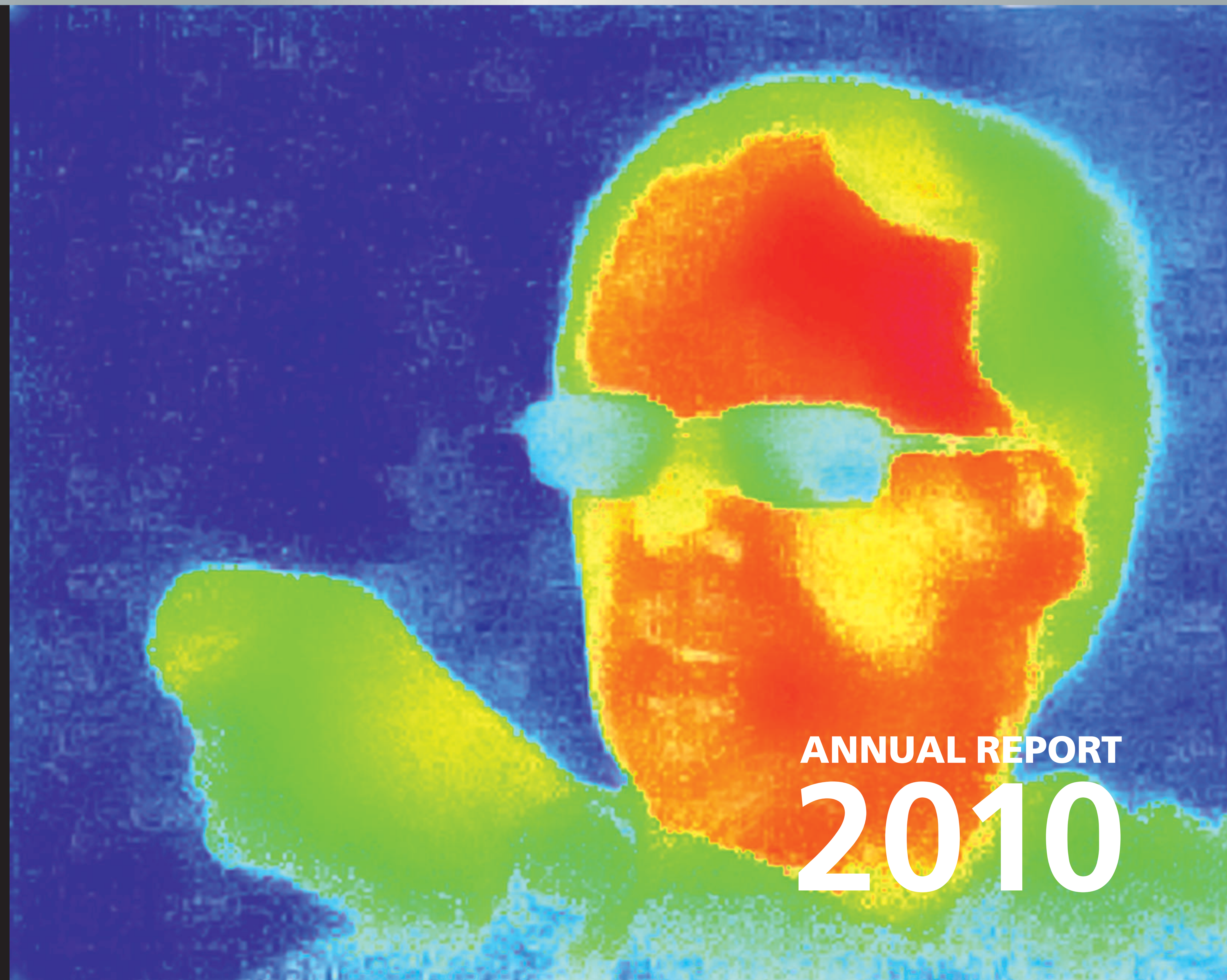
Fraunhofer
IMS

FRAUNHOFER-INSTITUT FÜR MIKROELEKTRONISCHE SCHALTUNGEN UND SYSTEME IMS



ANNUAL REPORT 2010

ANNUAL REPORT OF THE FRAUNHOFER-INSTITUTE FOR MICROELECTRONIC CIRCUITS AND SYSTEMS IMS DUISBURG 2010

PREFACE

The end of the global economic crisis led to a good operating result in the 26th year of Fraunhofer IMS. The Fraunhofer IMS operating budget in 2010 amounts to 20,8 million euros. In comparison to last year the number of employees slightly increased again.

The IMS used the challenging global economic situation in 2009 to concentrate on new strategic challenges and emerged from the crisis stronger than before. We could generate a series of public proceeds and gain also new, major industrial projects. The pick-up of the national and international markets allows for good future prospects for 2011.

Project Highlights 2010

A main focus of our work laid on IR-Imagers. The IMS developed an infrared-imager with VGA-resolution for the detection of thermal radiation for a wavelength range of 8 µm to 14 µm. A part of the required process steps for the IR-Imager will be performed in the 2011 new opened MST-Lab.

In the field of high temperature electronics we develop in cooperation with a project partner modern ASICs which are applicable for operating temperatures up to 250°C. Since several years, high temperature electronics have been one of the strategic fields of activity of Fraunhofer IMS.

In 2010, the Fraunhofer IMS processed, for our long lasting partner Infineon, SOI-Wafer, whose ICs are applied in power switches. This successful cooperation will be also an important pillar for us in 2011.

In a common international project inside the “HTA”, an association of the Fraunhofer Group of Microelectronics, Leti (FR), CSEM (CH) and VTT (FIN), high voltage transistors for a 0, 25 µm process are developed.

Events 2010

In 2010, a multitude of events and workshops have been performed at Fraunhofer IMS and at Fraunhofer InHaus Center. In March 2010, the GMM-Workshop "Reliability of semiconductor devices", carried out at the Fraunhofer Inhaus Center, attracted numerous experts to come to Duisburg. National and international experts discussed the opportunities and methods to design devices, which also fulfill the strict medical and industrial requirements in future. Continuative discussions and network contacts resulted from the attractive supporting program.

Our 5th CMOS Imaging Workshop in May 2010 attracted again more than hundred national and international guests and orators. In accordance with the global technological trend, the topic of the workshop was "CMOS Low-Light-Imaging".

The Win² event in June and the inHaus forum in September 2010 dealt both with the topic "buildings of the future". The events focused on solutions for the technical modernization and the use of sensor technologies for the building services engineering.

From the 4th to 6th November, more than 30 pupils participated at the Fraunhofer Talent School in our institute. The Fraunhofer Talent School offers young, talented pupils the possibility to deal practically with scientific-technical topics. The participants set up radio circuits, learned about microchip design and simulated and designed microchips at the computer.

The Fraunhofer IMS was co-organizer of the workshop for "Energy self-sufficient sensors and sensor networks" of the Fraunhofer Gesellschaft in Munich.
There, ten Fraunhofer Institutes presented their current trends and developments.

Personnel

In 2010, three Fraunhofer IMS employees were offered a professorship. We are happy about the career advancement of Professor Dr. Stockmanns, Professor Dr. Krisch and Professor Dr. Ressel and wish them success in following their new responsibilities. This pleasant progress verifies the academic esteem of the German universities.

For the overall excellent business year 2010, thanks are due to our partners and customers in commerce and the public authorities as well as in the ministries.
In this context, the rise in orders coming from our European neighbors is especially pleasant.

Finally, I particularly would like to thank our employees, who enabled our common success by their dedicated work. Many thanks.

Professor Dr. rer. nat. Anton Grabmaier

Duisburg, March 2011

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PROFILE

FRAUNHOFER IMS IN DUISBURG

The Fraunhofer Institute for Microelectronic Circuits and Systems (IMS) was established in Duisburg in 1984. The Fraunhofer IMS is, through continued growth and innovative research and development, one of the leading institutes in Germany for applied research and development in micro-electronics and CMOS-technology.

Fraunhofer IMS	
Employees	260
Budget	18,5 Mio. Euro
Industrial Projects	50 % of Budget
Public Projects	25 % of Budget
Fraunhofer Projects	25 % of Budget

Infrastructure
Fraunhofer IMS offers a wide range of services and production of in silicon based devices and systems.

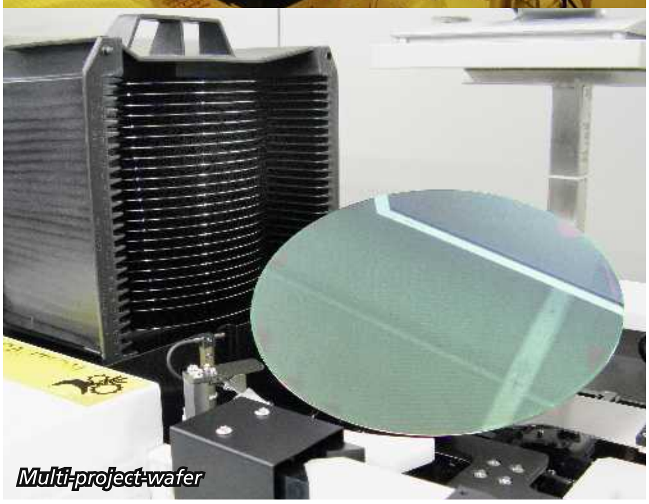
The fabrication takes place in class ten cleanrooms, wafer-testing rooms and an assembly-line with together more than 2500 square meters.

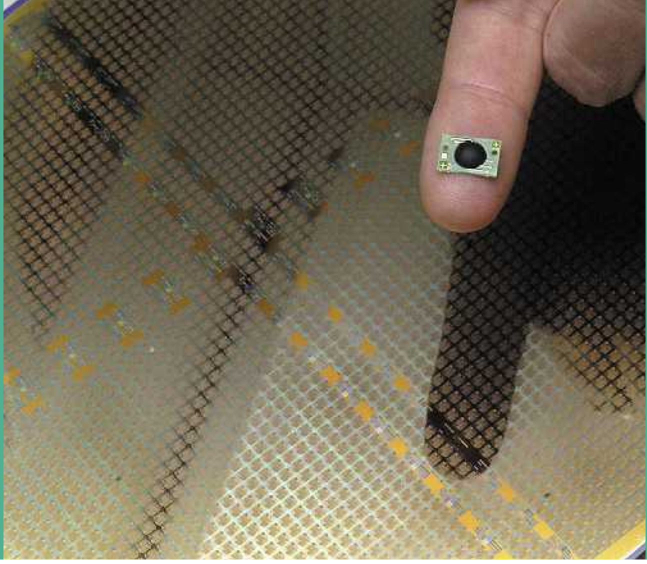
Fraunhofer IMS CMOS Wafer Fab	
Wafer size	200 mm (8 inches, 0.35 µm)
Cleanroom area	1300 square meters
Cleanroom class	10
Employees	app. 120 in 3 shifts 7 days a week
Capacity	> 70.000 wafer/year

IMS Production and Development
Fraunhofer IMS develops, produces and assembles smart sensors, integrated circuits and discrete elements (ICs and ASICs). It also offers the fabrication of devices on a profes-sionally managed CMOS production line in small to medium quantities.


