localization algorithms)
- Applications for Ambient Assisted Living (AAL), therapy and rehabilitation

During many years of work in the area of circuit and system design, a huge knowledge in application specific integrated circuits (ASIC) design has been accumulated. Special know-how and experience exist in the field of PLD and FPGA (field programmable gate arrays) design and application.

Many different systems have been designed, e.g. systems for real time processing, rapid prototyping systems for image processing, vibration pattern recognition systems and coupling of simulators and emulators. Research areas include:

- System design of heterogeneous microsystems in cooperation with the Chair of Microsystems and Precision Engineering and the Center of Microtechnologies
- Research work in logic and system design and application of FPGAs and PLDs
- High performance arithmetic for different special purposes (e.g. MPEG video decoders, image compression, graphic controllers)
- Design of re-usable components and IP (Intellectual Properties), development of design environments for re-usable components and applications
- Specification capturing, formal specification with interface-based design methods
- Development and application of a modular system (including graphical user interface) for real time functions (inspection of textile surfaces, analysis of skin diseases, real time image processing, fuzzy classification systems, controlling of projection systems)
- Low power design
- Methods to improve reliability and testability of systems
- Design of analog and digital circuits and short-range communications for sensors (fracture and humidity detection, sports equipment)
- Design of control circuits for medical applications

Although many projects have been processed through the years, there is still a lot of work ahead.

Recently, the chair has 35 employees, most of them working on application specific industrial research projects. Some of those projects, for example, are:

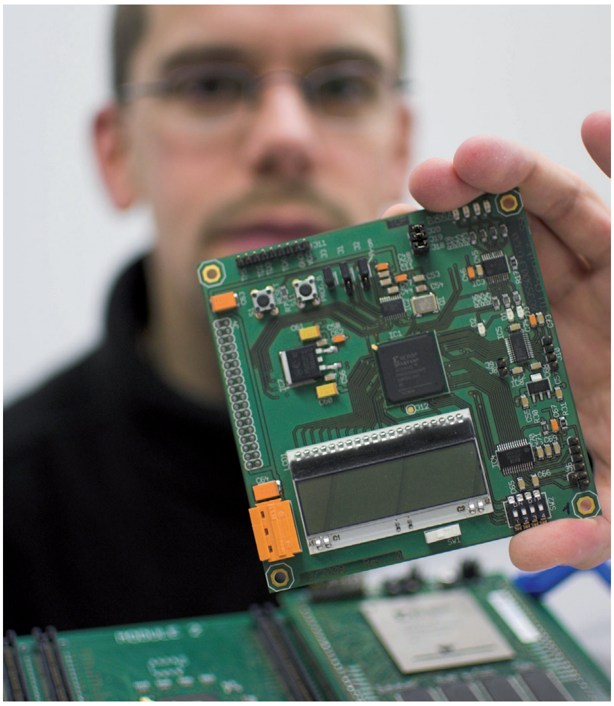


Fig. 1: Daniel Kriesten presenting an FPGA board, built and designed at the Professorship SSE.

- BMBF-project Innoprofile „Generalisierte Plattform zur Sensordaten-Verarbeitung GPSV“
- Joint project (BMBF): Kompetenznetzwerk für Nanosystemintegration: subproject: NEMS/MEMS-Elektronik-Integration für energieeffiziente Sensorknoten
- BMBF-project ForMaT2: Faserkunststoffverbunde mit integrierter Zustandsüberwachung in Echtzeit (FIZ-E)
- Joint project (DLR): SEIS: subproject: Entwurf und Bewertung eingebetteter IP-basierter Netze
- ZiM-AiF-project: “ProTecT - Progressive Techniques for Testing Embedded Systems“
- ZiM-AiF-project: “Entwicklung eines therapeutischen Reizstrombodys“

Selected Publications:

Paulo, R.; Johansson, A.; Kriesten, D.; Heinkel, U.: **Wake-up vs. Duty Cycle - wie können diese beide Netzwerke hinsichtlich Energieeffizienz verglichen werden.** 21st International Scientific Conference Mittweida, Nr.3, Drahtlose Kommunikationssysteme, IWKM 2011, 26. - 27. Oktober 2011, Mittweida, ISSN: 1437-7624 , pp. 44-47

Giegerich, P.; Jerinic, V.: **Toolgestützte Bewertung und Optimierung einer IP-E/E-Architektur in der Entwurfsphase**. 20. September 2011

Paulo, R.; Johansson, A.; Kriesten, D.; Heinkel, U.: **Expedient Usage of Wakeup Receivers in Wireless Network Applications**. 2011 Proceedings of the Ninth Workshop on Intelligent Solutions in Embedded Systems, WISES 2011, 07. Juli 2011, Regensburg, ISBN: 978-3-00-033401-6, pp. 27-31

Langer, J.; Horn, T.; Heinkel, U.: **Enabling the synthesis of very long operation properties**. Electronic System Level Synthesis Conference (ESLsyn), 2011, 05. und 06. Juni 2011, San Diego, CA, USA, E-ISBN: 978-1-4577-0632-5, Print ISBN: 978-1-4577-0634-9, pp. 1-6

Kriesten, D.; Pankalla, V.; Heinkel, U.: **Entwurf eines FPGA-basierten heterogenen rekonfigurierbaren eingebetteten Systems**. Dresdner Arbeitstagung Schaltungs- und Systementwurf 2011, 03. und 04. Mai 2011, Dresden, Fraunhofer Verlag, ISBN 978-3-8396-0259-1, pp. 102

Langer, J.; Froß, D.; Billich, E.; Rößler, M.; Heinkel, U.: **Multi-Level Synthesis on the Example of a Particle Filter**. Southern Conference on Programmable Logic, Cordoba, Argentinien,13. bis 15. April 2011

Kriesten, D.; Kratzert, S.; Heinkel, U.: **Embedded Linux Distributionen - Das Ende der schwarzen Magie?** CLT Chemnitzer Linuxtage 2011, 19. bis 20. März 2011, Chemnitz, ISBN 978-3-941003-29-3, pp. 21-28

Rößler, M.; Froß, D.; Langer, J.; Heinkel, U.: **FPGA-Accelerated Exploration of Monte Carlo Simulations Using High-Level Design Methodology**. DATE 2011 Workshop “Design Methods and Tools for FPGA-Based Acceleration of Scientific Computing”, 18. März 2011, Grenoble, Frankreich

Shende, M.; Wolf, P.; Markert, E.; Roßberg, C.; Herrmann, G.; Heinkel, U.: **Modeling of Aerodynamic Effects of Wind Turbine for Development of a Strain Gauge Sensor using VHDL-AMS**. 8. GMM/ITG/GI-Workshop Cyber-Physical Systems – Enabling Multi-Nature Systems, 23.-24. Februar 2011, Bremen, pp. 65-70, Verlag Universität Bremen, ISBN 978-3-00-033757-4

Lämmermann, S.; Markert, E.; Braun, A.; Ruf, J.; Kropf, T.; Rosenstiel, W.: **Eigenschaftsbasierte Verifikation von MEMS**. 8. GMM/ITG/GI-Workshop Cyber-Physical Systems – Enabling Multi-Nature Systems, 23.-24. Februar 2011, Bremen, Verlag Universität Bremen, ISBN 978-3-00-033757-4

Chair Electronic Devices of Micro and Nano Technique

Contact: **Prof. Dr. John Thomas Horstmann**

Phone: **+49 (0)371 531-37114**

Email: **john-thomas.horstmann@etit.tu-chemnitz.de**

Main working fields:

- layout and verification of analog- and mixed-signal circuit designs for microsys-tem technology
- sensor signal evaluation and actuator control of discrete and integrated microsystems
- modeling and simulation of electronic devices for microsystem electronics and Sub-50nm-MOS-transistors
- electrical measurement, development of test structures and parameter extraction on wafer level
- matching analysis on nano-sized CMOS transistors
- integrated circuit design for microsystem electronics, especially low noise, low power and high voltage
- development, analysis and characteriza-tion of next-generation nano electronic devices

The main research topics at the Chair of Elec-tronic Devices of Micro and Nano technique are:

- development of new circuit concepts for nano electronic mechanical systems
- evaluation of In-Die parameter variations, planning of experiments to reduce parameter deviations and assistance for suitable test structures creation.
- evaluation and investigation of trench isolations and characterization of the electrical behavior
- development of strategies to reduce sta-tistical parameter fluctuations of very small MOS-transistors
- development of low-power-circuits using the weak-inversion-region of MOS-Transistors for autarkic sensors and ener-gy-harvesting-systems
- characterization and simulation of sub-50nm-MOS-transistors
- analysis of physical mechanisms of micro and nano electronic devices

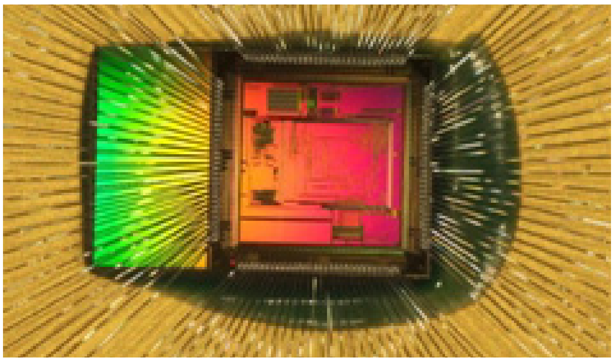


Fig. 1: µ-Controller based on the Intel 8051

- evolution of measurement methods for analysis of the electrical parameters of next generation nano electronic devices
- invention of new materials in the CMOS-process for next generation nano devices.

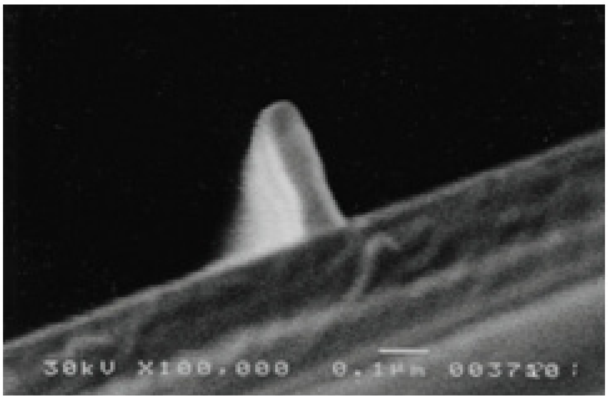


Fig. 2: SEM-picture of the gate electrode of a sub-50nm-MOS-transistor

Main areas of responsibility in the research activities of the “Microsystem Electronics” working group at the Chair of Electronic De-vices of Micro and Nano Technique are the development of integrated electronic mi-crosystems and electronic micro and nano devices and the solution of customer-oriented problems.

The current research projects are:

- in the BMBF project “ModElan” a module platform for customized solutions of com-pact electrical drives are investigated
- smart-power applications realized by a trench isolation, which contains the design of integrated high-voltage electronics and characterization of high voltage isolation structures to optimize the production technology
- research and development of applications for energy-efficient sensor systems and investigation of weak-inversion circuit techniques are the content of the “nano system integration network of excellence – application of nano technologies for energy-efficient sensor systems”
- the DFG-Research Unit 1713 “Sensoric Micro- and Nanosystems” investigates at the integration of different technologies and functionalities in a microsystem to transmit signals and information’s and to interact with the environment
- “SmarFilter – intelligent filter monitoring system” is a further BMBF-project. The development of a system for accurate monitoring of the filter contamination level and the temperature is the project objective
- design of intellectual properties for the MEMS-technologies, currently for a 1µm-CMOS-technology with monolithic inte-grated pressure sensors
- development of next generation electrical drive systems, e.g. electric motors with high efficiency and smart-power-control-concepts
- development of customized measuring strategies and characterization of In-Die parameter variations for semiconductor structures in nano technologies
- electrical and physical design and charac-terization of analog and mixed-signal standard circuits for the CMOS-process
- creation of simulation models for SOI-devices
- investigation and modeling of isolation structures for high-voltage-ICs

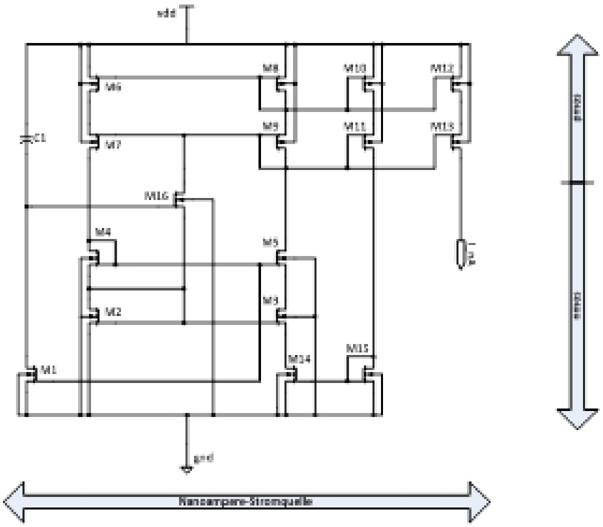


Fig. 3: Circuit of a 3.5 nA current source

Chair Electrical Measurment and Sensor Technology

Contact: **Prof. Dr. Olfa Kanoun**

Phone: **+49 (0)371 531-36931**

Email: **olfa.kanoun@etit.tu-chemnitz.de**

Main research focus:

- Sensors and Measurement systems
- Energy storage for mobile and stationary applications
- Energy autonomous system

Measurement and sensor technologies are gaining importance in technical systems because of continuous ever-increasing of the demand for automation, quality assurance, safety and comfort. The research activities at the Chair for Measurement and Sensor Technology (MST) have a strategic focus on measurement methods, sensor technology, impedance spectroscopy, design of sensor systems and model-based signal processing.

Impedance spectroscopy is a powerful measurement method used in many application fields such as electro chemistry and material science. The research activities of MST in this field include several methodological contributions involving the main aspects of measurement techniques, physical-chemical modeling and signal processing. One example can be given by research projects dealing with diagnosis of Li-Ion batteries.