The Fraunhofer Institute of Microelectronic Circuits and Systems (IMS)


200 mm-CMOS-cleanroom


Multi-project-wafer



In the new microsystems technology lab (MST-Lab) we integrate different micro- and nanofunctions directly on top of the signal processing CMOS circuits. This procedure is called post-processing. (600 square meters)

The ICs are assembled in the cleanroom (400 square meters) of Fraunhofer IMS assembly facility. This facility supports the production of ICs in ceramic packages or as COB (Chip on board, COB). COB assembly is available from small quantities to several million units per year.

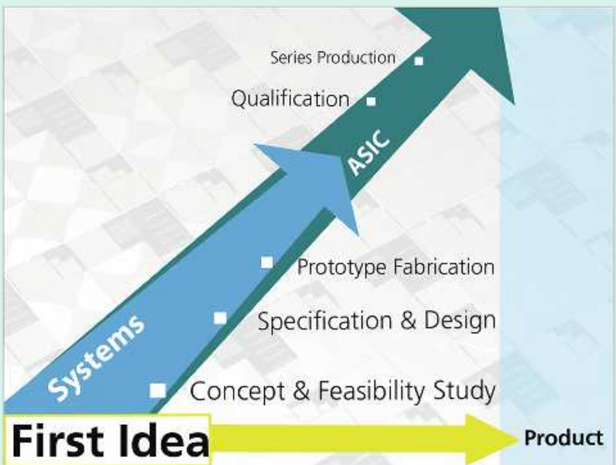
Supply and Service

The Fraunhofer IMS offers R&D services tailored to our customer needs, providing efficient solutions ranging from the initial studies to the series products.

Cooperation possibilities:

- Studies and feasibility studies
- Consulting and concept development
- Demonstrator and prototype development
- Chip production (ASIC Production)
- Development of soft- and hardware

From idea to production



CMOS Imaging Sensor

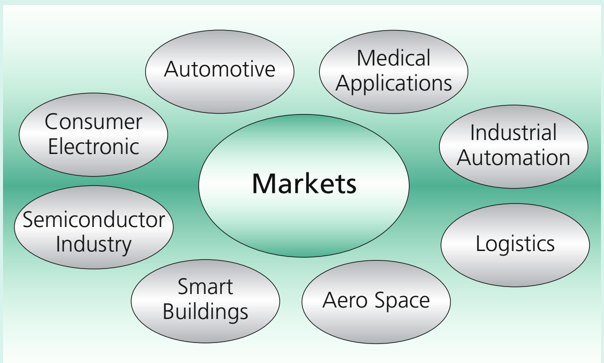
RFID System

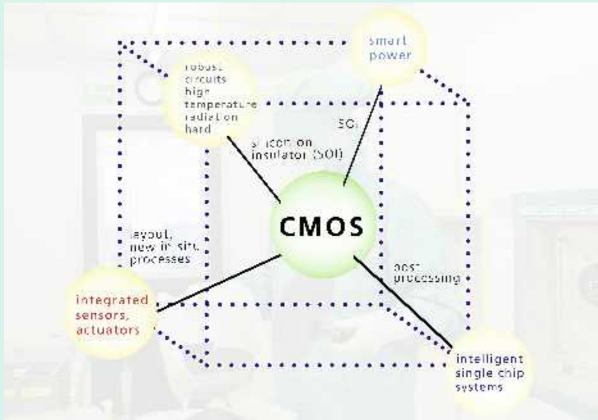
FRAUNHOFER IMS BUSINESS FIELDS AND CORE COMPETENCIES

RESEARCH AND DEVELOPMENT AT THE FRAUNHOFER INSTITUTE FOR MICROELECTRONIC CIRCUITS AND SYSTEMS

The Fraunhofer IMS conducts research and development in many different application areas including
- Automotive
- Medical
- Consumer
- Smart Buildings
- Communication
- Aero Space
- Logistics
- Industrial Automation
- Semiconductor Industry

These applications are served by our business fields:
- CMOS process
- ASIC design und development
- Sensors
  - Pressure Sensors
  - Image Sensors
  - Infrared Sensors
  - Bio Sensors
- Embedded systems hardware and software
- Wireless systems, ICs and transponders
- Smart Buildings





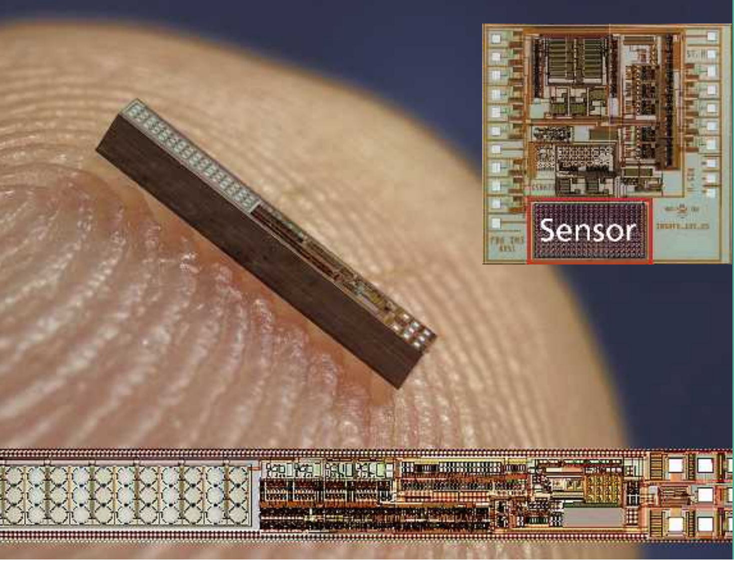
1. CMOS Process and Assembly

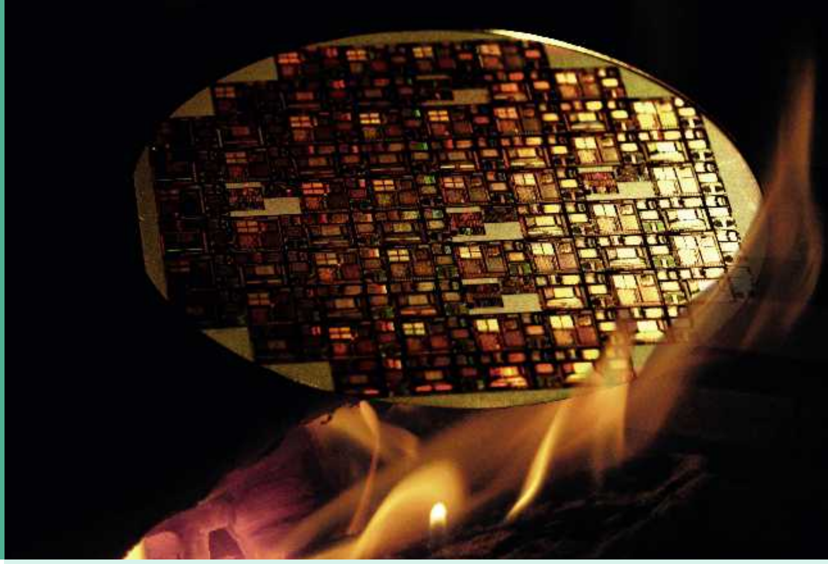
Based on standard CMOS process technology, IMS develops customer-specific processes and special options for standard processes (e.g. capacitors, polysilicon and thin-film resistors, high voltage transistors, EEPROM, OTP and several types of sensors).

Pressure-Sensor-Process

With a clear view on the needs of a rapidly growing sensor market, IMS leveraged its long experience in research and development of CMOS-compatible integrated sensors to establish micro-mechanical pressure sensors as one of its product lines.

At the heart of this product line is a pressure sensor that is integrated into standard CMOS technology. This micro-mechanical pressure sensor was designed for a large range of pressures, and can be monolithically integrated with many electronic devices, e.g. MOSFETs, capacitors, resistors or EEPROMs. The layout of the pressure sensor determines its pressure range, as the membrane's stiffness is directly related to its diameter.





High Temperature SOI Process

The high temperature SOI CMOS process uses SOI substrates for the production of ASICs that operate at temperatures of up to 250° C.

Only fully CMOS compatible process steps are used to manufacture not only standard CMOS circuit elements, including EEPROM, but also silicon based sensors, actuators and power devices.

Power Devices

In close cooperation with industrial partners, Fraunhofer IMS provides a 600V-CMOS-process for half- and full bridge driver chips for IGBTs. Also a novel discrete power MOS transistor process based on trench technology has been developed at IMS. It features an ultra low on-resistance so that transistors with less than 1 mOhm on-resistance can be realized on a small die, while keeping the number of process steps low. Such low loss switches are used in power supply, automotive and other low voltage applications.

CMOS Fabrication

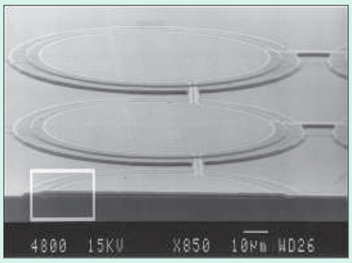
Fraunhofer IMS provides numerous semiconductor production services in its 200 mm CMOS production line. The professionally managed class 10 clean room has more than 1300 m^2 floor space. The 24 hour, 7 days a week operation ensures the uniform quality of our products.

The Fraunhofer IMS production line especially caters to the production of smaller and medium quantities of ASICs. The production line operates under an ISO 9001:2000 and TS 16949 certified quality management system, assuring stability and reliability of products and production. Timely, reliable and customer-oriented production is our and our customers key to success.

2. Sensors

Pressure Sensors

The basic element of our pressure sensors is a surface micromechanical sensor that is fabricated using standard CMOS processing equipment. These sensors can be realized for a wide range of pressures, sharing a single chip with all electronic devices available in a CMOS process, e.g. MOSFETs, capacitors or EEPROMs. The sensors can be configured as absolute with capacitive readout. The necessary signal conversion, linearization and amplification circuits are realized on the same chip, effectively eliminating interference on sensor wiring that is a major issue for discrete solutions. We have already created a variety of innovative products using this monolithic integration of sensors and signal processing functions like programmable amplifiers, sensor linearization, temperature compensation or wireless interfaces.