Energy storage is gaining increasingly more importance because of its key role in the sectors electro mobility, energy and entertainment electronic. Long term stability, suitable charging and discharging processes and behavior prediction are decisive factors demanding the development of novel technologies and management systems. Smart battery management systems can be developed using impedance based methods in combination with suitable models (Fig. 1).

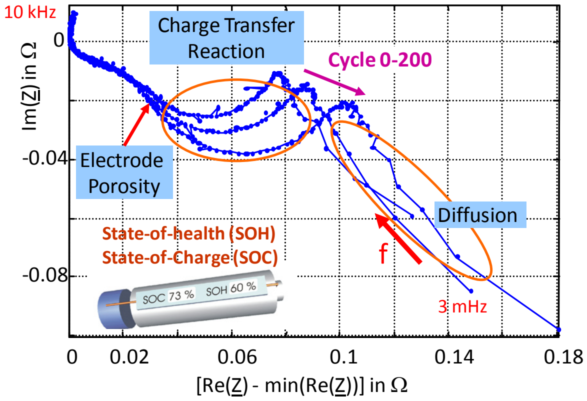


Fig. 1: Diagnosis of Li-Ion batteries by impedance spectroscopy.

The use of ambient energy to power small electronic devices allows the realization of autonomous systems having reduced installation and maintenance costs. A variety of energy conversion principles and technologies can be

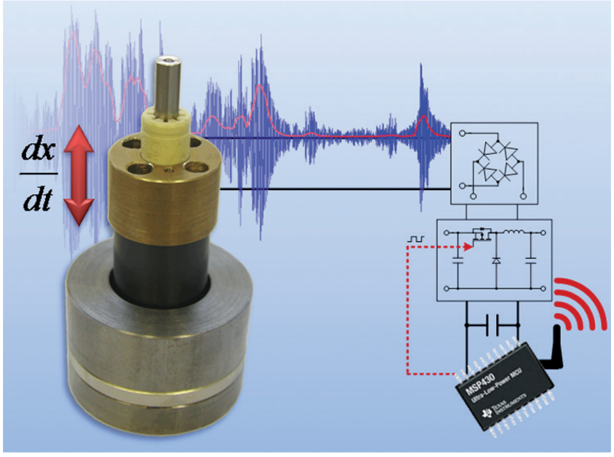


Fig. 2: Electro magnetic vibration harvester .

nowadays adopted to convert temperature differences, vibration (Fig. 2) or electrostatic energy. In order to bridge low energy availability, system should be capable to accumulate energy and to manage energy flows between converter, storage unit and application. The limited efficiency of energy converter, the heavy fluctuations of energy availability changing environmental conditions and the limited capacity of storage units are challenging aspects for the system design. Novel energy harvesting solutions have been developed for specific application requirements. Sophisticated energy management concepts have been developed considering high fluctuations of energy availability.

The technological progress in the field of micro and nano technology allows promising possibilities for new sensors and sensing principles. Novel sensors with outstanding performance can be realized using multi-walled and single-walled CNTs in different technologies and allowing the measurement of versatile measurement quantities. Different activities are in progress aiming to demonstrate the benefits of CNTs for sensors particularly for mechanical quantities. For example, CNT thin films have been realized for use as strain gauges (Fig. 3). Homogeneous CNT-films have been manufactured with different methods and in different forms. They are self-adhesive and show a high sensitivity and a big measurement range in comparison with metallic strain gauges.

Current research projects focus on:

- Energy storage for mobile and stationary applications
- Battery diagnosis (state of charge, state of health, state of function)
- Simulation of batteries and behavior prediction
- Material testing by impedance spectroscopy
- Meat quality assessment by impedance spectroscopy
- Cable fault detection and localization
- Availability and conversion of ambient energy
- Experimental evaluation of thermo electrical converters
- Design of energy autonomous systems
- Energy conversion from electrostatic field
- Smart energy management
- Strain gauges based on carbon nanotubes

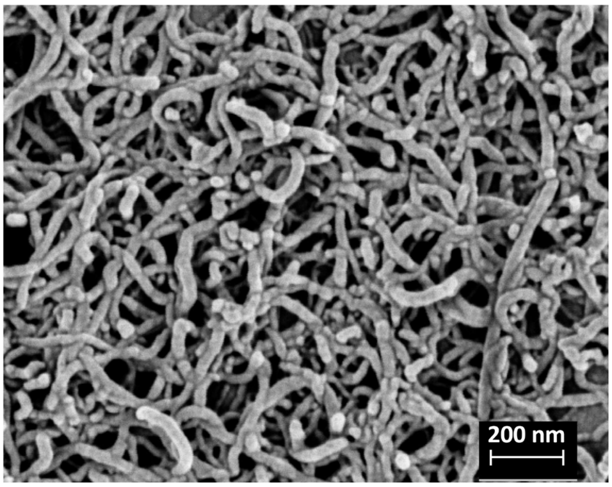


Fig. 3: CNT-films manufactured by spin coating.

Selected Publications:

Kanoun, O.**: Lecture Notes on Impedance Spectroscopy: Measurement, Modeling and Applications**. Vol. 3, ISBN 978-0-415-64430-3 (Hbk), ISBN 978-0-203-07512-8 (eBook), 2012.

Tröltzsch, U.; Kanoun, O.**: Generalization of transmission line models for deriving the impedance of diffusion and porous media**. Electrochimica Acta, Volume 75, 30 July 2012, Pages 347–356.

Viehweger, C.; Baldauf, M.; Keutel, T.; Kanoun, O.**: Hybrid Energy Harvesting for Autonomous Sensors in Building Automation**. IEEE International Instrumentation and Measurement Technology Conference, pp. 610-613, 3-16 Mai 2012, Graz, Austria.

Büschel, P.; Tröltzsch, U.; Kanoun, O.**: Use of stochastic methods for robust parameter extraction from impedance spectra**. Electrochimica Acta, Volume 56, Issue 23, 30 September 2011, Pages 8069-8077.

Gerlach, C.; Lange, J.; Kanoun, O.**: Carbon nanotube composite for application in gait analysis**. 2012 IEEE 9th International Multi-Conference on Systems, Signals and Devices, March 20-23, 2012, Chemnitz, Germany, ISBN: 9783981476644.

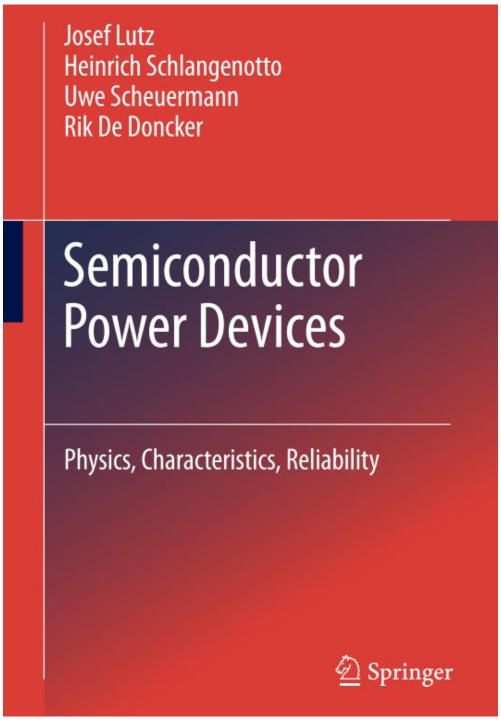
Chair Power Electronics and Electromagnetic Compatibility

Contact: **Prof. Dr. Josef Lutz**

Phone: **+49 (0)371 531-33618**

Email: **josef.lutz@etit.tu-chemnitz.de**

The education covers power devices, thermo-mechanical problems of power electronic systems, power circuits and electromagnetic compatibility. The lecture on "Semiconductor Power Devices" is given in English.



Josef Lutz
Heinrich Schlangenotto
Uwe Scheuermann
Rik De Doncker

Semiconductor
Power Devices

Physics, Characteristics, Reliability

Springer

The focus of research is on power devices, especially their reliability. The main fields of research are:

- Dynamic avalanche and ruggedness: At high stress conditions in dynamic avalanche, current tubes or filaments occur. Of most importance is the nn^+-junction. Designs with improved ruggedness are deduced.
- Surge current capability of power diodes in Si and SiC. Figure 1 shows the new "Inverse Dependency of Emitter Efficiency" Diode.

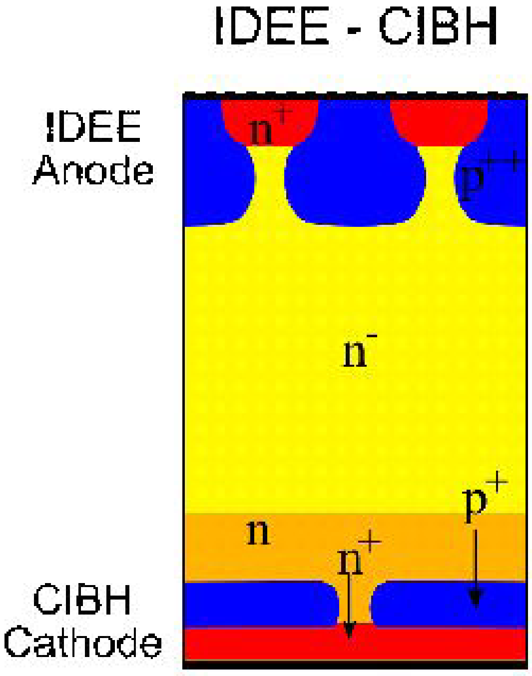


Fig. 1: Inverse Dependency of Emitter Efficiency (IDEE) Diode. Usually, the emitter efficiency decreases at high current density. For the IDEE diode, it is increasing.

- Short circuit capability of high-voltage IGBTs: Power devices must be capable to withstand extreme high loads at fault conditions.

- Long term blocking stability of power devices: A hot reverse test station, DC 2500V, T_j up to 200° C, has been built and is running.

- Reliability of packaging technologies: The focus is on power cycling. Seven self-build power cycling stations are running. A new 2000A station is in construction.

- Simulation of thermal-mechanical stress in power devices: The analysis shows the local mechanical stresses and strains in the package, which result from the mismatch in the thermal expansion of the material layers.

- Failure analysis: Electrical measurements, opening of power modules, inspection, if necessary REM analysis etc., failure reports including evaluation.

Important research projects:

- Electric components for active gears – EfA: joint project 2006 – 2011 for increased energy density of the electric components in the power train of a hybrid vehicle

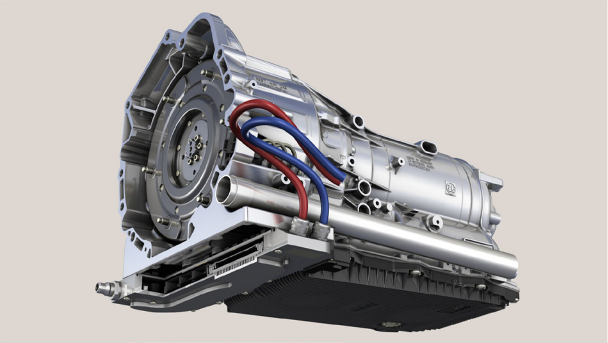


Fig. 2: Active gear for hybrid vehicles with integrated power electronics. (figure from ZF AG, Friedrichshafen).

- Investigation of a power module design for high thermal stress applications in automotive, aerospace and space – HiT-Modul. Joint project supported by BMBF.

- High power converters for offshore applications, joint project with NTNU Trondheim and SINTEF Norway. Power cycling capability and design rules for long lifetime of high-power converters for future large offshore wind parks.

- Reliability and lifetime of Converter – Energy-storage – Systems: subproject of ESF- and SAB-funded junior research group ‘Intelligent on-site energy storage systems’.

- Robustness of high-voltage IGBTs with special consideration of gate drive conditions – industry project.

Selected publications:

Lutz, J.; Schlangenotto, H.; Scheuermann, U.; De Doncker, R.: **Semiconductor Power Devices**. Physics, Characteristics, Reliability; Springer 2011.

Baburske, R.; Lutz, J.; Schulze, H.-J.; Siemieniec, R.; Felsl, H.-P.: **A new diode structure with inverse injection dependency of emitter efficiency (IDEE)**. Proc. IEEE International Symposium on Power Semiconductor Devices & ICs, Hiroshima, Japan, 2010.

Poller, T.; Lutz, J.: **Comparison of the Mechanical Load in Solder Joints Using SiC and Si Chips**. Proc. International Seminar on Power Semiconductors, 1 – 3 September 2010, Prague: CTU, 2010, S. 217 – 222.

Lutz, J.; Baburske, R.: **Dynamic Avalanche in Bipolar Power Devices**. Proc. International Seminar on Power Semiconductors, 1 – 3 September 2010, Prague: CTU, 2010.

Baburske, R.; Lutz, J.; Heinze, B.: **Effects of Negative Differential Resistance in High Power Devices and some Relations to DMOS Structures**. Proc. Interational Reliability Physics Symposium, Anaheim, California, IEEE, 2010.

Hensler, A.; Lutz, J.; Thoben, M.; Guth, K.: **First Power Cycling Results of Improved Packaging Technologies for Hybrid Electrical Vehicle Applications**. Proc. 6th International Conference on Integrated Power Electronics Systems (CIPS) 2010.

Chair Materials and Reliability of Microsystems

Contact: **Prof. Dr. Bernhard Wunderle**

Phone: **+49 (0)371 531-24450**

Email: **bernhard.wunderle@etit.tu-chemnitz.de**

The chair "Materials and Reliability of Microsystems" has been held by Bernhard Wunderle since July 2009. Currently the research group consists of seven full time employees, six of them are academic research staff.

Lectures:

The professorship is responsible for the scientific education in the field of material science for students of electrical engineering and microelectronics and focuses on the reliability assessment and prediction for micro and nano systems for graduate students, including the new international master's program in micro and nano systems.

Research:

Reliability as a scientific discipline is concerned with the analysis, assessment and prediction of the lifetime of microelectronic systems (e.g. of interconnects and interfaces of standard and advanced packages, BEOL-layers, MEMS, 3D-architectures, SIP, etc.).

The main challenges involved therein are the handling of the complexity of microsystems (system reliability), the correlation of degradation to the nanostructure of the materials (nano reliability) and the generation of lifetime models for the transferability between field and lab testing conditions (definition of accelerated and combined tests).

Reliability prediction crucially hinges upon the correct and accurate description of the respective failure mechanisms. The research therefore comprises the development of lifetime models for microsystems starting from the material level up to the system level, based on the physical understanding of the materials involved in terms of their properties and failure mechanisms as function of their structure and external loading conditions ("physics of failure").

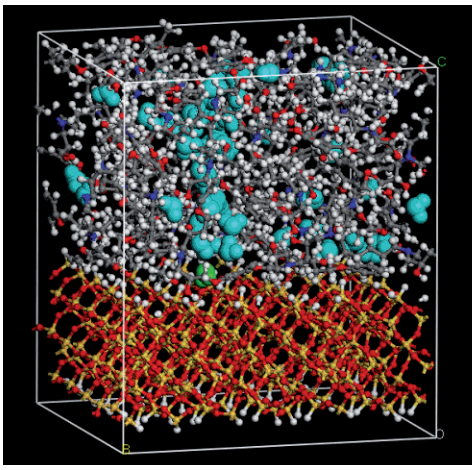


Fig. 1: Molecular dynamics simulation of cross-linked epoxy resin on SiO_2 with H_2O molecules to study moisture diffusion and adhesive properties under different temperature and pressure boundary conditions to obtain structure-property correlations.

The following fields of competence are being built up in a close collaboration with the Fraunhofer ENAS and Fraunhofer IZM:

Material characterization:

- Thermal and mechanical characterization of materials and compounds of microsystems under typical, application-relevant loading conditions such as temperature, moisture and vibration.
- Characterization of cracks in materials and interfaces by means of fracture-mechanical methods considering also process influences on the materials.

Simulation:

- Calculation of failure parameters as a function of external loading conditions.

- Multi-physics approaches to couple e.g. thermal, mechanical and fluidic fields (Finite Element simulations, Computational Fluid Dynamics) for system simulation.

- Multi-scale approaches (e.g. Molecular Dynamics simulation) to obtain structure-property correlations between the nano-scale and the continuum.

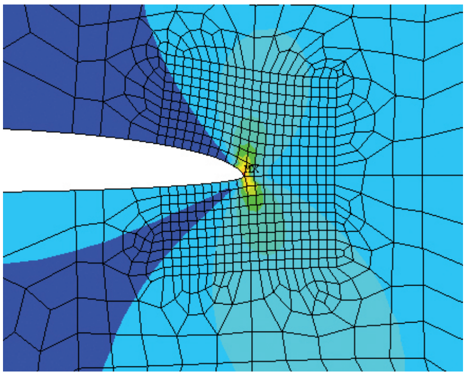


Fig. 2: Finite Element simulation of (asymmetric) crack tip: stress field to investigate mixed mode crack growth at the interface between silica-filled epoxy resin and a copper surface.

Experimental analytics:

- Modern non-contact deformation analysis to verify simulation results on various length scales, in this vein degradation and cracks can be observed in-situ in the micro and nano domain (e.g. nm-resolution by microDAC in combination with REM, AFM or FIB).

- Mechanical testing, reliability testing and crack tracing (e.g. by pulse IR thermography) on specimens of small geometry under combined loading conditions.

Prof. Wunderle is a member of the European Centre for Micro and Nano Reliability (EUCEMAN) and participates in a joint initiative with Fraunhofer ENAS and industrial partners to establish a keylab for micro-reliability in Chemnitz. There is also a close collaboration with Fraunhofer IZM in Berlin.

Current Projects:

- EU-IP eBRAINS: Ambient intelligent nano sensor systems: 3D-SiP architectures in Silicon

- DFG Research Group “Sensoric Micro and Nanosystems”: Design of sensors based on nanostructures

- VW Foundation: Integration and Reliability of CNTs into sensor structures

- EU-IP Smartpower: Smart integration of GaN & SiC high power electronics

Selected Publications:

Wunderle, B.; Michel, B.: **Lifetime Modeling for Microsystems Integration – from Nano to Systems**. J. of Microsystem Technologies, Vol. 15, No. 6, pp. 799 – 813, 2009.

Wunderle, B.; Dermitzaki, E.; Hölck, O.; Bauer, J.; Walter, H.; Shaik, Q.; Rätzke, K.; Faupel, F.; Michel, B.; Reichl; H.: **Molecular Dynamics Approach to Structure-Property Correlation in Epoxy Resins for Thermo-Mechanical Lifetime Modeling**. J. Microelectronics Reliability, Vol. 50, pp. 900 – 909, 2010.

Brunschwiler, T.; Paredes, S.; Drechsler, U.; Michel, B.; Wunderle, B.; Reichl, H.: **Angle-of-attack investigation of pin fin arrays in non-unifrom heat-removal cavities for Interlayer cooled chip stacks**. Proc. Semitherm Conf., San Jose, USA, March 20 – 24, 2011.

Hölck, O.; Bauer, J.; Wittler, O.; Lang, K. D.; Michel, B.; Wunderle, B.: Experimental Contact Angle Determination and Characterisation of Interfacial Energies by Molecular Modeling of Chip to Epoxy Interfaces. Proc. 61st ECTC Conf. Orlando, Fl., USA, May 30 – June 3, 2011.

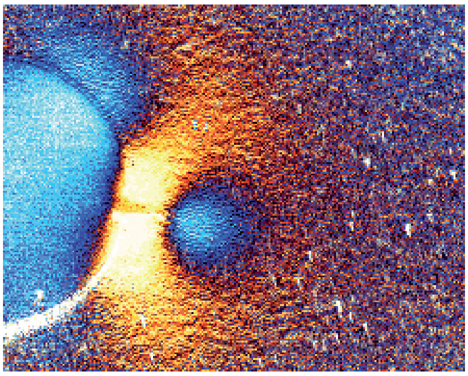


Fig. 3: IR phase image of a mK-temperature field generated during subcritical periodic loading of a crack in PMMA allowing e.g. precise determination of the crack tip position

Honorary Professor for Nanoelectronics Technologies

Contact: **Prof. Dr. Stefan E. Schulz**

Phone: **+49 (0)371 45001-232**

Email: **stefan.schulz@enas.fraunhofer.de**

The most advanced technologies within micro and nanoelectronics have achieved minimum pattern widths smaller than 30 nm for transistors and metallization. Further shrinking (More Moore) will meet scientifically-technological as well as economical limits within a foreseeable future. Thus, an ongoing development of well-known technologies is no longer the only answer. The necessity for the introduction of nano-scale materials and functional layers gets more and more emphasis in order to cope with the physical and technological challenges. Moreover, radical technology changes (Beyond CMOS) will become necessary.

The research group of the professorship is working on process and material development including modeling and simulation to overcome present technology challenges driven by miniaturization. On the other hand, new technology concepts as well as new approaches within materials area are part of research for future electronic devices. This is done in close collaboration with the Center for Microtechnologies at Chemnitz University of Technology as well as the Fraunhofer Institute for Electronic Nano Systems ENAS.

Main working fields:

Process and material development for advanced interconnect systems: Miniaturization leads to faster operating speed for transistors, but rises signal delays (RC-product) in the interconnect system due to smaller structures and increased complexity. Thus, research emphasis is on reduction of RC-product and associated parasitic effects. For that purpose the application of materials with a low dielectric constant (low-k and ULK dielectrics) is examined. Due to their specific properties like low mechanical strength and inherent porosity, integration of those materials into the entire technology flow is of special importance. Damage-poor patterning and cleaning methods as well as development of repair processes are investigated. As new and alternative technology approach the Air-Gap-technology is considered here.

Carbon nanotubes (CNT) for interconnect applications as a new technology approach for replacement of copper in vias. The deposition of high-quality CNTs by low-temperature CVD with different catalyst materials, structural and electrical characterization of CNTs, and process integration into the complete technology flow of an interconnect system are research topics in that field (see to article „CNTs for interconnect and sensor applications”).

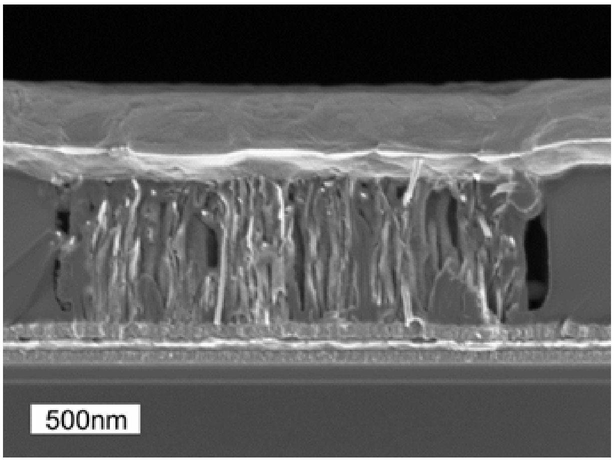


Fig. 1: SEM images after top contact deposition.

Development of thin films with high tensions (Stressors) for the increase of the carrier mobility in MOS-transistors in combination with simulation and modeling of stress fields in MOS-transistor structures and their influence on the transistor characteristics (see to article „Stressor films for enhanced transistor performance “).

Concepts and metallization processes for the integration of electronics and micro/nanosystem components: Development of integration schemes (3D-Integration) using Through Silicone Vias (TSV) considering the special requirements of micro/nanosystem components. TSV metallization using copper-CVD and ECD in order to achieve good step coverage and defective-free filling of TSVs with high aspect ratios (AR ≥ 4).

Atomic layer deposition of metal and metal oxide layers: Process development based on metal-organic precursors, evaluation of new precursors and integration of the processes and materials into the technology flow for the manufacturing of interconnect systems or sensor applications (e.g. GMR sensors or functionalization of CNTs).

Materials and metallization for NEMS: Synergy with micro and nanosystem technology arises from materials which are applicable for sensor functions. Examples are CNTs with selected characteristics and exact positioning by Dielectrophoresis, thin film deposition and patterning processes for device production (e.g. metallization processes, ALD layers, dry etching of multi-layer systems for spintronic applications).

Simulation and modeling of devices, processes and equipment: The development of new materials and technologies requires new or optimized processes and equipment. Advanced models and simulation tools support the development of improved process conditions, tool configurations and film properties. Of special importance is the development of quantum-mechanical simulation models for the description of nano-scale devices and their integration in continuum-based device simulators; e.g. simulation of the transportation characteristics in CNTs and transition to metallic contacts.

Selected publications:

Ahner, N.; Zimmermann, S.; Schaller, M.; Schulz, S.E.: **Optimized wetting behavior of water-based cleaning solutions for plasma etch residue removal by application of surfactants**. 10th International Symposium on Ultra Clean Processing of Semiconductor Surfaces, Os-tende (Belgium), 2010 Sep 20 – 22; Proceedings, pp. 48 – 49.

Fischer, T.; Ahner, N.; Zimmermann, S.; Schaller, M.; Schulz, S.E.: **Influence of thermal cycles on the silylation process for recovering k-value and chemical structure of plasma damaged ultra-low-k materials (Talk)**. Advanced Metallization Conference, Albany, NY (USA), Oct 5 – 7, 2010.

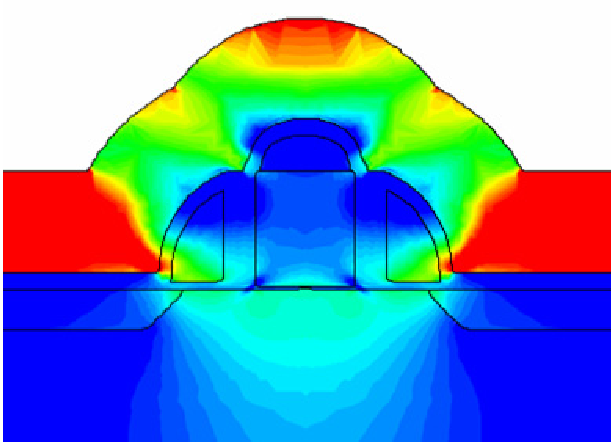


Fig. 2: Stress σ_{xx}, nFET, tensile 2 GPa

Zimmermann, S.; Ahner, N.; Blaschta, F.; Schaller, M.; Zimmermann, H.; Ruelke, H.; Lang, N.; Roepcke, J.; Schulz, S.E.; Gessner, T.: **Etch processes for dense and porous SiCOH materials: plasma states and process results**. 3rd International Workshop Plasma Etch and Strip in Microelectronics, PESM 2010, Grenoble (France), 4 – 5 March, 2010.

Schulze, K.; Jaschinsky, P.; Erben, J.; Gutsch, M.; Blaschta, F.; Freitag, M.; Schulz, S.E.; Steidel, K.; Hohle, .; Gessner, T.; Kuecher, P.: **Variable-Shaped E-Beam lithography enabling process development for future copper Damascene technology (Poster).** 36th International Conference on Micro- and Nanoengineering (MNE), Genoa (Italy), Sept 19 – 22, 2010.

Hermann, S.; Fiedler, H.; Waechtler, T.; Falke, M.; Ecke, R.; Schulz, S.E.; Gessner, T.: **Approaches for Fabrication of Carbon Nanotube Vias**. Nanoelectronic Days 2010, Aachen (Germany), Oct 4 – 7, 2010; Poster presentation.

Hofmann, L.; Ecke, R.; Schulz, S.E.; Gessner, T.: **Pulse Reverse Electroplating for TSV Filling in 3D Integration**. Smart Systems Integration, Como (Italy), Mar 23 – 24, 2010; Proceed-ings (ISBN 978-3-8007-3081-0).