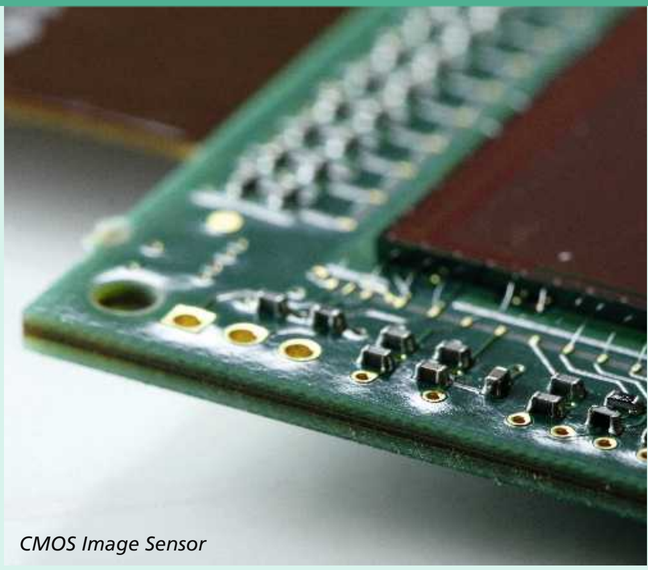


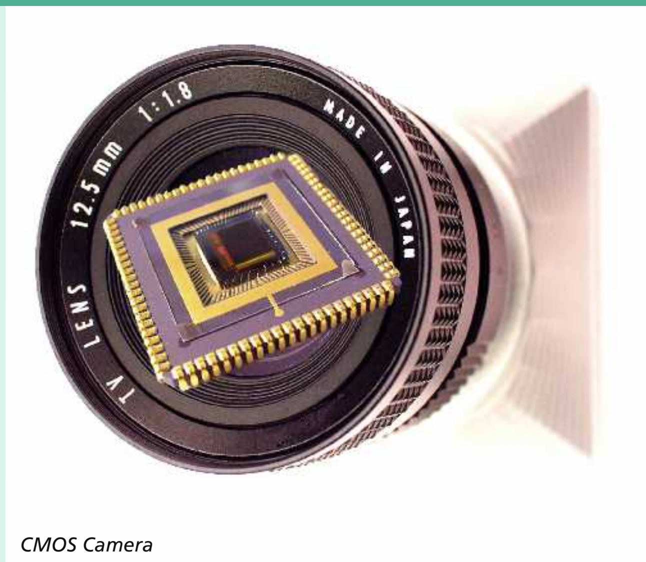
The layout of the sensor element determines its pressure range, which may be situated between 0.5 to 250 bar, as the sensor diameter controls the stiffness of the membrane: Smaller and stiffer membranes shift the pressure range to higher pressures. Thus the sensors are suitable for the measurement of pressures ranging from blood, air, and tire pressure all the way to hydraulic oil pressure. The small size of the sensor and its associated electronics enables innovative medical applications for the in vivo measurement of the pressures of blood, brain, eye or other body fluids.

CMOS Image Sensors

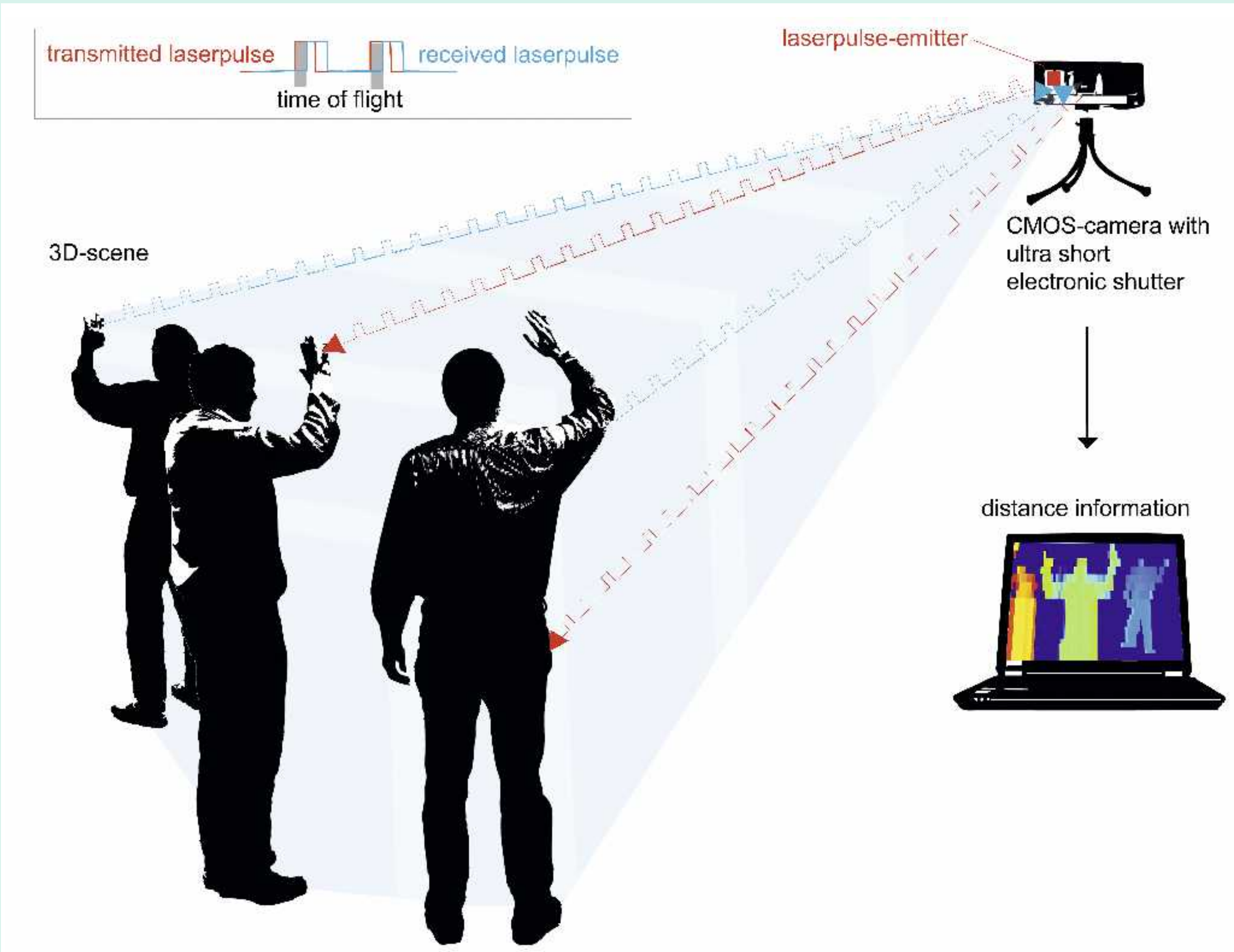
Fraunhofer IMS image sensors are based on CMOS technology, which enables the monolithic integration of sensor and circuit elements on a single chip. This integration is used e.g. to control the sensitivity of each individual pixel to avoid blooming. Fraunhofer IMS has developed a dedicated 0,35 µm Opto CMOS process.

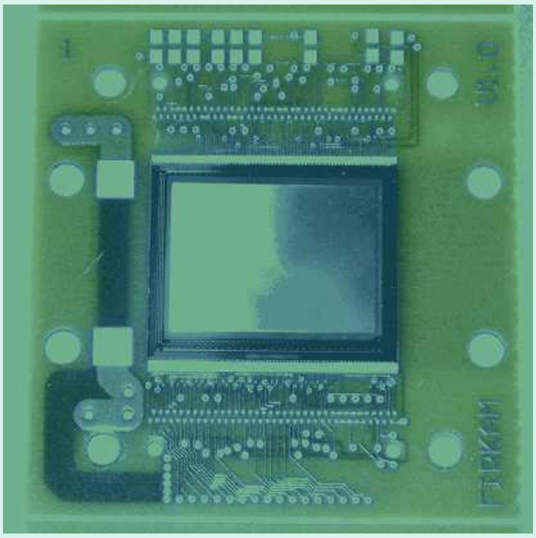
A wide range of CMOS image sensors has been developed for our customers and in research projects. The realized sensors include high dynamic range sensors, high speed sensors – which deliver 1000 high quality images per second – and high-resolution sensors with “region of interest” function for faster readout of subsections of the pixel array. The CMOS image sensors suppress smearing and blooming effects and always deliver sharp images. Electronic high-speed shutters enable the realization of 3D imagers base on laser pulsed based time-of-flight measurement.


CMOS Image Sensor



CMOS Camera



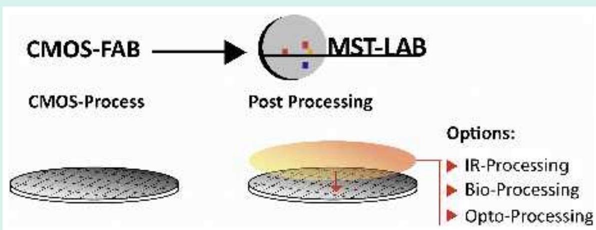


Infrared Sensor

The demand for uncooled infrared focal plane arrays (IRFPA) for imaging applications is constantly increasing. Examples for the application of IRFPAs are thermography, pedestrian detection for automotive, firefighting and infrared spectroscopy.

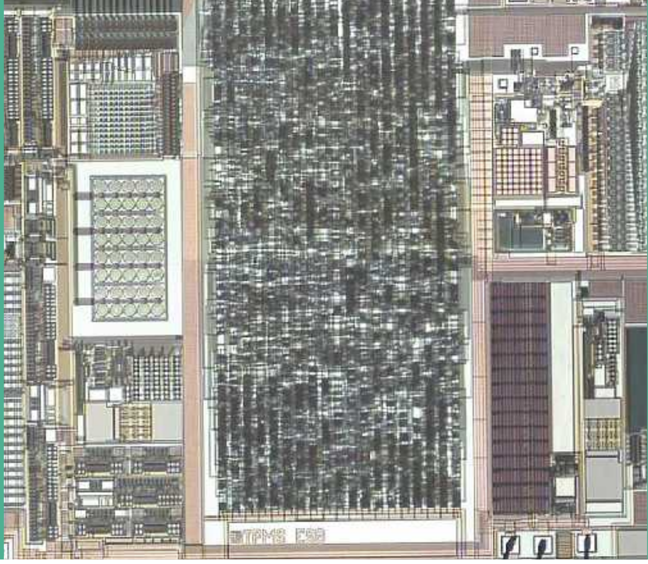
IRFPAs consist of an array of microbolometers located on top of a CMOS substrate which comprehends the readout circuit. Typcal array sizes are for lowcost applications 160 x 120 or 320 x 240 pixels. State-of-the-art IRPGAs achieve VGA-resolution with 640 x 480 pixels.