Waechtler, T.; Ding, S.-F.; Hofmann, L.; Mothes, R.; Xie; Oswald; Detavernier, C.; Schulz, S.E.; Qu, X.-P.; Lang, H.; Gessner,T.: **ALD-grown seed layers for electrochemical copper deposition integrated with different diffusion barrier systems**. Materials for Advanced Metallization (MAM), Mechelen (Belgium), Mar 7 – 10, 2010.

Wolf, H.; Streiter, R.; Friedemann, M.; Belsky, P.; Bakaeva, O.; Letz, T.; Gessner, T.: **Simulation of TaNx deposition by Reactive PVD.** Microelectronic Eng., 87 (2010) pp. 1907 – 1913 (ISSN 0167-9317).

Zienert, A.; Schuster, J.; Streiter, R.; Gessner, T.: **Transport in carbon nanotubes: Contact models and size effects**. IWEPNM, Kirchberg (Austria), Mar 6 – 13, 2010; phys. stat. sol. (b), 247 (2010) pp. 3002 – 3005.

Honorary Professor for Opto Electronic Systems

Contact: **Prof. Dr. Thomas Otto**

Phone: **+49 (0)371 45001-231 (Fraunhofer ENAS)**

+49(0)371 531-36650 (ZfM)

Email: **thomas.otto@enas.fraunhofer.de**

thomas.otto@zfm.tu-chemnitz.de

Main technology fields:

- Development of micro-opto electro-mechanical systems MOEMS
- Development of polymer based (functional polymers, nanocomposites) technologies and components for sensors and actuators
- Development of polymer based micro fluidic systems for different Lab-on-Chip systems
- Prototype service of components and systems

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 TQ Systems GmbH Chemnitz. The systems can be configured for different wavelength bands and hence used in various applications. To the fields of application of this spectro-meter belong, for example, food studies, environmental monitoring, medical diagnostics, metrology or the physical forensic analysis.

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. A big challenge is to bring nanoparticles, nanorods or nanowires in contact to the micro and macro world. To overcome these difficulties, we favor different approaches such as the use of special conditioned composits (interfaces, orientation of inclusions) or self-assembling technologies.

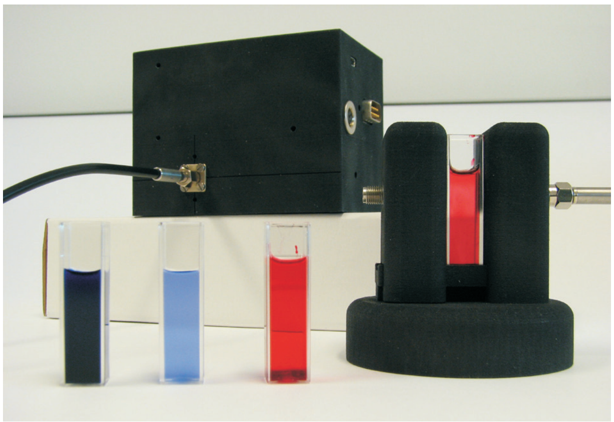


Fig. 1: NIR/MIR MEMS Spectrometer

Lab on chip technologies, i.e. the realization of whole laboratory scale analytical processes on chip-scale devices, promise a giant leap in the quality and availability of health services for the public. Challenges for the development of such smart systems are the integration of all necessary components like fluid transport, temperature control, optical/electrical readout and data interpretation and management. Microfluidics, enabling the handling of small fluid volumes in the µl- and nl-Range (less than one drop) is one of the key elements on the way to miniaturization. The decrease of sample volume leads also to an decrease in the use of pricy reagents and thus in the reduction of the overall cost per test. Typically fields of application for such smart systems are the direct detection of pathogens in various scenarios (bedside testing, food testing,...) as well as the detection of pathological states.

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.

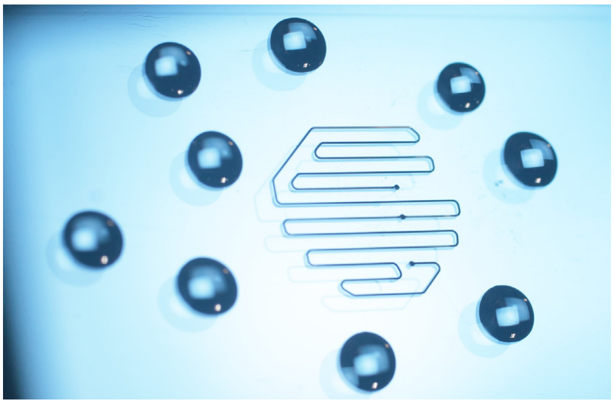


Fig. 2: Laser-micromachined microfluidic channel structure as part of a lab-on-chip system

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.

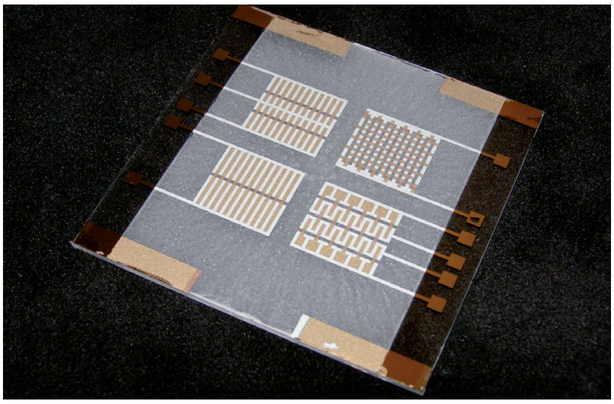


Fig. 3: Humidity sensor based on nanocomposites

Selected publications:

Enderlein, T.; Baum, M.; Nestler, J.; Otto, T.; Besser, J.; Wiemer, M.; John, B.; Hänel, J.; Gessner, T.: **Laser Micromachining and micro hot embossing for highly integrated Lab-on-Chip Systems**. Smart Systems Integration (SSI) 2012, Zurich, 2012 March 21-22, Proceedings, Paper 34, VDE Verlag GmbH, Berlin (ISBN 978-3-8007-3423-8).

Martin,J.; Piasta,D.; Otto, T.; Gessner, T.**: Influence of Charges on the Photolumindescence of Semiconductor Nanocrystals**. Smart System Integration (SSI) 2011, Dresden, 2011 March 22-23, Proceedings, paper 85, VDE Verlag GmbH, Berlin (ISBN 978-3-8007-3324-8).

Martin, J.; Schwittlinsky, M.; Piasta, D.; Streit, P.; Billep, D.; Otto, T.; Gessner, T.**: Thermoelectric generators based on polymers and nanocomposites**. Smart System Integration, Como (Italy), Mar 23 – 24, 2010; Proceedings (CD-ROM), Paper 80, VDE Verlag GmbH 2010. ISBN 978-3-8007-3208-1.

Möbius, M.; Weiss, A.; Otto, T.; Gessner, T.**: Chip-basec optical sencor to determine the arterial oxygen concentration**. Smart Systems Integration (SSI) 2012, Zurich, 2012 March 21-22, Proceedings, Paper 78, VDE Verlag GmbH, Berlin (ISBN 978-3-8007-3423-8).

Nestler, J.; Morschhauser, A.; Hiller, K.; Otto, T.; Bigot, S.; Auerswald, J.; Knapp, H.F.; Gavillet, J.; Gessner, T.**: Polymer Lab-on-Chip systems with integrated electrochemical pumps suitable for large scale fabrication**. Int. J. Adv. Manuf. Technol., 47, 1 (2010) pp. 137 – 145 (ISSN 0268-3768).

Schumacher, S.; Nestler, J.; Otto, T.; Wegener, M.; Ehrentreich-Foerster, E.; Michel, D.; Wunderlich, K.; Palzer, S.; Sohn, K.; Weber, A.; Burgard, M.; Grzesiak, A.; Teichert, A.; Brandenburg, A.; Koger, B.; Albers, J.; Nebling, E.; Bier, F.F.**: Highly-integrated lab-on-chip system for point-of-care multiparameter analysis**. ; Lab Chip 12 (2012), p 464-473 (in press) (ISSN1473-0197).

Streit, P.; Schulze, R.; Billep, D.; Otto, T.; Gessner, T.**: Comparison of lumped and finite element modeling for thermoelectric devices**. Smart Systems Integration (SSI) 2012, Zurich, 2012 March 21-22, Proceedings, Paper 88, VDE Verlag GmbH, Berlin (ISBN 978-3-8007-3423-8).

Otto, T.; Saupe, R.; Weiss, A.; Stock, V.; Throl, O.; Graehlert, W.; Kaskel, S.; Schreck, H.; Gessner, T.**: MEMS Analyzer for fast determination of mixed gases**. MEMS/MOEMS Conference, San Jose, Proceedings of SPIE (2009).

Otto, T.**: Micro- and Nanotechnologies for Smart Systems**. Micromaterials and Nanomaterials, 12/2010, pp. 54-58 (ISSN 1619-2486).

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

Scientific Reports of Chairs of the Center for Microtechnologies

Micro Synthetic Jet Actuators

Christian Helke[1], Martin Schueller[2], Robert Schulze[1], Karla Hiller[1], Joerg Nestler[1], Thomas Otto[1,2] and Thomas Gessner[1,2]
[1] Center for Microtechnologies, Chemnitz University of Technology
[2] Fraunhofer ENAS, Chemnitz, Germany

1 Introduction

A µSJA (Micro Synthetic Jet Actuator) is an active flow control device for applications in aeronautics. This device consists of a cavity and an orifice that build up an acoustic subsystem. A bonded bulk piezoelectric transducer at the opposite of the membrane is used to actuate the electromechanical subsystem (Fig. 1). The bottleneck of the manufacturing is the bonding step of the bulk PZT ceramic to the thin silicon membrane because it faces some limitations regarding the bonding process.

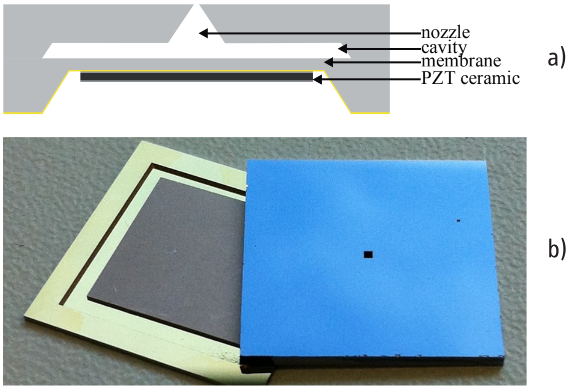


Fig. 1: a) Schematic and b) two manufactured µSJA samples with a 500µm x 500µm nozzle

2 Concept

The new PZT ceramic bonding approach is based on a conductive polymeric interlayer system, which can be structured e.g. by laser machining. Therefore, structures can be realized in different geometrical designs and with a significant repeatable accuracy. These two properties represent the two main advantages compared to liquid or paste-like glues. Benefits of this interlayer system are the low temperature (max. 130°C) and a low bonding pressure of estimated 0.5 bar.

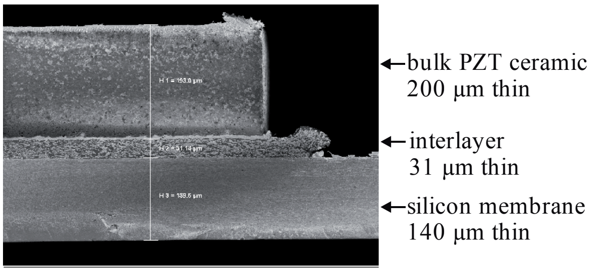


Fig. 2: REM cross-sectional view of the electromechanical subsystem

3 Characterization and Results

Different characterization steps were performed to verify the quality of the µSJAs. Especially for bonding of PZT ceramics with this new developed bonding technique yield tests and shear tests of bonded bulk PZT test chips with different bonding pressures have been done (see Table 1). The shear tests have been realized with the shear strength test tool (TIRAtest 2805). The 6E-3 bar test chips did not withstand the shear strength test.

Tab. 1: Comparison of the conductive polymeric bonded test chips

bonding pressure [bar]	6E-3	0.5	1	2
yield [%]	57	80	93	100
Ø shear strength [MPa]	x	30.2	30.9	29.9

The exit jet velocity at different actuation voltages was used to validate the performance of the µSJAs. A typical result of the µSJAs is shown in Fig. 3. With an applied voltage of 100 V at the resonance frequency of 21.2 kHz exit jet velocities of about 40 m/s can be achieved.

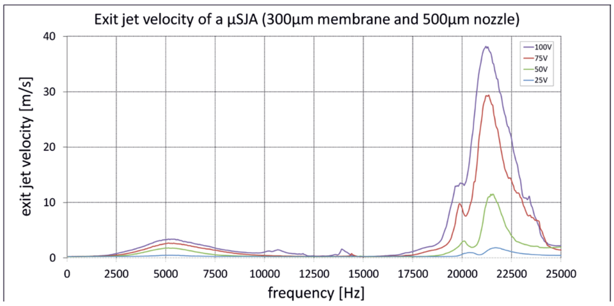


Fig. 3: Measurement of the exit velocity of a µSJA with a 500µm x 500µm nozzle

4 Conclusion and Outlook

First characterization measurements of the µSJAs show good results. Furthermore, the new bonding technology has been proofed. Therefore, the described joining concept represents a promising concept especially for transducers based on thin silicon membranes. Due to the usage of standard bulk PZT ceramics, a bonding process for MEMS has been established without the need of special pre-treatments. Next steps are the adaptation of the new bonding technology for different applications and the investigation of the feasibility of the technology for MEMS based bender structures.

MEMS Acoustic Emission Sensor with mechanical noise rejection

Christian Auerswald, Marco Dienel, Alexey Shaporin, Alexander Sorger, Jan Mehner
Chair of Microsystems and Precision Engineering, Chemnitz University of Technology
Chemnitz, Germany

Abstract – The presented paper describes the use of a new approach to develop a high frequency acceleration sensor with good low frequency noise rejection and in contrast to conventional resonant sensors a short settling time, as it is needed for acoustic emission testing.

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1 Introduction

Acoustic emission testing (AET) is an established technique among a variety of non-destructive testing methods. Acoustic emission (AE) is based on the propagation of transient elastic waves originating from damage in a mechanically stressed material. AET can be used in different applications such as scientific laboratory testing or for condition monitoring of machines or buildings, where it is security-related and economic-related [1]. The goal is to detect damage before the structure fails or in other applications to adapt the service intervals on the actual wear and to replace parts only if it is really necessary. Sensors based on the piezoelectric principle are established, but their disadvantage is the high price. Due to the high-volume batch processing technology, micro-electromechanical (MEMS) sensors offer the potential of lower prices at comparable performance and thereby a wider field of use [2], [3].

An Acoustic Emission (AE) signal is a fast sequence of low amplitude, high bandwidth bursts in the range of approximately 100 kHz to some MHz [4]. AE has to be separated from the low frequency signals below 50 kHz, which are the results of mechanical noise and machine vibrations, because they do not deliver information about the structural health or overload conditions. Due to those specific properties, the requirements for an AET are, apart from high sensitivity and good signal-to-noise ratio, a high bandwidth around 100 kHz, a low sensitivity below 50 kHz and most importantly a short settling time.

Conventional MEMS based vibration sensors are often designed as resonators with high quality factor Q. This implies a high sensitivity at resonant frequency, a medium low frequency rejection and a high settling time [5]. The last fact is a disadvantage for measuring short, burst-like signals, which are probably much shorter than the time the sensor needs so start swinging. Compared to these conventional micro-electro-mechanical resonant acceleration sensors, the presented MEMS sensor has advantages in settling time and bandwidth.

2 Sensor Model

The acceleration sensor consists of two mechanically decoupled spring-mass-damper systems (SMD), so called low-frequency- (LF) and high-frequency-resonators (HF). The resonators have different eigenfrequencies ($f_{0LF} < f_{0HF}$) and a low quality factor Q of ten, which results in a short settling time. The comb electrode system acting as transducer between mechanical and electrical domain is shown in fig. 1. It is designed for common mode rejection. Both resonators are deflected by an external acceleration. The output signal depends on C_{res}, which is:

$$C_{res} = C_{LF}+C_{HF}\,. \qquad (1)$$

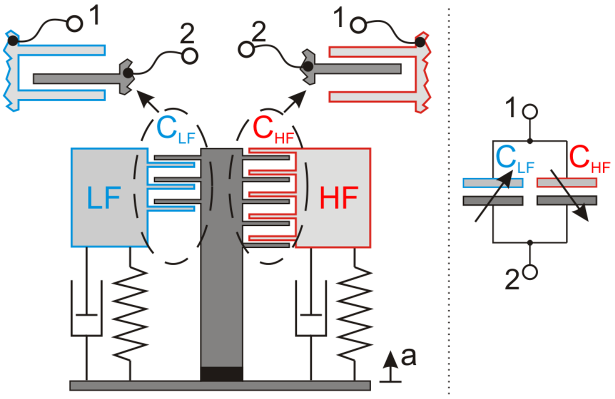

Fig. 1: Schematic representation of the sensor principle [6]

The phase shift between the two resonators is frequency dependent: below f_{0LF} and beyond f_{0HF}, both SMDs are mechanically in phase. Within the pass band between these two frequencies, they are inversely phased. Because of the frequency dependent mechanical behavior and the anti-parallel connection of the comb electrodes, the resulting capacitance of the overall system is also frequency dependent. This means within the passband, the two sub capacities interfere additive and out of this range they compensate each other to zero. The result is a sensor with inherent electro-mechanical band pass characteristics, that means high sensitivity in the passband and a good noise rejection in the stop band.

The complex frequency response of the overall electromechanical system $H_{em}(\omega)$ describes the relationship between the acceleration a, which is to be measured, and the sensor output current i:

$$H_{em}(\omega) = \frac{i}{a}\,. \tag{2}$$

It can be separated into the electrical H_e (ω) and the mechanical system H_m (ω):

$$H_{em}(\omega) \;=\; H_e(\omega)\, H_m(\omega)\,. \tag{3}$$

The mechanical frequency response $H_m(\omega)$ describes the ratio of displacement $\hat{x}_r$ vs. acting acceleration a:

$$H_m(\omega) = \frac{x_r(\omega)}{a} = \frac{1}{\omega^2 - j\omega\frac{2\pi f_0}{Q} - (2\pi f_0)^2}\;. \tag{4}$$

Q is the quality factor, f_0 the eigenfrequency and □ the angular frequency. Due to the higher eigenfrequency of the HF resonator, it has a lower mechanical sensitivity. For noise rejection in this range by the abovementioned principle, the lower mechanical sensitivity of the HF resonator has to be compensated by a higher electrical sensitivity S_HF. It has to be higher than the electrical sensitivity S_LF of the LF resonator according to their ratio of static displacement V_stat:

$$V_{stat} = \frac{S_{HF}}{S_{LF}} = \frac{{f_{0HF}}^2}{{f_{0LF}}^2} \tag{5}$$

The increase in sensitivity can be easily accomplished by raising the number of electrode fingers, as suggested in fig. 1. The transformation of the mechanical displacement x_r into an electrical value is achieved by applying a constant bias voltage V_bias across the sensing capacitor and processing the motion induced current i

i= V_bias dC/(dx_r) (dx_r)/dt= V_bias dC/(dx_r) v . (6)

The electrical frequency response H_e (j□) describes the relationship between the current i and the displacement of the seismic mass:

H_e (□)=i/x_r . (7)

The introduction of S_comp, the linearized sensitivity of the comb electrodes within the operation point, leads to:

H_e (□)=j□V_bias S_comp . (8)

Due to the opposite electrode configuration and the sensitivity compensation of the LF and HF resonator the following is valid:

S_NF=-□V_”stat” S□_HF (9)

The sensor output current is the sum of the LF and HF current i_LF and i_HF respectively:

i=i_LF+ i_HF (10)

i=H_(em,sys) (□)a (11)

The resulting frequency response H_(em,sys) (□) of the whole sensor, consisting of the LF and HF resonator, is combined as follows:

H_(em,sys) (□)=H_(em,LF) (□)+H_(em,HF) (□) (12)

Fig. 2 shows the amplitude frequency response of the two resonators and of the overall sensor system.

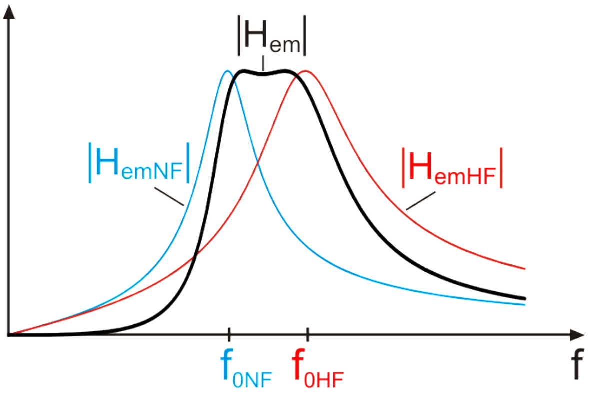

Fig. 2: Electro-mechanical frequency response of both resonators and the resulting overall system

3 Spice-Simulation

A macro model of the sensor chip was designed in LTspice IV, assuming small signal behavior. Afterwards it was simulated alone and in combination with the signal conditioning electronics.

The sensor model has one input and five output ports. An acceleration proportional voltage is fed in as sensor excitation. Two outputs deliver a voltage representing the displacement of the seismic mass of the LF and HF resonator respectively. These ports are associated to the mechanical domain of the sensor, the remaining three ports are associated with the electrical domain. They represent the potential of the movable seismic mass and the two fixed electrodes.

The mechanical system is described using a mechanical-electrical analogy listed in tab. 1.

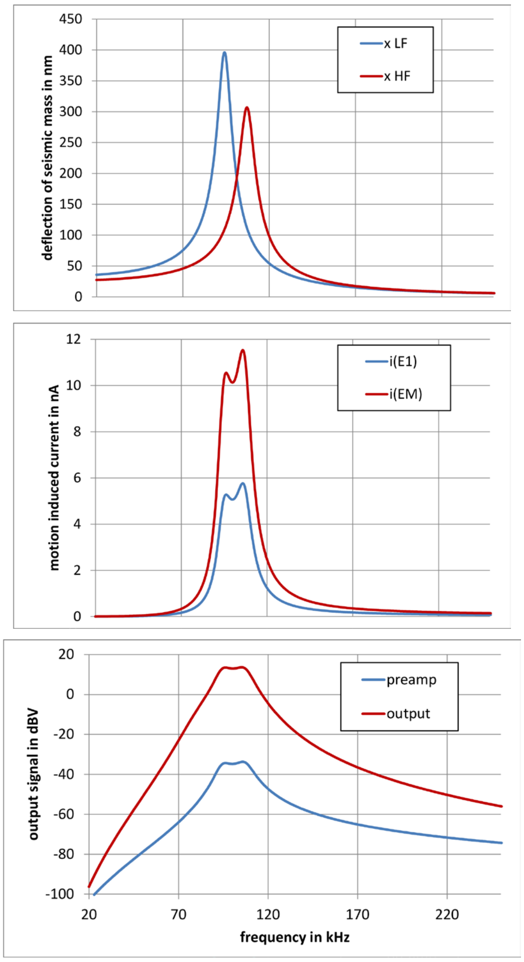

Fig. 3: Simulation results (top: mechanical displacement of seismic mass; middle: primary electrical sensor output; bottom: preamp and output voltage)

The input acceleration is transferred into a mechanical force F_m using a programmable voltage source and the connection

$$F = m\,a\,. \qquad (13)$$

A second force, acting on the seismic mass, is the electrostatic force F_el, which has its origin in the electric field between the comb electrodes. F_el is found:

$$F_{el} = \tfrac{1}{2}\, V^2\, dC/dx \qquad (14)$$

The SMDs are modeled using the analogies in tab. 1 as a series resonant circuit. The current through R represents the velocity of the seismic mass. This current is integrated, using a third programmable voltage source and transferred into a voltage proportional to the displacement of the seismic mass. The parameterized SMD model is used twice, one for LF and one for HF resonator, only different in the particular mechanical parameters.

The output ports of the model - the three electrodes of the differential capacitor - are formed by two programmable current sources, which use the position and velocity of the seismic mass and the applied voltage across the electrodes to calculate the resulting motion induced current.

The model is only applicable for small signal behavior. The effect of electrostatic spring softening, which leads to a decrease of the center frequency, is also modeled by introducing the electrical force F_el into the simulation. Fig. 3 shows the simulation results, representing different physical and logical domains: the mechanical displacement of the seismic mass, the motion induced current as the primary sensor output and the output signals of different stages of signal conditioning.

Tab. 1: Electrical-mechanical analogy

Electrical domain		**Mechanical domain**	
R	resistance	b	Damping coefficient
L	inductance	m	mass
C	capacitance	1 / k	1 / stiffness
V	voltage	F	force
I	Current	v	velocity

4 Sensor System and Electronics

The sensor chips have been manufactured using BDRIE (Bonding and Deep Reactive Ion Etching [7]), implying that the sensor is only sensitive to in-plane accelerations. This has to be taken into consideration during the mechanical development of the sensor node. To detect and measure mechanical out-of-plane waves in the structure or device under test, the sensor has to be mounted vertically to the underground. For reasons of contacting and bonding, not only the sensor but the whole circuitry have been arranged in that way. The sensor is made from silicon, a hard and brittle material. Several tests have been performed in order to bring an edge of the sensor in direct contact to the underground material to avoid any intermediate layer, which could reduce the measured AE signal. Good results have been made this way, but it arose that this contact is very fragile and in some cases parts of the chip simply broke away. In order to avoid this, an aluminum chip carrier was designed, which acts as a waveguide and a protection of the sensor. The chip is glued to the carrier with a conductive epoxy. A milled edge is used to couple the acoustic wave not only by shearing of the adhesive on the bottom side of the sensor chip but by direct contact of the chip frame to the carrier.

Due to reasons of testability there are two separate and independent sensor structures on each sensor chip. Each of them consists of LF and HF resonators. The two structures are wired in parallel on the PCB.

The sensor system consists of the chip carrier and several electrical functional parts: the AE-sensor by itself, the signal-conditioning electronics and the power supply, which converts the input of 12 volt (10,5 to 18 volt) to regulated +10 volt for the operational amplifiers (linear step-down regulator) and to +60 volt bias for the AE sensor (step-up switching regulator). The step-up converter and some parts of the signal conditioning electronics are designed as stackable modules in order to save lateral area. Fig. 4 shows the setup.

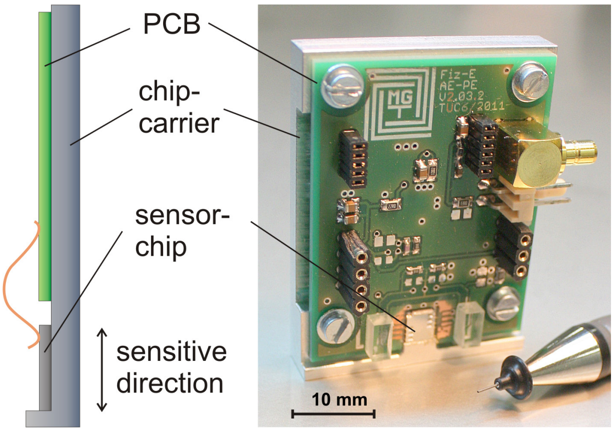

Fig. 4: Setup of the prototype, without stackable modules

Fig. 5 shows the first stage of signal conditioning. An unbalanced bias voltage V_bias is used to polarize the differential capacitor. Due to differences in isolation, the voltage across the two sub capacitances would not split even without the two balancing resistors in the mega ohm range. After this, the motion induced sensor output current is AC coupled through the capacitor C and fed into a current-to-voltage converter (I-V-converter). Its transimpedance is calculated as following:

v_out□i = -R□□ □□□□

The I-V-converter is followed by a bandpass filter (Butterworth 4th order, center frequency approximately 100 kHz, bandwidth 45 kHz, gain 26dB).