The microbolometer is a special infrared sensor. The IR-sensitive sensorelement based on the principle for a micro-bolometer is fabricated by post-processing on CMOS wafers. The microbolometer converts the infrared radiation into heart energy and this induces a temperature rise resulting in a change of the electrical resistance. Typical microbolometers have pixel pitch values of 35 µm or 25 µm.



Biosensors

Biosensors for point-of-care and home diagnostics are increasingly asked for. Therefore Fraunhofer IMS advances in the development of a new generation of biosensors. These special sensors are developed in the Microsystems Technology Lab where standard CMOS circuits are prepared for or – in future – combined with bioactive layers. Typically, additional metals or oxides are added, as well as special surface treatment and activation or the dispension of anchor chemistry for later analyte receptor immobilization. This new technology is called post-processing and it enables the production of different sensors for different applications by joining biosensitive layers with CMOS electronic readout circuitry. This “Bio to CMOS” processing leads to Biohybrid Systems.



3. ASIC Design

The development of analog, digital and mixed analog-digital integrated systems is a core competence of Fraunhofer IMS. Application specific integrated circuits (ASICs) enable our customers to provide cheaper and more powerful products. We offer the full spectrum from custom to IP-based ASIC solutions.
Full-custom ASICs are designed from scratch to accommodate the specific requirements of the customer, providing a highly optimized product. The IP-based ASIC is based on proven generic components, with lower design time and cost. Using a mix and match approach both design styles can be combined to leverage the benefits of both.

The close co-operation with our in house CMOS production line provides a seamless and efficient path from concept to series production. Our long experience in the development of integrated circuits, starting from concept through design, layout, and fabrication to testing ensures a short development time and a minimized design risk.

Our fields of design expertise are:
• Embedded microcontroller
• High-temperature ASICs
• Smart power integration
• Non-volatile memories
• Mixed-signal design
• Sensor transponder
Beside standard ASIC solutions for all kinds of applications, ASICs with sensors and sensor signal processing integrated on a single chip have been realized.

These ASICs often combine our core competences in ASIC design,
• System-on-Chip (SoC) solutions,
• Mixed-signal signal processing and
• Integration of RF building blocks for wireless energy and data transfer.
Our customers benefit from our research in these areas, which provides viable solutions for their applications – applications that demand miniaturization, energy-efficiency, cost-optimization and reliability.

4. Wireless Systems and Transponders

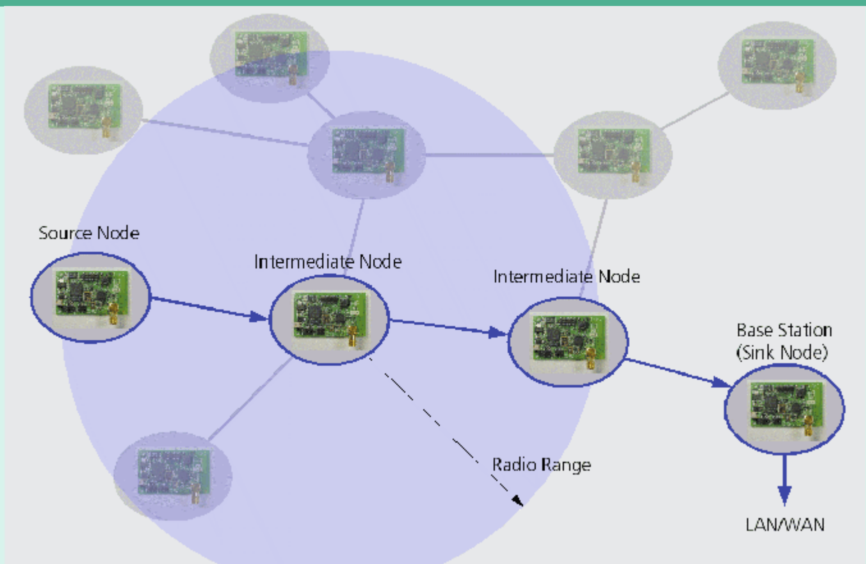
A core-competence of Fraunhofer IMS is the development and realization of wireless systems. Research and development focuses, among other things, on wireless sensor networks. These networks comprise autonomous sensor modules that are distributed over a large area or volume, and measure physical, chemical and other quantities. The measured values are transferred to a central agency, making use of intermediate nodes for data transfer, or they can be used by similarly distributed actor modules for decision-making and control processes. Development in this field includes new methods for communication (e.g. protocol stacks, localization) and the realization of cost-efficient, miniaturized components. The realization of new products in an efficient and timely manner is facilitated by the use of modular hardware and software components that allow a quick adaptation to application requirements.

High-frequency measurement chamber at Fraunhofer IMS

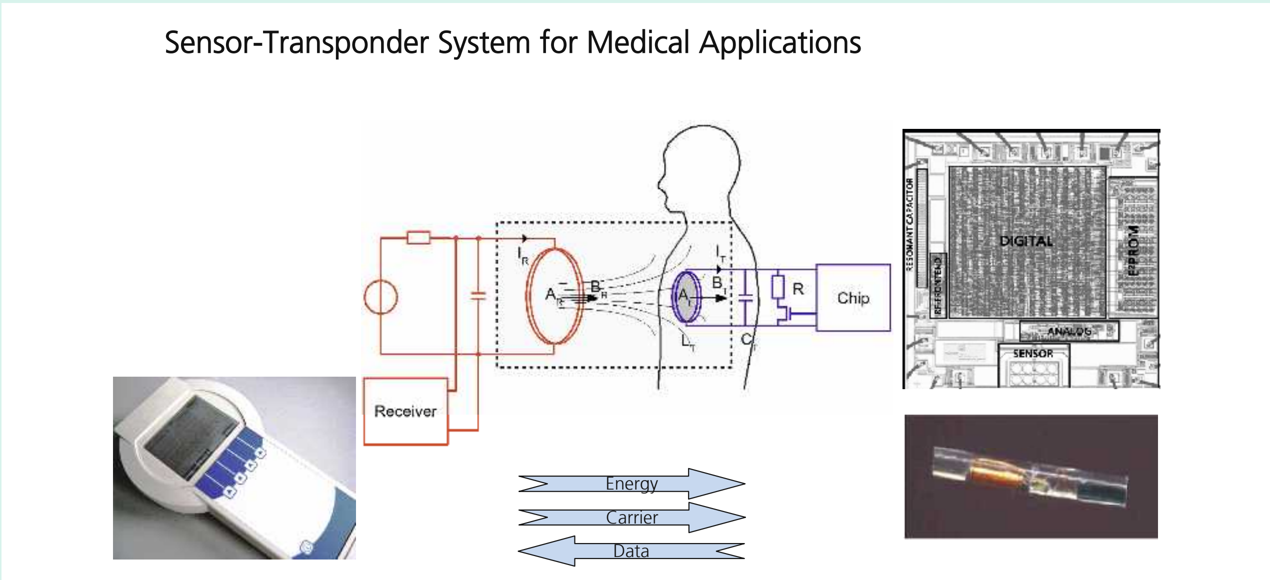
The advantages of wireless sensor networks were successfully demonstrated in some projects.

Important applications of **wireless sensor networks** are in the field of:
• Industrial automation, e.g. logistics and inventory control.
• Agriculture e.g. monitoring of air and soil parameters.
• Facility management, e.g. remote monitoring of buildings and infrastructure elements.

Our customers face a number of challenges that are adressed by our R&D activities. One set these activities addresses tools for network development, deployment and maintenance. Others address the field of energy harvesting, the ability to extract module power from the environment and obviating the need for batteries or power cables.



The **transponder systems** unit at the Fraunhofer IMS offers system solutions for the integration of novel portable or stationary transponder read-write devices and base stations into smart network-systems.
It also provides base stations for transponder ASICs with integrated micro sensors developed at Fraunhofer IMS, thus offering complete system solutions.
These transponder systems are used in smart buildings and vehicles, industrial automation, medical devices and logistics.



5. Smart Room & Building-Solutions

At the **Fraunhofer-inHaus-Center,** Europe's leading innovation center for smart homes and buildings, IMS cooperates with six Fraunhofer-Institutes and nearly 100 industrial partners to develop, test and demonstrate innovative solutions of all kinds for different application fields in smart buildings. In detail IMS offers research, development and complete systems-solutions to component and systems manufacturers, builders and operators of homes and commercial buildings for new and added value functions on the basis of electronics and software.

At the **inHaus1-Facility (Smart Home-Lab)** new domotic techniques to control lighting, doors and windows as well as heating and ventilation for energy efficiency in homes are developed and tested. One focus lies on solutions for smart metering for more transparency in energy consumption. In the SmartHome-Segment we have also a lot of experience in the field of user interface solutions for easyer control of technical equipment in homes. User acceptance tests in the smart home lab garantee the new industrial products to have a better success chance on the market.

At the **inHaus2-Facility (Smart Building-Lab)** new technical solutions for commercial properties are being developed, e.g. for new benefits in facility management and building operation, in the operation process of nursery homes, hotels and offices.

One main IMS focus lies on the development of new concepts and electronic systems that provide unobtrusive assistance for elderly and handicapped people in order to maintain a self-determined life at nursery homes with commercial operation and to optimize the care service process. We concentrate especially on solutions like microelectronic sensor networks in rooms with software interpretation of data to get benefits like automatic detection of problems or emergency cases (ambient assisted living AAL).

Another main field of R&D in all inHaus-application segments is energy efficiency, like in the smart home field. In cooperation with component and systems manufacturers and also energy providers next-generation-metering and building automation technologies for energy efficiency are developed, tested and demonstrated.

The inHaus Center offers R&D and complete systems-solutions to builders, modernizers or operators of homes and commercial buildings, to implement complete electronic and ITC systems for new and added value functions. This includes the following aspects:

- Safety and security
- Multimedia
- Support for the elderly
- Energy saving
- Light management

DEVELOPMENT OF THE IMS

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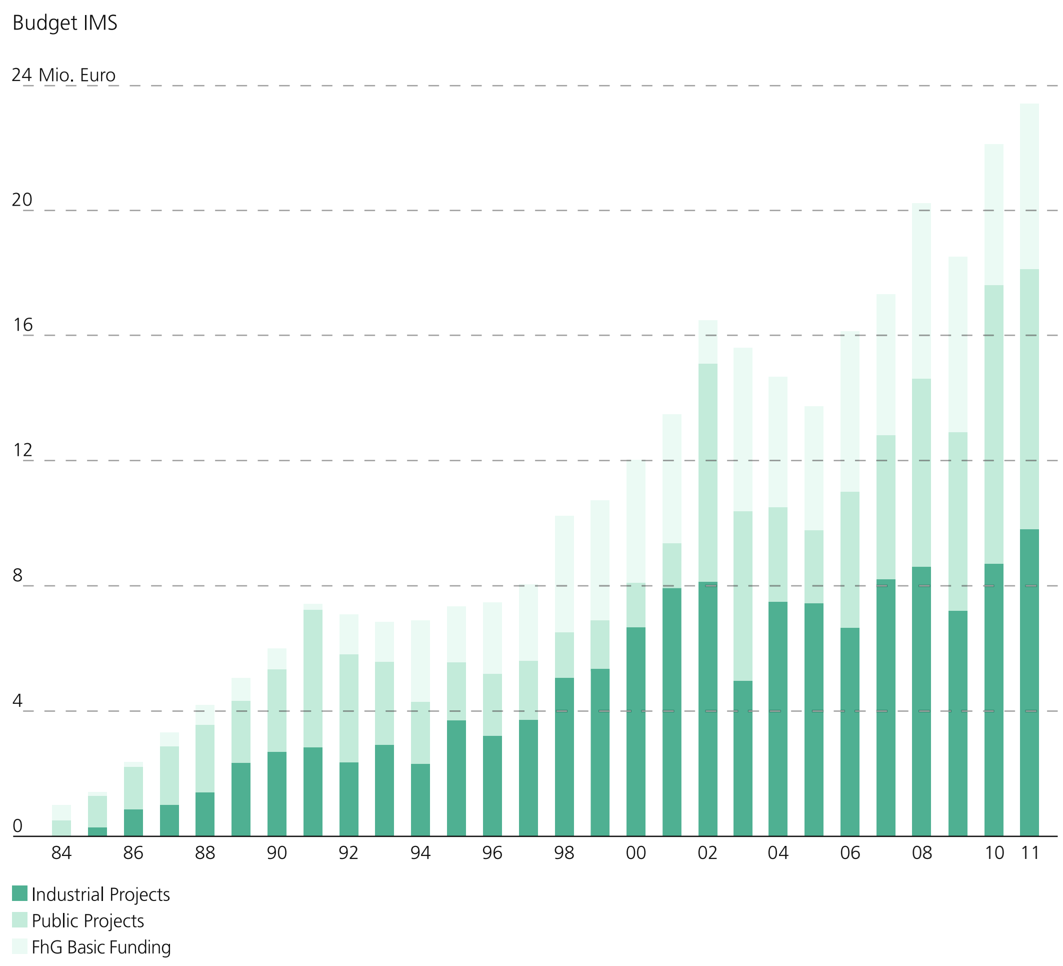
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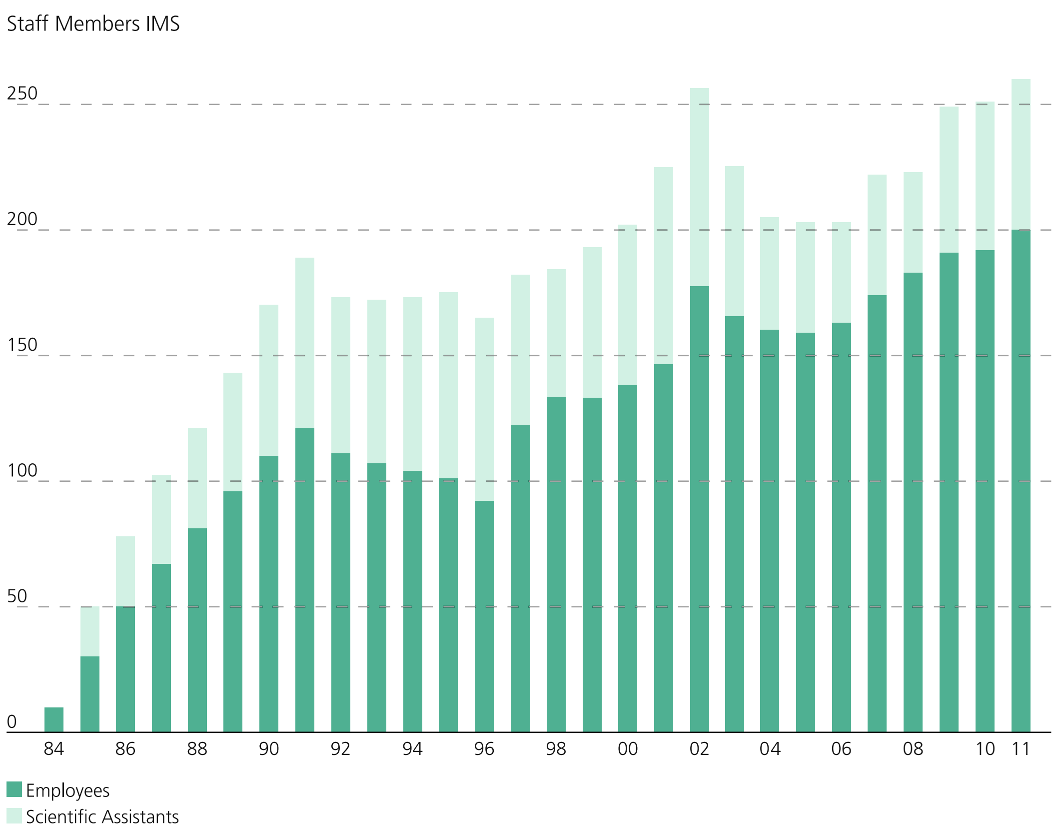
Industrial Projects
Public Projects
FhG Basic Funding


Staff Members IMS
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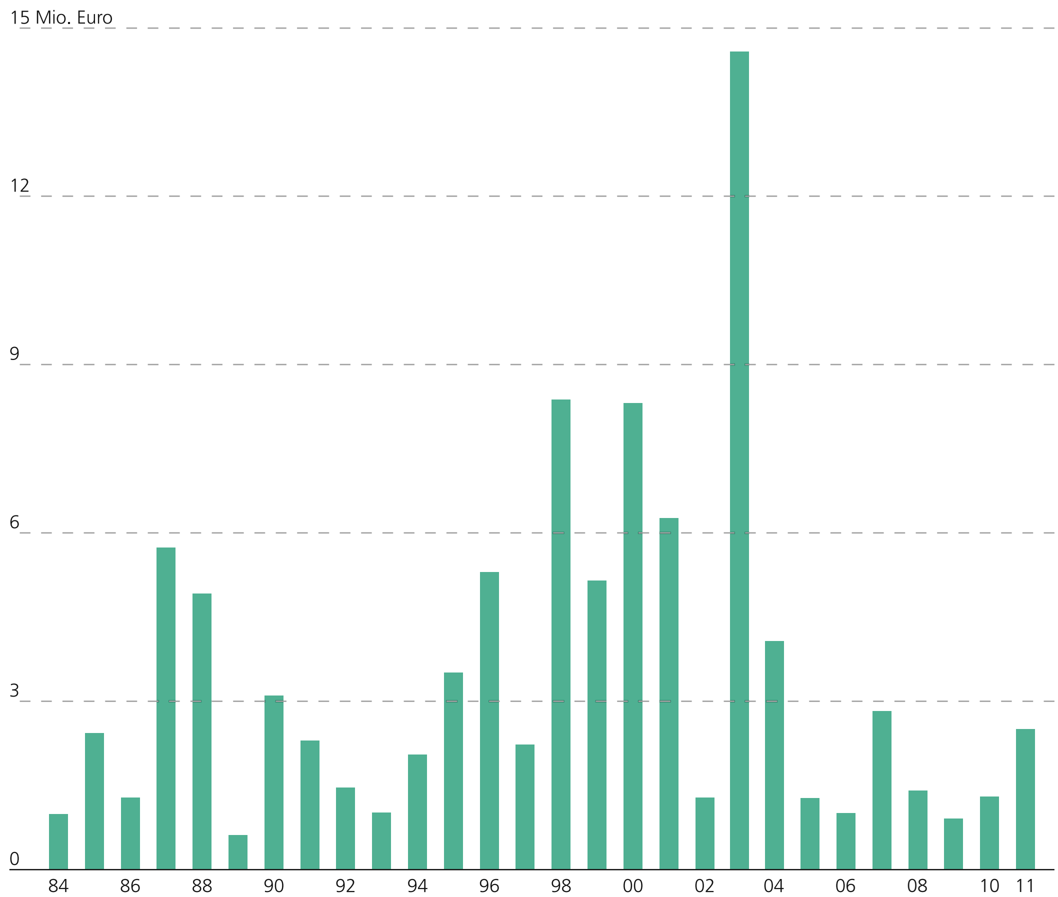
Employees
Scientific Assistants

DEVELOPMENT

FRAUNHOFER IMS

Capital Investments IMS



SELECTED PROJECTS OF THE YEAR 2010

Selected Projects of the Year 2010

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MICRO- AND NANOSYSTEM TECHNOLOGIES ON CMOS

H. Vogt, M. Ruß

The semiconductor industry has followed Moore's law since the early 70s. Doubling or even tripling the performance (integration density, speed) every two years through transistor scaling has yielded a better performance-to-cost ratio of products, generating an exponential growth of the semiconductor market. This in turn allowed an increased investment in equipment and processes, again stimulating the scaling. This "More Moore" approach has been accompanied by roadmapping, especially the ITRS roadmap, and is still a driver of the state of the art technology.

Since a few years, however, there is a new trend evolving. Due to the enormous investment and development costs, "Moore More" is handled by a few consortia on a world-wide basis only, concentrating on the large volume markets (memories, processors). In addition a "More than Moore" approach has emerged, where added value to devices is achieved by functionalities that typically do not scale according to "Moore's Law".

Especially in Europe this trend is obvious, where semiconductor companies are seeking their markets by adding power handling capability, robustness or sensing/actuating devices to their CMOS processes. Application areas are to be found in the automotive industry, in industrial or medical electronics, but also in consumer products.