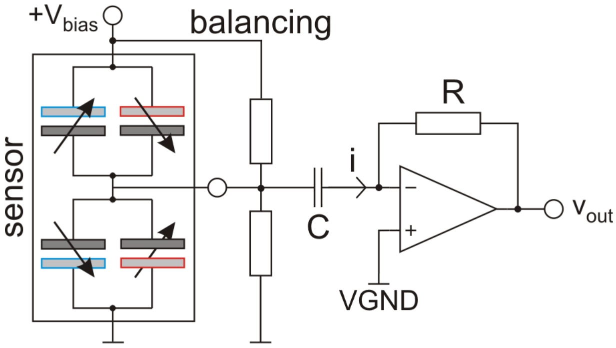

Fig. 5: AE sensor and first stage of signal conditioning

5 Characterization

The characterization is, due to the capacitive transducer principle, only possible with signal conditioning electronics.

Fig. 6 shows the test setup for measuring the frequency response. The sensor system (AE-sensor and primary electronics) is excited with a piezo-electric shaker (Panametrics V101). The velocity at the chip frame is measured by a laser-doppler interferometer LDI (Polytec OFV 3000 & OFV 502) and afterwards digitalized by an EG&G 7265 DSP Lock-In amplifier. The PC control software calculates the acceleration of the measured velocity and controls the output amplitude of the lock-in amplifier in order to get a frequency independent acceleration at the chip frame of the AE-sensor. This way, the non-ideal frequency response of the shaker in wide ranges has no effect on the measurement. As a second channel the output signal of the primary electronics is digitalized and recorded by the lock-in amplifier and the PC control software.

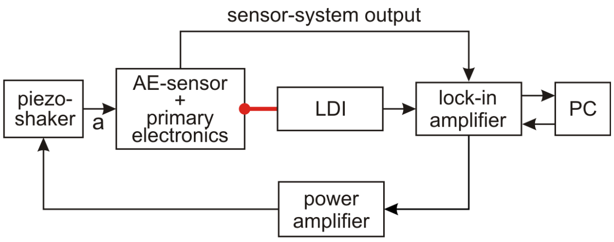

Fig. 6: Principle of test setup using a closed loop acceleration regulation [6]

The resulting frequency response is shown in fig. 8 in the next section, in comparison with a conventional resonant sensor (grey) and the simulated system response (blue). The amplitudes have been normalized for a better comparability.

To test the response to burst-like signals, the sensor system was clamped on a round, 4 mm thick stainless steel plate of 1050 mm diameter (fig. 7). Then hardened steel balls of different diameters from 16 to 5 mm were released from different heights to generate burst signals with different ascending amplitudes. The release height was reduced step by step. In doing so it was proven that the sensor system is sensitive to bursts and, furthermore, some first optimizations could be realized.

Next, a pencil break test (PBT) was conducted. This is a standard test in AET: the fracture of a pencil lead introduces a low amplitude burst into the underground. The test signal is reproducible and can be used to evaluate the distance between the pencil and the sensor system, in which the burst signal can be detected. It has shown that an AE-signal produced by a PBT is detectable with this system (fig. 8), but further analyses have to be carried out concerning the range of detection.

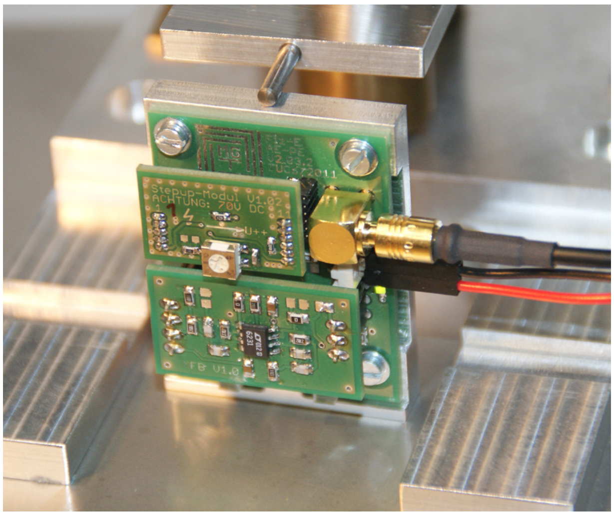

Fig. 7: Sensor system mounted on steel plate using a clamping mechanism

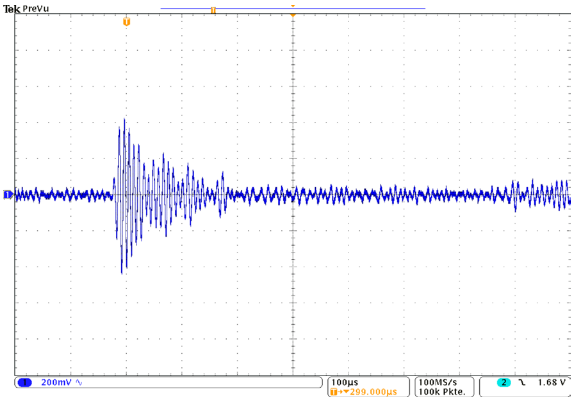

Fig. 8: Pencil break test induced burst measured by the presented bandpass sensor system

6 Comparison Simulation vs. Measurement

The comparison between simulation and measurement can only be done in the frequency domain. AE Burst signals in the time domain are difficult to model within a simulation.

For comparison, a conventional resonant sensor with the same quality factor of ten has been developed. This quality factor ensures a comparable short settling time. The recorded amplitude frequency response of a bandpass AE sensor (red: measured, blue: simulated) and in contrast a conventional resonant sensor (grey) is shown in fig. 9. The amplitudes of all three curves have been normalized for easy comparison.

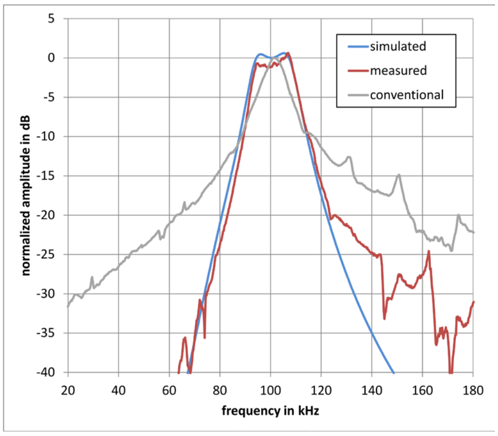

Fig. 9: Frequency response of bandpass (blue and red respectively) and resonant sensor (grey) normalized

Within the passband there are only little differences between measurement and simulation. In higher frequency ranges the measurement is imprecise owing to the fact that output signals of both the AE system and the laser interferometer in this range are strongly damped and the signal-to-noise ratio is getting worse. In contrast to the bandpass sensor, the conventional acceleration sensor has a much smaller passband and a lower rejection for high and, first of all, for lower frequencies.

7 Summary and Outlook

A new MEMS based Acoustic Emission sensor has been developed and first practical tests have been performed. The sensors were designed such that the center frequency f_c is 100 kHz at a bandwidth of 45 kHz. The new sensor principle combines low settling time with improved stop band rejection. The simulation and measurement show a good agreement.

Further work will be focused on raising the sensitivity and overall performance of the sensor system, which will be achieved by optimizing the ratio of chip size vs. active sensing area. The coupling between underground and sensor chip has to be improved and the PCB can be further minimized. Due to the high eigenfrequency and spring stiffness, higher bias voltages can be applied.

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A Specification Utility for Microsystems

Erik Markert, Thomas, Horn, Milind Shende, Matthias Sauppe, Göran Herrmann, Ulrich Heinkel
Chemnitz University of Technology, Chair Circuit and Systems Design,Chemnitz, Germany

Abstract

The specification is the starting point of the design process and so has a major influence on the design success. To raise the efficiency of this process requirement management systems are used. This paper gives a short introduction into the tool SpecScribe. This software offers direct design support using code generation and supporting formal verification. It can be used for digital as well as for analog problems.

1 Introduction

The system complexity is rising following Moore's law, forcing the design process to become more quickly to handle the emerging technology features. Design process using top-down methodology starts with the system specification. Today this is usually a collection of informal texts or pictures. It is a hard and time-consuming process to ensure the consistency and unambiguity of informal language. Several Requirement Management Systems (RMS) like DOORS or HP Quality Center help the designer teams during design process. But these tools lack of direct design support (see section 2 for details).

The tool SpecScribe will fill this gap by combining requirement management features with modeling and code generation options. Section 3 gives an overview on the currently available and planned features. The goal of the tool is toreduce the Time-to-Market of products by assisting the designer teams in recurring work items and by reducing delays caused by ambiguities from informal specifications. SpecScribe is not meant to be ”yet another document management system” as it includes formal specification methods and interfaces to common modeling languages like VHDL and SystemC(-AMS) together with formal languages like PSL.

2 Related Work

Requirements Management (RM) tools have become generally established in design processes in the last years. Depending on the specific demands of a project, different aspects have to be considered. In [2], a collection of criteria for RM tools is presented.

Generally, there is a wide range of tasks that these tools are able to accomplish, and hence used for. Requirements can be tracked, i.e. every change to a requirement is recorded, including information such as who made a change and when was it made. It is also a common feature to trace dependencies between requirements and provide a visualization of these dependencies. Verification and testing are important aspects during design, as they are necessary to determine whether requirements are met. This is reflected by providing the possibility to link test cases and test plans to certain requirements, thus establishing a direct connection between specification and testing.

There are classical tools like IBM Rational Doors [3], that help designers to clearly organize requirements in a defined and well-arranged way. Other tools focus on Application Lifecycle Management (ALM) and provide functionality to cover aspects like testing, bug reporting and tracking or continuous application development. Examples for this kind of tools are HP Quality Center [4], MKS Integrity [5] or Siemens Teamcenter [6]. Unfortunately these tools not fully support a classical electronic design flow using SystemC or VHDL and have limited capabilities for formal verification. The tool SpecScribe tries to fill this gap.

Fig. 1. Screenshot of wind turbine specification in SpecScribe tool

3 The tool SpecSribe

The tool named SpecScribe, a development of our chair, supports the engineer in the specification, design and verification process. The concepts of the tool were described earlier [7], now the main parts of the tool are implemented and applied to real world examples. The data given by the specification engineers usually consist of a huge amount of non-formal textual or graphical descriptions sometimes even without a structure. Due to the textual form these descriptions often are ambiguous or inconsistent. The first step in formalization is therefore the structuring of the requirements in a hierarchical order to identify dependencies. In the next step the textual/graphical requirements need to be formalized which requires a differentiation regarding the time-continuous and digital parts.

Digital behavior means a discretisation of the time axis so a step-by-step execution of these algorithms is possible. This allows the usage of finite state machines (FSM) in ADeVA notation [8] with a state-based model of computation. Once an FSM is present in a design, model checking tools can be used to prove the system correctness. Behavioral components like FSM can be arranged hierarchically in structured components. The subcomponents communicate via signals and allow a partitioning of the system.

The analog electrical and non-electrical behavior can be formally specified defining either a reference signal form (sensor transfer function) including tolerances or a non-linear behavior using hybrid automata. Hybrid Automata [9] are an extension to digital finite state machines with time-continuous behavior taking place inside the states. Additionally information about electrical circuits can be saved. This includes the electrical connection data as well as chip packaging information for PCB design. This information will be used to perform plausability checks like level comparisons (5V vs. 1.8V) in one of the next versions of the tool. In digital domain these checks can already be performed using properties. SpecScribe currently offers interfaces to PSL and NuSMV, others are planned.

To gain acceptance of the system level designers an easy-to-use GUI is necessary. Fig. 1 shows the GUI of SpecScribe. On the left hand side the specification structure is visualized where new items can be appended. The right hand side includes the detailed information of the chosen specification item. In the figure a textual requirement is shown. Requirements can be extended by subrequirements like the “blade” requirement.

The three-layered architecture of SpecScribe with structural components and requirements on the inner (first) layer, behavioral description on the second layer and tool interaction (code export/import, model checker interaction) on the outer (third) layer is realized using the platform independent languages Python and Qt. The specification data is collected using a hierachical structure of requirements which can be refined and lead to digital or hybrid automata. For continuation of the design process several code generators are available. Pure digital systems may be exported to VHDL and SystemC while analog (electrical and non-electrical) parts can be converted to a SystemC-AMS model. SystemC-AMS [10] is an extension library to SystemC (IEEE Std. 1066) for modeling analog and mixed signal behavior at system and algorithmic level and currently under standardization.

Other big issues of RMS are tracking and tracing. This means on the one hand to show who has changed what at

which time. On the other hand tracing means connecting requirements and implementations to keep in mind why the implementation was made exactly this way. The tracing of changes can be done automatically using the database interface. Several types of dependencies can be chosen like implements or verifies. To observe the status of the design project all the specification items include a satisfaction state. This state describes the current fulfillment of the requirements in different granularities like boolean or as a percentage value.

4 Specification Process

The specification process starts with the definition of the key requirements: What should the system do and what are the basic environment conditions to be met. Environment not only includes the physical conditions of operation but also government policies, financial limitations and safety issues. These requirements need to be refined by the system engineers, leading to a collection of textual, graphical and perhaps also (from former projects) reused items. Speci-fications usually contain several thousands requirements, so a fast database system is necessary to provide parallel access to the data. For smaller systems an object-oriented database is used. Larger specifications may require a relational database for faster access. This feature is currently under development.

SpecScribe allows the entry of textual requirements and the attachment of files in a flat as well as in a structured way. So a first brief (and informal) description of the system can be introduced. Usually these first requirements lack of clearness and testability. One of the main sources of errors during the specification process are ambiguous system descriptions so it is important to qualify these requirements. One solution is to pass a time-consuming review process, another solution is the formalization of the specification.