A method to enhance the capability of an integrated device is post-processing or "above–CMOS technology". CMOS wafers serve as "intelligent" substrates. They may contain sensor readout or driver circuitry, temperature sensors, analogue signal processing, and interfaces to the outside world (analogue, digital, wired or wireless). On top of these CMOS wafers you may now deposit additional layers, structures and devices for sensing and actuating

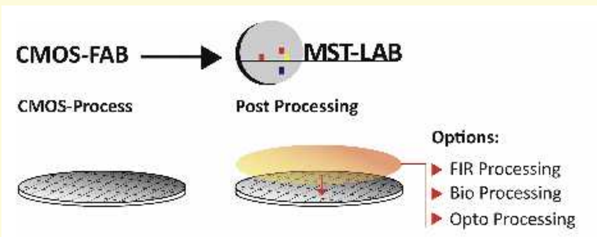

Figure 1: Post-Processing approach

Compact, "intelligent" micro- and nano-systems will result. Several advantages arise from post-processing:

- Compact sensors contain application specific interfaces
- The ultra short distance between sensor and readout allows detecting very small signals and it allows reading out arrays of sensors.
- Processing is done with proven semiconductor processing equipment, but may include specialized machines and processes
- A large material variety (compared to CMOS) is available
- Sensor/actor manufacturing is quasi independent from CMOS processing, but sensor and circuit functioning are very closely coupled.

To enable IMS following this emerging technology trend and to enable IMS to react to the requests from our R&D customers from the semiconductor industry but also from automotive and industrial users, we have started a project in late 2009 to set up a facility for post-processing at IMS. A 16 million Euro grant from the European Union, the German Federal Ministry of Education and Research (BMBF) and the Ministry of Innovation, Science and Research (MIWF) of North-Rhine-Westphalia is used for establishing a clean room and selecting and installing equipment for post-processing on 200 mm wafers.

600 sqm of former laboratory space have been transformed to a class 10/100 clean room. The challenge was to integrate a raised floor, a wall system, and all facility interconnections

despite of the limited height of the existing rooms. Filter fan units provide clean air, a clean wall system separates clean room and service area.

MEMS fabrication will use equipment sets for lithography, deposition, etching, metrology and packaging partly similar to CMOS, partly dedicated to new MEMS processes. Lithography uses 1:1 proximity and a 5:1 wafer stepper, both with front to back alignment capability. The stepper is unique in that additionally to 350nm resolution the front to back accuracy is better than 175nm. Thin and thick photo resist as well as polyimide and red/green/blue colour filters may be processed. Deposition systems range from CVD of dielectric and semiconductor layers to sputtering, evaporation and atomic layer deposition (ALD). Whereas ALD provides high precision thin metal or dielectric films, electroplating yields Cu, Sn, Ni, and Au layers up to several µm thick. Plasma etching is used to pattern metal or dielectric layers. Unique to MEMS processing are Ion Beam etching and Deep Reactive Ion Etching. DRIE offers bulk micro-machining and etching for Through Silicon Vias.

A set of metrology systems guarantees reproducible processing and a quick feedback for process development.

Packaging equipment, using this term in a very broad sense, comprises of wafer-to-wafer bonding, chip to wafer bonding, grinding and thinning for chip scale packages, but also for structures made of single crystalline semiconductor layers and devices on top of the CMOS wafer.

At the end of 2010, the new clean room is now "ready for equipment". Most of the machines cited above have been ordered, several are already delivered and have been installed, basic processes are available, and several projects are well on the way to support our customers.

The developments we are offering range from consulting, delivery of individual process steps for process modules, both interesting for semiconductor and MEMS companies, to the development and delivery of complete sensors on CMOS dedicated to industrial, automotive and medical users.

Two groups of scientists and technicians support the new MEMS facility. The operating group cares for machine installation, maintenance, and process step development as well as organising clean room and facility operations. The MEMS development group devises new device concepts from specification over simulation, prototype fabrication, characterization and tests. Close cooperation with the CMOS development groups, CMOS operations and facility allows the MST lab to benefit from synergy effects and guarantees true integration of sensors and actuators on top of our CMOS. Last but not least our circuit design groups at IMS contribute their know-how in analogue and mixed signal circuits to complete the developments on fully integrated single chip "intelligent" micro- and nano-systems.

Several projects have already been started or even finished in the new facility. We have developed a doped amorphous silicon layer to be integrated onto custom CMOS wafers stemming from a silicon foundry. Finally this layer was transferred to our customer's facility. Electroplating is used to enhance CMOS current driving capability and as a basis for SLID technology (soldering with solid liquid interdiffusion).

Pressure sensors and optical sensors will be integrated on top of our CMOS wafers. The most complex process developed so far serves the integration of a micro-bolometer array on top a readout circuit.

The cross section in Fig 2 depicts typical steps of CMOS followed by post-processing to integrate a sensor on top: a planarised surface of the CMOS, followed by additional metal layers, surface micro-machining exploiting a sacrificial layer with the thin sensor membrane on top and provisions to allow chip scale packaging. In addition we are working on bio-sensors integrating highly specific detection layers to

MICRO- AND NANOSYSTEM TECHNOLOGIES ON CMOS

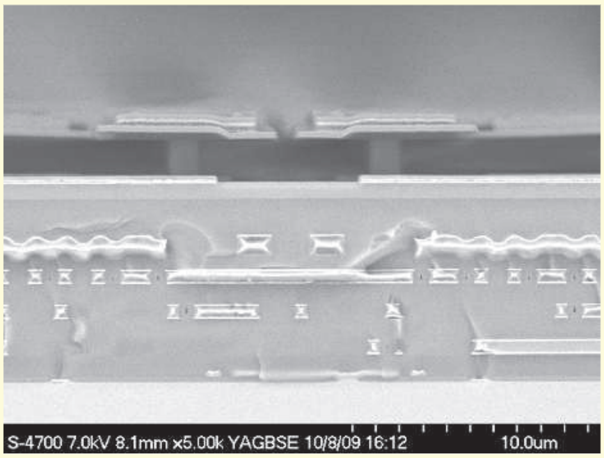

Figure 2: Microbolometers on top of CMOS readout

get marker free sensors. Nano-structures like semiconductor nano wires or carbon nano tubes will be applied to enhance sensitivity.

Post-processing on CMOS is the way IMS has chosen to advance CMOS applicability, to generate new devices and to serve our customers. The new Microsystems facility at IMS is ideally suited to support this goal.

CMOS-BASED EUV SENSOR

F. Hochschulz, U. Paschen, H. Vogt

Introduction

The detection of light in the extreme ultraviolet region of the spectrum (EUV or XUV, 4 – 50 nm) is not possible with standard front side illuminated CMOS image sensors as the radiation is almost completely absorbed in the dielectric layers that cover the silicon. This required the use of back-thinned and backside illuminated image sensors or focused ion beam (FIB) procedures for EUV image sensors. With the development of the deep optical stack etching (DOSE) process enhancement the production of pure CMOS front side illuminated EUV photo diodes has been enabled.

Applications

The detection of EUV radiation is part of many scientific research efforts, for example solar EUV imaging or microscopy of biological samples in the so called water window (2.3 – 4.4 nm) where water becomes transparent but carbon absorbs the radiation. Radiation with 13.5 nm is also used in the next generation lithography called EUV-L, which is supposed to be used for technology nodes with feature sizes of 15 nm and below. EUV-L still suffers from many unsolved problems, one of which is the inspection speed of masks and mask blanks. The DOSE process enhancement allows the development of specific image sensors for the mentioned applications, for example fast yet sensitive image sensors for EUV-L mask blank inspection.

The process

The underlying CMOS process used for the DOSE process is a 0.35 µm mixed signal process. For the DOSE process a polysilicon layer is deposited in photo active regions and the chip is processed until the pad opening. At this point a photoresist is applied and the pad areas are opened together with the photo–active areas lithographically. Using the standard pad opening etch the silicon nitride passivation is removed completely and the silicon oxide is removed partly in photo active regions. After a reapplication of the resist only the photo active regions are opened lithographically. Subsequently the remaining oxide on top of the polysilicon stopping layer and the stopping layer itself are removed. This leaves only a thin thermal oxide on top of the silicon in photoactive regions. This thin thermal oxide serves as an etch stop and protects the silicon surface. A shematic illustration of the DOSE process is shown in Figure 1, a SEM image of 7 µm x 7 µm DOSE photo diodes is shown in Figure 2.

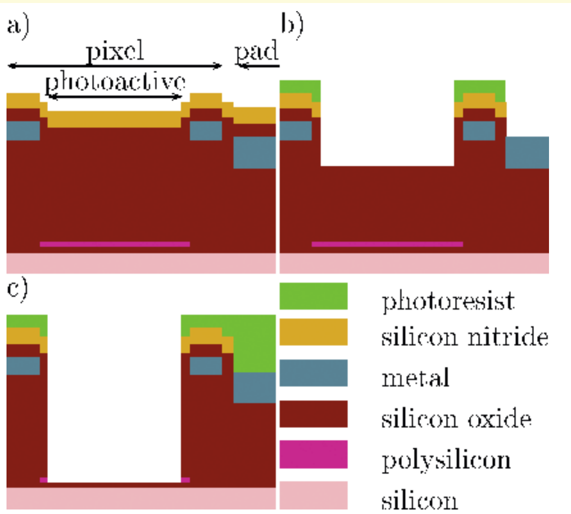

Figure 1. Schematic illustration of the DOSE process. a) CMOS process until pad opening. b) Photo resist is applied, pad regions are opened together with photoactive regions lithographically and pad etching is performed. c) Photo resist is reapplied, photoactive regions are opened lithographically, remaining layers (oxide and polysilicon) are etched.

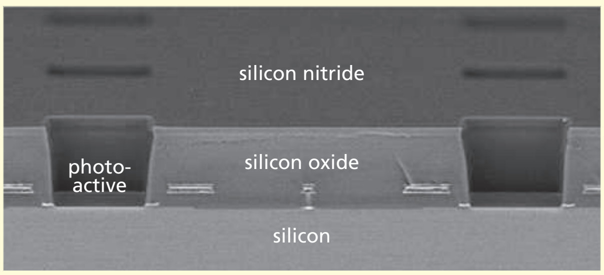

Figure 2: SEM cross section of DOSE photo diodes with a size of 7 µm x 7 µm.

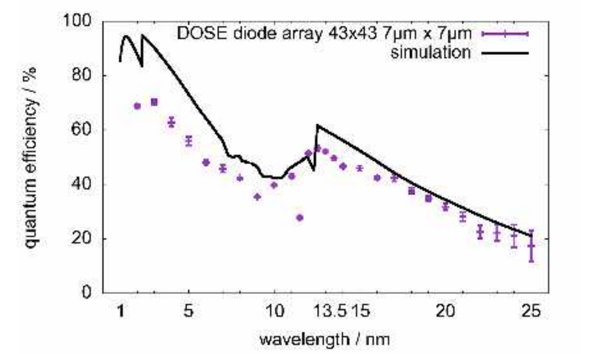

Figure 3: Sensitivity of an array of 43 x 43 DOSE photo diodes with a size of 7 µm x 7 µm compared to a simulation. The quantum efficiency is the amount of detected electron hole pairs divided by the number of impinging photons and the amount of electron hole pairs that are generated per absorbed photon. This amount is calculated using a mean electron-hole pair creation energy of 3.7 eV.

Sensitivity measurements

The sensitivity of a photo diode can be described by its quantum efficiency. The quantum efficiency is the amount of electrons detected per impinging photon, divided by the number of electron hole pairs that are generated upon absorption of a photon. It is calculated from the photon energy, the photo current of the diode (corrected by the dark current and in this case without external bias), the beam power that hits the photo diode and the number of electron hole pairs that are generated per absorbed photon.

The quantum efficiency of DOSE photo diodes has been characterized at the PTB's (Physikalisch Technische Bundesanstalt) XUV beamline at BESSY II, Berlin, in cooperation with the Fraunhofer ILT. The result for an array of 43 x 43 diodes with a size of 7 µm x 7 µm is shown in Figure 3. A quantum efficiency of around 50% at 13.5 nm is obtained, which is comparable to state of the art backside illuminated image sensors.

Conclusion and Outlook

Using the DOSE process extension photo diodes have been manufactured employing only common CMOS fabrication tools, which feature sensitivity to EUV radiation comparable to state of the art backside illuminated image sensors. As no expensive back-thinning or FIB processes are needed, this allows the development of cheaper application specific image sensors. Currently an imager with DOSE photo diodes is planned that will feature an increased frame rate compared to available EUV image sensors. The sensor will feature a resolution of 1280 x 960 pixels, a pixel pitch of 12 µm and a maximum frame rate of 200 fps. It is designed to improve, for example, the scan speed of inspection tools in this wavelength range.
Future work will focus on reducing the thickness of the thermal oxide in photo active areas in order to improve the sensitivity.

THERMALLY ISOLATED MONO-CRYSTALLINE SILICON DIODES AS DETECTORS FOR MICROBOLOMETERS

P. Kropelnicki

Bolometers are used as sensing elements for the detection of IR-radiation in the LWIR (8 ... 14µm) range. A new kind of diode bolometer can increase the thermal resolution of infrared detectors by reducing the noise of the sensor element. This is achieved by using a mono-crystalline substrate for the bolometer instead of an amorphous sensing layer which is typically employed in conventional bolometers. A mono-crystalline diode reduces the 1/f-noise and therefore increase the signal to noise ratio. The diode bolometer can be integrated by post-processing into a process flow based on CMOS-readout circuits to ensure mass production.

Introduction

Amorphous silicon [1] or vanadium oxide [2] are frequently used as the temperature sensing materials for standard microbolometers. The drawback of these amorphous materials is their high electrical 1/f-noise, which limits the signal to noise ratio. A promising way to limit 1/f noise is the use of mono-crystalline materials and it has been shown that diode microbolometers can be formed in mono-crystalline silicon [3]. However, the need for thermal isolation requires that the diodes are suspended from the bulk material by removing the underlying silicon substrate material. This limits the fill factor and makes it impossible to have a CMOS read-out circuitry directly under the pixel. A solution to this problem is to bond an additional sensor wafer to the wafer containing the CMOS read out circuit [4]. This approach combines a high fill factor and the possibility to integrate the read-out circuit in the proximity of the pixel with a mono-crystalline sensing material. Fraunhofer-IMS has developed a thermally isolated single-crystal silicon diode as a detector for microbolometers.

Test-structure

To determine the characteristics of the diode bolometer different single-crystal SOI diode test structures have been fabricated as shown in Fig. 1. It is possible to use this kind of test structure due to the fact that the thermal and electrical characteristics of a mono-crystal SOI diode test structure are very similar to those of a diode bolometer, but without the need for a sacrificial etch process. An typical geometry of such a test diode is shown in Fig. 2.

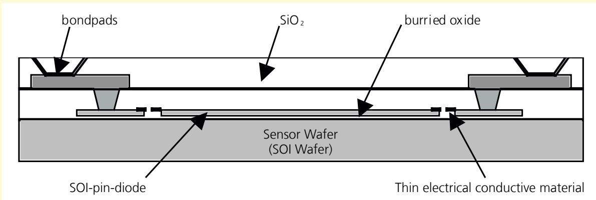

Fig.1: Cross section of a SOI-pin-diode test structure

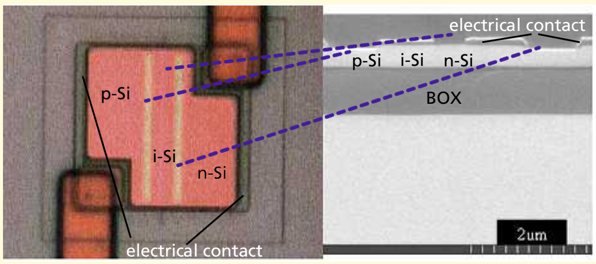

Fig.2: Top view (left) and technological cross section (right) of a SOI-pin-diode test structure

THERMALLY ISOLATED MONO-CRYSTALLINE SILICON DIODES AS DETECTORS FOR MICROBOLOMETERS

Temperature DC-model

A complex diode model of the temperature dependent IV-characteristic of a SOI-pin-diode is shown Fig. 3.

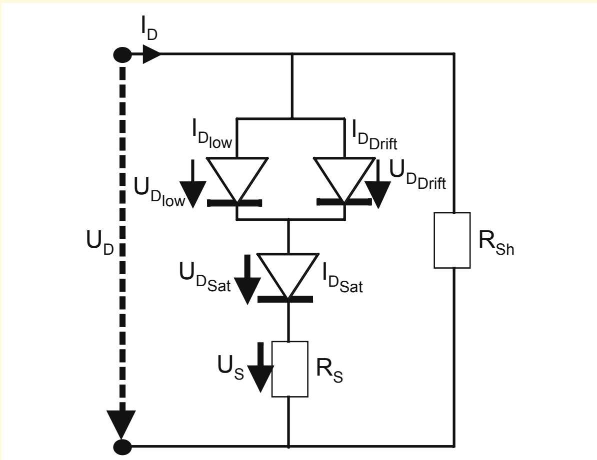

Fig.3: Temperature dependent DC-model for a SOI-pin-diode test structure and diode bolometer

This model describes the change of the ideality factor and the saturation current as a function of the temperature and the operating point. The comparison of the measured and modeled temperature dependent IV-characteristic is depicted Fig. 4.

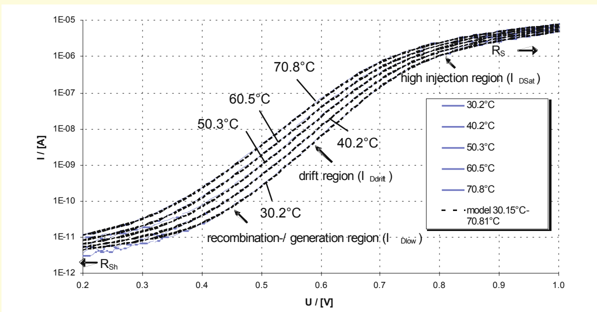

Fig.4: Measured and modeled temperature dependent DC-characteristic

Using the spice simulation software it is possible to numerically determine the temperature coefficient of the current as shown in Fig. 5.

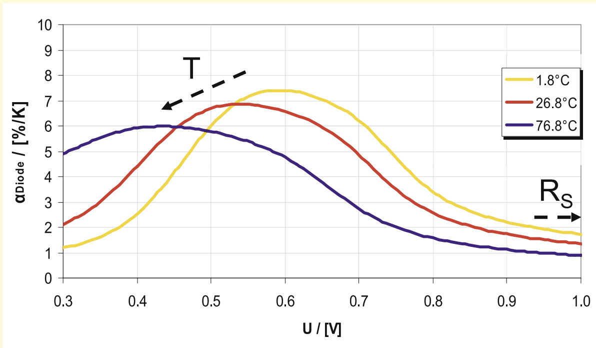

Fig.5: Temperature coefficient of the diode current as a function of temperature and voltage

Noise

The thermal resolution of an IR-detector based on a diode bolometer is limited by the noise of the pn-junction. To determine the noise of the component, even at extremely low frequencies, a noise measurement station is necessary (Fig. 6). A good shield against low-frequency electromagnetic radiation is achieved by using an enclosure consisting of two layers, Mu-metal and aluminum. With this measurement setup it is possible to measure noise down to 10^{-26} A^2/Hz and with frequencies as low as 10^{-1} Hz.

Readout-circuit

Typically, bolometers are read out by an integrator which converts the electrical current change due to infrared radiation into an analog voltage. This read out principle is used for the determination of the theoretical thermal resolution. It is shown that the influence of the shot-noise with respect to the resolution decreases clearly with higher currents of the diode bolometer. However, with higher bolometer currents, the negative influence of the 1/f-noise regarding the resolution

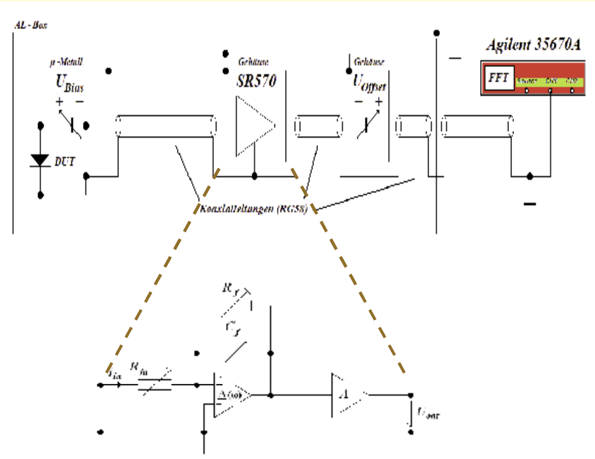

Fig.6: Noise measurement setup for noise determination of diodes

gets stronger and the decreasing temperature coefficient strengthens this effect. Measurements using test structures indicate a possible NETD of <100mK.

Process flow

A "low temperature direct wafer bond" process step was developed to enable the production of the mono-crystalline diode bolometer (Fig. 7).