The formalization of requirements, e.g. based on analytical equations also enables further design automation. Two ways of formalization for analog behavior can be used. On the one hand the definition of ReferenceSignalForms like for the system transfer function is possible, on the other hand more complex issues can be formalized using digital or hybrid automata. To use such automata it is necessary to map the system equations on certain states.

The key point of formalization is machine readability which allows the specification to be checked automatically in future e.g. for consistency or completeness. As addition to formalized descriptions also source code files of different hardware description languages and simulators can be included in the tool. As automata (hybrid as well as digital) have a fixed structure it is possible to generate simulation models from the descriptions. The hybrid automata can be converted into a SystemC-AMS model. This allows a simulation and so a first verification of the system idea. Also structural models can be described in SpecScribe and generated as SystemC-AMS source code allowing complex system models as well as testbenches. SystemC-AMS models can be further refined to implement the system as described in [11].

The automated model generation eliminates an important source of errors in the design process: the transfer of the specification into the first step of the implementation phase. As also the makefiles and a testbench framework are generated the system level designer can easily start simulation without deeper knowledge of the description language. The included ReferenceSignalForms (RSF) act as verification items. Each RSF contains a function and a tolerance range around it. So each RSF can be translated to a monitor which checks the proper system behavior by analysing the output function. This is another step for a (semi-) automation of analog verification.

5 Current applications and outlook

The tool SpecScribe supports multi-domain modeling as well as different levels of abstractions. In the last years it was used for many projects. Some examples are a MEMS-based wind turbine monitoring system [12], an inertial navigation system [13] and telecommunication systems. Furthermore the tools was used to support the replacement of obsolete components.

Future work focusses on three main issues. One project deals with the reduction of energy consumption of components and systems. Another project investigates the influence of nano-components on the specification process. The third focus of research is on the collection of requirements for electric mobility. Here not only technical requirements are investigated but also non-countable human requirements.

6 Accknowledgments

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Department Lithography/Etch/Mask

Contact: **Dr. Andreas Bertz**

Phone: **+49 (0) 371 531-33129**

Email: **andreas.bertz@zfm.tu-chemnitz.de**

The department "Lithography/Etch/Mask" represents the technological basis for all patterning processes of the Center for Microtechnologies and its partners. In a class 4 (ISO 14644-1) clean room a complete process line for mask fabrication and lithography is available:

- Large variety of wet and dry etching steps
- 4 inch and 6 inch wafers can be processed
- 5 inch and 7 inch mask fabrication
- Partially process tools are available even for 8 inch wafers
- Optical lithography is based on a mask aligner (up to 8 inch wafers) and an i-line wafer stepper (up to 6 inch wafers)

In addition to the conventional lithography processes, the department is experienced with double-side exposure, spray coating on 3D-surfaces and the treatment of special resist types like SU-8 by using advanced systems. Furthermore cavities can be filled individually by a special spray robot.

With respect to nanopatterning, a 20 years experience exists within the e-beam lithography field. In combination with about 10 dry etch tools, sub quarter micron structures have been etched into numerous materials. Using resist patterns made by partners and special hard masks, feature sizes smaller than 100 nm have been transferred .

Beside these technology services for internal and external partners – the department is performing R&D projects focusing on dry etching processes and High-Aspect-Ratio-MEMS (HAR-MEMS). This work is addressing applications in microsystems technologies, microelectronics, spintronics and photovoltaics as well. Therefore etching of new materials and surface modification steps are investigated. Based on the developed and patented AIM-Technology (Airgap Insulation of Microstructures) a sensor and actuator fabrication platform is available. Using this technology high performance low-g and vibration sensors are provided to several partners for system integration. For this, much effort has been spent additionally in device characterization at wafer level and yield improvement. Another example of successful technology research is the development of a new thin film encapsulation procedure in order to reduce the package size and costs of the devices.

Fig. 1: Wafer inspection within the lithography clean room

Department Layer Deposition

Contact: **Dr. Christian Kaufmann**

Phone: **+49 (0) 371 531-35096**

Email: **christian.kaufmann@zfm.tu-chemnitz.de**

The department "Layer deposition" is highly competent in the development and fabrication of conductive and isolating layers and layer stacks for microelectronic and microsystems technologies. For this purpose, the department provides state-of-the-art equipment including a new clean room. The department offers support for advanced process modules for research and development purposes and small volume prototyping. Process modules available include:

Fig. 1: Equipment for Electron Beam Evaporation and Sputter Deposition

Physical Vapor Deposition (sputtering, electron-beam):
- Vertical sputtering system MRC 643 (materials: Ti, TiN, Ta, TaN, Cu)
- Vertical sputtering system MRC 643 (materials: Al, Al-Alloys, Cr, TiW, W)
- R&D sputtering system FHR MS 150 x 4 (materials: Ag, Al, Au, Co, Cr, MoNi, MoFe, Ti, TiN)
- R&D sputtering system FHR MS 150 x 4-AE-B (materials: Al, Al-Alloys, Hf, Pyrex)
- R&D Electron-Beam-Evaporation (materials: Al, Cu, Pd, Pt ...)

Chemical Vapor Deposition (MO-CVD, PE-CVD, LP-CVD):
- MO-CVD R&D system Varian Gartek (materials: Cu, TiN)
- PE-CVD system Precision 5000 Mark II Applied Materials (materials: SiO_2, Si_3N_4, $Si_xO_yN_z$, Si-COH, SiCH)
- PE-CVD system Plasmalab Plasma Technology (materials: SiO_2, Si_3N_4)
- PE-CVD system Microsys 400 Roth & Rau (material: Diamond-like Carbon)
- LP-CVD system LP-Thermtech (materials: SiO_2, Si_3N_4, polysilicon)

High temperature processes (diffusion / thermal oxidation / annealing / RTP):

For the characterization of the deposited layers and layer stacks we use a lot of measuring methods and systems, for example:
- KLA Tencor surface profiler Alpha step 500
- Thin film stress measurement system TENCOR FLX 2900
- White light interferometer Nanometrics NanoSpec / AFC
- Ellipsometer: Gaertner L11B (632.8 nm)
- Spectroscopic Ellipsometry: Sentech instruments GmbH SE 850 (190 nm – 2550 nm).

Equipment and Service Offers

The ZfM facilities include 1000 m² of clean rooms (300 m² of them class ISO 4). Modern equipments were installed for processing of 4 inch, 6 inch and 8 inch wafers as well as design and testing laboratories providing the basis for the following processes:

Design

- MEMS/NEMS,
- IC, ASICs and FPGAs
- low power and low noise, analog-mixed signal integrated circuits
- integrated high-voltage circuits
- Design support
- Optimization by means of novel approaches, methodologies and dedicated design tools
- Design for reliability

Modelling and Simulation

- Equipment and processes for micro and nanoelectronics
- Physical domains and their interaction
- Thermal simulation
- Electronic devices
- Defects and their influence

Processes

- Mask fabrication: 3 inch ... 7 inch mask size
- Proximity and contact double-side lithography
- In-line wafer stepper
- Mask aligner double-side exposure
- High temperature processes: Diffusion / thermal oxidation / annealing / RTP
- Physical Vapour Deposition PVD
- Sputtering
- Electron beam evaporation
- Chemical Vapor Deposition CVD
- Plasma enhanced CVD (PE-CVD)
- Low-Pressure CVD (LP-CVD)
- Metall-Organic CVD (MOCVD)
- Electroplating: Cu, Ni, Au
- Etching (dry: Plasma- and RIE-mode & wet: isotropic / anisotropic)
- Dry etching (Si, SiO_2, Si_3N_4, Polysilicon, Silicides, Al, refr. metals, TiN, Cr, DLC, low k dielectrics, DRIE of Si)
- Wet etching (SiO_2, Si_3N_4, Si, Polysilicon, Al, Cr, Au, Pt, Cu, Ti, W)
- Wafer lithography
- Chemical Mechanical Polishing CMP (Copper, Silicon, SiO_2)

Characterization and Test

- MEMS/NEMS
- Nanoelectronic devices
- Parametric testing: Waferprober, HP Testsystem
- Characterization of analog-mixed signal circuits up to 500 MHz
- Characterization and modeling of devices from low-voltage and high-voltage micro technologies

Analytics

- Scanning electron microscopy SEM / EDX
- Atomic force microscopy AFM
- Variable angle spectroscopic ellipsometry
- Laser profilometry
- Surface profilometer
- US-Microscope
- Tension/Compression testing machine Zwick 4660 universal
- Perkin-Elmer DMA 7e dynamic mechanical analyser
- Micromechanical testing instrument
- Lifetime scanner

Fig. 1: View into the new clean room facilities, equipment for depositing foto resist

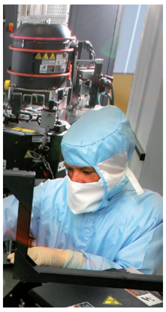


Fig. 3: Wafer inspection at the microscope

Fig. 2: P5000 used for deposition of Copper

Lectures 2011/12

Chair Microtechnology

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

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

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

Micro Technology
Lecturers: Prof. Dr. T. Gessner, Dr. R. Streiter

Microoptical systems
Lecturer: Prof. Dr. T. Otto

Technology of Micro and Nanosystems
Lecturers: Prof. Dr. K. Hiller, Dr. A. Bertz

Micro and Nano Technology
Lecturers: Prof. Dr. T. Gessner, Dr. D. Reuter

Lectures of International Research Training Group
Lecturer: Prof. Dr. Thomas Gessner, Prof. Dr. S.E. Schulz, Dr. R. Streiter

Chair Microsystems and Precision Engineering

CAD (Computer-aided Design)
Lecturer: Prof. J. Mehner

Gerätekonstruktion (Design in Precision Engineering I)
Lecturer: Prof. J. Mehner

Mikromechanische Komponenten (Micromechanical Devices)
Lecturer: Prof. J. Mehner

Mikro- und Feingerätetechnik (Design and Manufacturing)
Lecturer: Prof. J. Mehner

Mikro- und Nanosysteme (Micro and Nano Systems)
Lecturer: Prof. J. Mehner

Grundlagen der Anatomie und Physiologie (Basics of Anatomy and Physiology)
Lecturers: Prof. Dr. J. Schweizer, Dr. A. Müller

Angewandte Optik (Applied Optics)
Lecturer: Dr. S. Voigt

Gerätetechnik (Design in Precision Engineering II)
Lecturer: Prof. J. Mehner

Grundlagen der Medizin für MST (Medical Basics)
Lecturers: Prof. Dr. J. Schweizer, Dr. A. Müller

Klein- und Mikroantriebe (Fractional Horsepower Drives)
Lecturer: Dr. R. Kiehnscherf

Mess- und Prüftechnik für MST (Metrology and Test for Microsystems)
Lecturer: Dr. S. Voigt

Microsystems Design
Lecturer: Prof. J. Mehner

Mikrosystementwurf (Microsystems Design)
Lecturer: Prof. J. Mehner

Spezielle Aspekte der Medizintechnik (Special Problems in Biomedical Engineering)
Lecturers: Prof. Dr. J. Schweizer, Dr. A. Müller

Chair Circuit and System Design

Integrated Circuit Design 1+2/ ASIC Design
Lecturer: Prof. Dr. G. Herrmann

System Design 1+2
Lecturer: Prof. Dr. U. Heinkel

EDA-Tools
Lecturer: Prof. Dr. U. Heinkel

EDA-Tools (English)
Lecturer: Prof. Dr. U. Heinkel

Components and Architectures of Embedded Systems (English)
Lecturer: Prof. Dr. G. Herrmann

Microprocessor Systems
Lecturer: Prof. Dr. G. Herrmann

Design of heterogeneous Systems
Lecturer: Dr. V. Jerinic, Dr. E. Markert

Design for Testability for Circuits and Systems (English)
Lecturer: Prof. Dr. G. Herrmann

Chair Electronic Devices of Micro and Nano Technique

Electronic Devices and Circuits
Lecturer: Prof. Dr.-Ing. J. Horstmann

Electronic Devices
Lecturer: Prof. Dr.-Ing. J. Horstmann

Integrated analog Circuit Design
Lecturer: Dr.-Ing. S. Heinz

Physical and Electrical IC Design
Lecturer: Dr.-Ing. S. Heinz

Microelectronics
Lecturer: Dr.-Ing. S. Heinz

Devices of Micro and Nano Technique
Lecturer: Prof. Dr.-Ing. J. Horstmann

Micro- and Nano Devices
Lecturer: Prof. Dr.-Ing. J. Horstmann

Integrated Circuit Design – Transistor Level
Lecturer: Dr.-Ing. S. Heinz

Lithography for Nano Systems
Lecturer: Prof. Dr.-Ing. J. Horstmann

Integrated Circuit Design
Lecturer: Dr.-Ing. S. Heinz

Chair Power Electronics and Electromagnetic Compatibility

Power Electronics
Lecturer: Prof. Dr. J. Lutz

Power Semiconductor Devices
Lecturer: Prof. Dr. J. Lutz,

Power Semiconductor Devices (English)
Lecturer: Prof. Dr. J. Lutz

Design and Calculations of Powerelectronic Systems
Lecturer: Prof. Dr. J. Lutz

Electrical Energy Technology
Lecturer: Prof. Dr. J. Lutz

Industrial Electronics
Lecturer: Prof. Dr. J. Lutz

Power Engineering
Lecturer: Prof. Dr. J. Lutz

Simulation of Electroenergetic Systems
Lecturers: Prof. Dr. J. Lutz, Dr. S. Koenig

Chair for Measurement and Sensor Technology

Electric Measurement Technology
Lecturers: Prof. Dr. O. Kanoun, Prof. Dr. N. Kroemer

Electric Measurement Technology
Lecturer: Prof. Dr. O. Kanoun

Smart Sensor Systems (English)
Lecturer: Prof. Dr. O. Kanoun

Sensor Signal Processing
Lecturer: Prof. Dr. O. Kanoun

Sensors and Actuators
Lecturer: Prof. Dr. O. Kanoun

Automotive Sensor Systems (English)
Lecturer: Prof. Dr. O. Kanoun

Intelligent Sensor Systems
Lecturer: Prof. Dr. O. Kanoun

Praxisseminar Measurement and Sensor Technology
Lecturer: Dr. M. Arnold

Photonics
Lecturer: Dr. M. Arnold

Chair for Materials and Reliability of Microsystems

Reliability of Micro and Nano Systems
Lecturer: Prof. Dr. B. Wunderle

Reliability of Micro and Nano Systems (English)
Lecturer: Prof. Dr. B. Wunderle

Materials of Electrical Engineering and Electronics
Lecturer: Prof. Dr. B. Wunderle

Materials of Micro Technology
Lecturer: Prof. Dr. B. Wunderle

Qualitätssicherung
Lecturer: Prof. Dr. B. Wunderle

Smart Systems Campus Chemnitz

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

The partners of the Smart Systems Campus Chemnitz are:

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

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

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

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

The Fraunhofer Institute for Electronic Nano Systems focuses on applied research. Since 1998 a strong cooperation exists between the Center for Microtechnologies ZfM and the Fraunhofer Institute for Electronic Nano Systems ENAS developed out of the former Chemnitz branch of Fraunhofer IZM. 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 Fraunhofer ENAS focuses on smart systems integration by using micro and nano technologies.

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

- Micro and Nano Systems,
- Micro and Nano Electronics / Back-End of Line as well as
- Green and Wireless Systems.

They address different markets and different customers.

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

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

They are the inner structure of the technology portfolio of Fraunhofer ENAS. These competences are of course supported by the cooperation with the Center for Microtechnologies ZfM of Chemnitz University of Technology, the Chair Digital Printing and Imaging Technology of the faculty of mechanical engineering of Chemnitz University of Technology and the Chair Sensor Systems of the faculty of electrical engineering of University Paderborn.

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

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

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

The first company in the park was the 3D-Micromac AG which develops and manufactures highly efficient and innovative machines for laser micro machining. Since May 2012 there is a second building – the microFLEX Center. The building is rent by 3D-Micromac AG and Fraunhofer ENAS as a common research and production line. Currently there is the Third building under construction. Based on the very positive development the EDC Electronic Design Chemnitz GmbH is building an own building, which will be finished in 2013.

Fig. 1: Smart Systems Campus with:
A – Institut für Physik und Reinraum Zentrum für Mikrotechnologien TU Chemnitz
B – Fraunhofer ENAS
C – Start-up Gebäude
D – Zentrum für integrative Leichtbaustrukturen der TUC
E – 3D-Micromac AG,
F – microFLEX Center

Networks

Networking is our formula for success. The Center for Microtechnologies is working in several national and international networks.

Silicon Saxony

Silicon Saxony e.V. is Europe's largest trade association for the microelectronic industry.

It was founded in 2000 as a network for the semiconductor, electronic and micro system industry. The association connects manufacturers, suppliers, service providers, colleges, research institutes and public institutions in the economic location of Saxony. The current number of members has risen to 270. The member companies employ about 35,000 people and the total turnover of the companies is 4 billion € per year. The ZfM belongs to the foundation members.

13 working groups are working within the network. The working group "Smart Integrated Systems" has been founded 2007. It is leaded by Prof. Thomas Gessner.

In 2009 Prof. Thomas Gessner became a member of Silicon Saxony Board.

IVAM

As international association of companies and institutes in the field of micro technology, nano technology and advanced materials, IVAM's priorities are to create competitive advantages for our members. Nearly 300 member companies and institutes from 20 countries open up new markets and set standards with the support of IVAM. Companies, institutes, products, services and contact persons are listed here online as well as in the printed IVAM directory. The Center for Microtechnologies is a member of the IVAM network since 2005.

Within 2007 Prof. Gessner became a member of IVAM Advisory Council. The IVAM Advisory Council helps impulses from application oriented science to be integrated into the work of the association. Apart from their consulting function, the members of the IVAM Advisory Council also represent IVAM in public.

Nanotechnology Center of Competence "Ultrathin Functional Films"

The Center of Competence "Ultrathin Functional Films" (CC-UFF) is coordinated by Fraunhofer IWS Dresden. It joins 51 enterprises, 10 university institutes, 22 research institutes, and 5 corporations into a common network. Activities within the frame of Nano-CC-UFF are subdivided into 6 working groups, each of them is administered and coordinated by one member.

WG 1: Advanced CMOS

WG 2: Novel components

WG 3: Biomolecular films for medical and technological purposes

WG 4: Mechanical and protective film applications

WG 5: Ultrathin films for optics and photonics

WG 6: Nano-size actuators and sensors

Working group 1 is headed by Prof. Thomas Gessner and working group 2 by Prof. Christian Radehaus (former member of the board of directors of the Center for Microtechnologies of Chemnitz University of Technology).

Nanett - Nano System Integration Network of Exellence

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

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

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

The three areas of competence with their research topics are:

Processes and technologies for nano scale material systems

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

Micro-nano-integration

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

Nano materials

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

The Center for Microtechnologies takes part with six Professorships in all three areas of competence within the following research topics: patterning of nano structures in unconventional materials, integration of nano structures with electromechanical functionalities, system design and architecture of energy efficient sensor networks, technologies for autonomous sensor nodes and Reliability of functional materials.

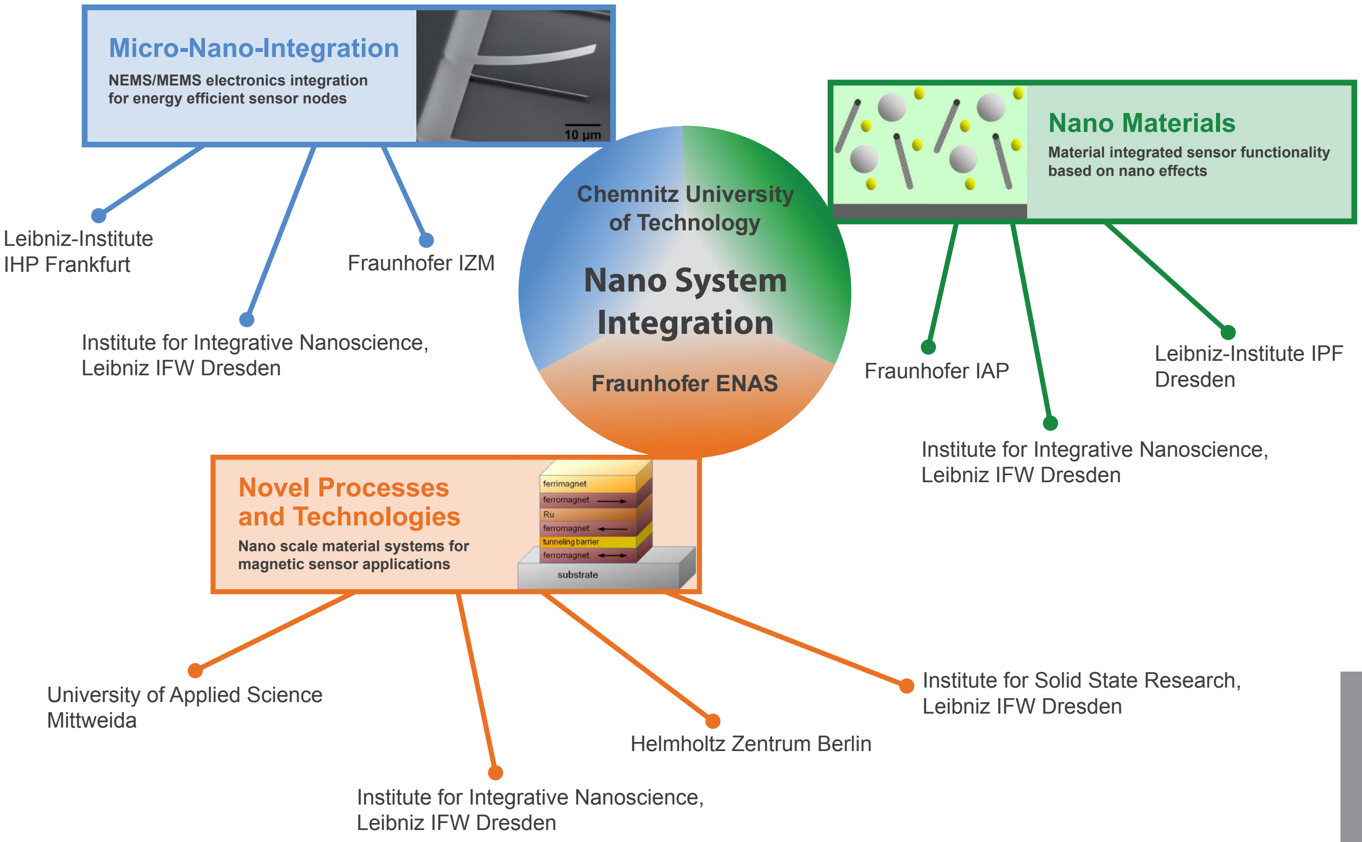
For more information please visit our website:

http://www.nanett.org/

nanett

nano system integration
network of excellence

Application of Nanotechnologies for Energy Efficient Sensor Systems



Chemnitz University of Technology

Nano System Integration

Fraunhofer ENAS

Micro-Nano-Integration

NEMS/MEMS electronics integration for energy efficient sensor nodes

Leibniz-Institute
IHP Frankfurt

Fraunhofer IZM

Institute for Integrative Nanoscience,
Leibniz IFW Dresden

Nano Materials

Material integrated sensor functionality based on nano effects

Fraunhofer IAP

Leibniz-Institute IPF
Dresden

Institute for Integrative Nanoscience,
Leibniz IFW Dresden

Novel Processes and Technologies

Nano scale material systems for magnetic sensor applications

University of Applied Science
Mittweida

Institute for Integrative Nanoscience,
Leibniz IFW Dresden

Helmholtz Zentrum Berlin

Institute for Solid State Research,
Leibniz IFW Dresden

TECHNISCHE UNIVERSITÄT CHEMNITZ

HOCHSCHULE MITTWEIDA
UNIVERSITY OF APPLIED SCIENCES

Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden

HELMHOLTZ ZENTRUM BERLIN
für Materialien und Energie

ihp
innovations
for high
performance
microelectronics

GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

Fraunhofer ENAS

Fraunhofer IZM

Fraunhofer IAP

Leibniz-Institut für Polymerforschung Dresden e. V.

SPITZENFORSCHUNG & INNOVATION
IN DEN NEUEN LÄNDERN

International Research Training Group

At a Glance

Since April 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 between the following institutions:

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

After a successful evaluation in March 2010, the second period of the IRTG program started in October 2010, now extending the scientific topic to “Materials and Concepts for Advanced Interconnects and Nanosystems”. The International rResearch Training Group will be fundend until March 2015.

This International Research Training Group (IRTG) is the first of its kind at Chemnitz University of Technology. It is led by Prof. Ran Liu of Fudan University and Prof. Di Chen of Shanghai Jiao Tong University as the coordinators on the Chinese side as well as Prof. Thomas Gessner as the coordinator on the German side. A graduate school like this offers brilliant young PhD students the unique opportunity to complete their PhD work within about three years in a multidisciplinary environment. Currently there are 19 PhD students of the German and 15 of the Chinese partner institutions involved in the program. The different individual backgrounds of the project partners bring together electrical and microelectronics engineers, materials scientists, physicists, and chemists. n particular, the IRTG is working to develop novel materials and processes for nanosystems as well as new concepts for connecting the individual transistors within nanoelectronic circuits. Smaller contributions are additionally made in the field of device packaging and silicides for device fabrication. In this respect, the IRTG is providing solutions for nanoelectronics and Smart Systems Integration.

Research Program

The research program of the IRTG concentrates on both applied and fundamental aspects to treat the mid- and long-term issues of microelectronics metallization and nanosystem integration. So, 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. Among the topics related to sensor applications, magnetic film systems on curved surfaces of nanoparticles are studied with respect to their performance as giant or tunnel magnetoresistance (GMR or TMR) sensor. Further works are related to polymer composite materials to be used in thermoelectric systems.

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. In that respect, the IRTG also prepares the PhD students for an ever more international economy.

Highlights 2012

One of the greatest highlights for the IRTG in 2012 was the Summer School held in Berlin end of July. It was just the 7th summer school organized within the IRTG. Eight students and professors of Fudan University and also eight from the Shanghai Jiao Tong University took part. Additionally to the presentations of the PhD students scientists has been invited to give special talks. One of them was Prof. Christophe Detavernier from the University gent in Belgique. He spoke about his work in the field of atomic layer deposition of nano porous materials. As always, the scientific program of the Summer School was accompanied by cultural and social events.

Currently there are five Chinese students working at the partner institutes in Germany and one German student working at the Fudan University.

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

Chinese and German PhD students and the professors and supporters of the IRTG 1215 met for a summer school in Berlin in July 2012.

Imprint:

Editor
Chemnitz University of Technology
Faculty of Electrical Engineering and
Information Technology
Center for Microtechnologies

Reichenhainer Strasse 70
09126 Chemnitz
Germany

phone: +49 (0) 371 531-24060
fax: +49 (0) 371 531-24069
email: info@zfm.tu-chemnitz.de
web: http://www.zfm.tu-chemnitz.de/

Director: Prof. Dr. Thomas Gessner

Editorial
Dr. Martina Vogel,
Chemnitz University of Technology

Photos
Chemnitz University of Technology
+++

Layout & Design
Andrea Messig-Wetzel,
Chemnitz University of Technology

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ZfM
Zentrum für
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Contact:

Prof. Dr. Thomas Gessner
President of the Board of Directors
of the Center for Mikrotechnologies

Chemnitz University of Technology
Faculty of Electrical Engineering and
Information Technology
Center for Microtechnologies

Reichenhainer Strasse 70
09126 Chemnitz
Germany

Phone: +49 (0) 371 531-24060
Fax: +49 (0) 371 531-24069

Email: info@zfm.tu-chemnitz.de
Web: http://www.zfm.tu-chemnitz.de/