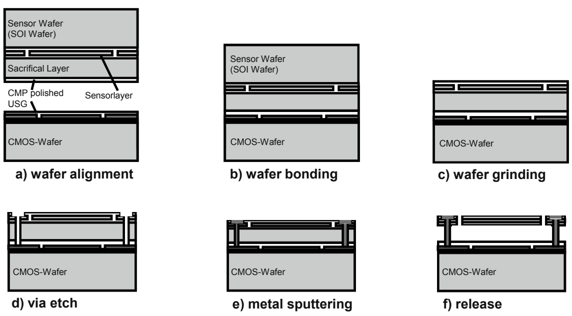

Fig.7: Process flow for the fabrication of a diode bolometer

This process step facilitates the bonding of the SOI sensor wafer with the CMOS wafer at low temperatures. Subsequently, during the wafer-grinding step, the back-side of the silicon based sensor wafer is grinded down to 5µm over the buried oxide. This is done so that the silicon can be selectively etched away afterwards. The remaining mono-crystalline bolometer membrane itself, which is placed above the CMOS wafer, can then be electrically connected with the CMOS wafer (Fig. 8).

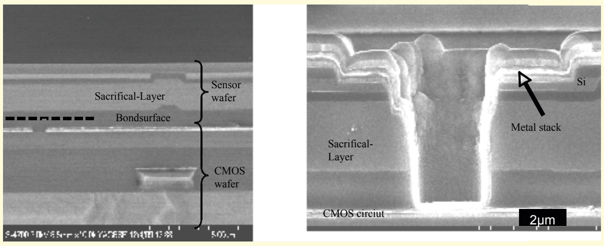

Fig.8: Bonded and grinded sensor- and COMS-wafer (left), electrical contact between both wafer (right)

Fig. 9 shows the geometry structure of a diode bolometer.

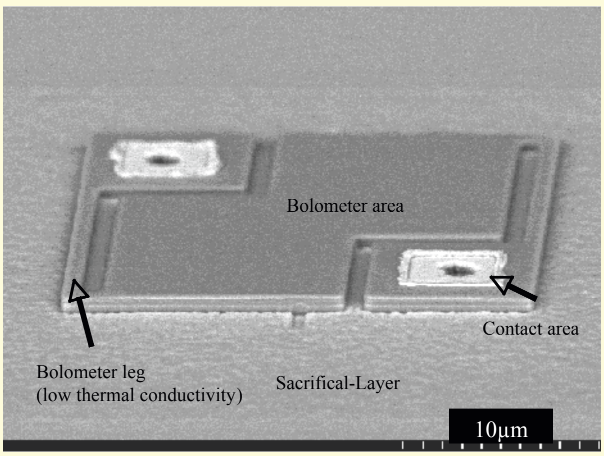

Fig.9: Diode bolometer before release step

THERMALLY ISOLATED MONO-CRYSTALLINE SILICON DIODES AS DETECTORS FOR MICROBOLOMETERS

In a final release step, the membrane can be thermally isolated from the substrate by removing the sacrificial layer as shown in Fig. 10.

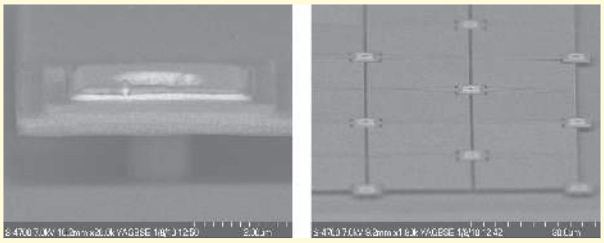

Fig.10: Contact plug of a diode bolometer (left), array of released diode bolometers (right)

Vacuum package

To reduce thermal losses by gas convection a vacuum package is required. To realize a reliable vacuum package a bond between a ceramic casing and a silicon lid, achieved by hard soldering the pieces together, is used. The principle of the vacuum package is shown in Fig. 11.

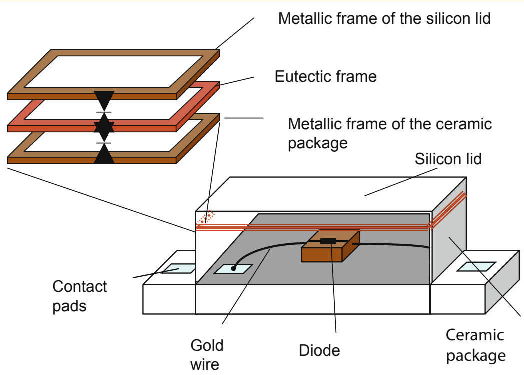

Fig.11: Schematic illustration of a vacuum package

The measured vacuum level reaches p<1x10-2 mbar. This vacuum level fulfills the requirements for the thermal isolation of a bolometer. To ensure the long term stability a getter is included inside the package. Fig. 12 shows the finished vacuum package.

Fig.12: Ceramic vacuum package after lid soldering

Conclusion

A full process flow for fabricating a mono-crystalline diode bolometer has been established, which is capable to integrate diode bolometer elements above a CMOS-circuit and therefore maximizes the fill-factor of an array. Also, a simple way to realize a Fabry-Perot structure to increase the IR-absorption can be achieved with this process flow. Due to low thermally conductive materials in the bolometer legs, a high thermal isolation can be realized. Diode bolometers can be used as the sensing element of an IR-detector with a high temperature coefficient of current and a low 1/f-noise and therefore a very low NETD.

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POST-CMOS MEMS INTEGRATION BASED ON NOVEL APPROACH WITH GE MICROMECHANICS

Q. Wang, A. Goehlich, H.-K. Trieu

Abstract

In order to avoid high-temperature-induced degradation of metal interconnects, transistors and other components in CMOS circuits, low temperature processes have to be applied for the post-CMOS integration of MEMS (Microelectromechanical systems). At Fraunhofer IMS novel approaches for the post-CMOS MEMS integration on the basis of silicon-germanium (SiGe) and germanium (Ge) were developed. Poly-SiGe films were deposited with a PECVD process at the substrate temperature of around 380 °C, and poly-Ge films were deposited with PECVD at the substrate temperature of around 340 °C. Capacitive pressure sensor elements with membranes of PECVD poly-SiGe and PECVD poly-Ge were fabricated. Due to the low deposition temperature of SiGe and Ge, a temperature budget of only 24 minutes at 380 °C in the case of SiGe membrane pressure sensor, and a temperature budget of only 26 minutes at 340 °C for Ge membrane sensor resulted. Sensor structures were examined with respect to the pressure sensitivity. It was found, that the mechanical properties of the structures with the SiGe or Ge membranes are comparable to the poly-Si structures. Poly-SiGe and poly-Ge films were deposited on metal interconnections in order to form direct electrical contact with the lower metal level. A via-resistance of circa 240 Ω of a poly-Ge via on Ti was measured. The via had a cross section area of 1.5 µm^2 and a height of 900nm. The demonstrated integration process performed with the low temperature depositions of poly-SiGe and poly-Ge is suitable for the post-CMOS integration of various MEMS structures.

Low-Temperature PECVD of poly-SiGe and poly-Ge films

It was reported, that the deposition of poly-SiGe and poly-Ge films can be carried out at temperatures lower than 450 °C with the LPCVD method [1], or with the PECVD method using pre-deposited LPCVD seed layer [2]. It was observed in this study, that poly-SiGe and poly-Ge films can be deposited at the substrate temperatures as low as 380 °C (for poly-SiGe) or 340 °C (for poly-Ge) solely with the PECVD method, if appropriate deposition parameters are chosen. The main advantage of PECVD method as compared to the LPCVD method is the much higher deposition rate of the former, which effectively reduces the thermal budget of the process. The typical deposition rate of LPCVD SiGe is about 0.6 nm/s [2] as compared to a deposition rate of 7.6 nm/s for poly-SiGe, and 5 nm/s for poly-Ge with the PECVD method, that were demonstrated during this study. In comparison to the method using pre-deposited LPCVD seed layer, our process takes less time, and it is also simpler. The resistivity of the in situ boron-doped poly-SiGe film is about 1.2 mΩ-cm, and that of the poly-Ge film is about 0.8 mΩ-cm.

Capacitive pressure sensor with SiGe and Ge membranes

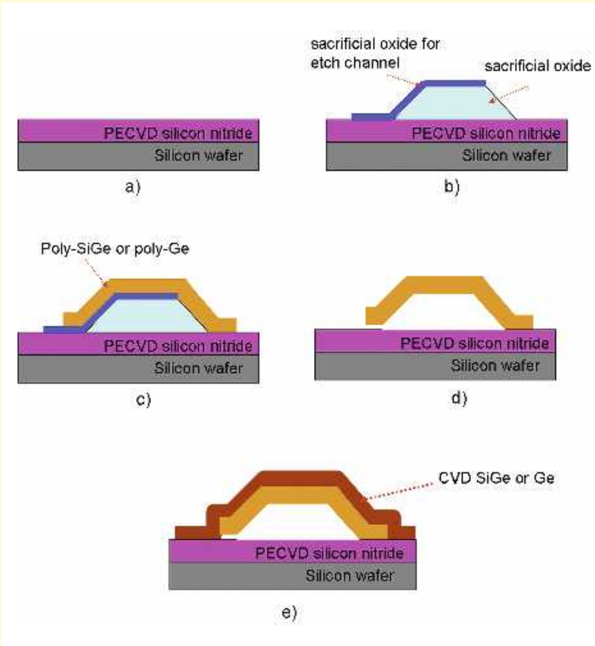

Figure 1: A simplified process flow for the production of the free standing structures sealed with SiGe or Ge. a) dummy wafer with PECVD silicon nitride; b) sacrifial oxide for the spacer of the "capacitors" and the etch channels are deposited and structured; c) poly-SiGe or poly-Ge films are deposited and structured; d) sacrificial oxide is removed; e) "capacitors" are sealed in vacuum using CVD SiGe or CVD Ge.

In order to verify the deposition process and the properties of the films, capacitive pressure sensor structures were produced. A schematic process flow of the fabrication of the pressure sensors is illustrated in Figure 1. To simulate wafers with completed CMOS electronics, silicon wafers with PECVD silicon nitride on top of them were used. A surface micromachined pressure sensor process at Fraunhofer IMS was modified, and utilized for the demonstration. The structure layer of the membranes was in situ boron-doped poly-SiGe or poly-Ge films. The stress of the films was optimized in such a way, that the structure layer bends lightly to the substrate, after the sacrificial oxide was removed. The capacitor structures were sealed with CVD SiGe or CVD Ge. A measurement of the central deflection of the membranes under different pressure load is depicted in Figure 2 for both materials. A linear dependence of the deflection on the applied pressure was observed. The pressure sensitivity (center deflection/bar) for both types of membranes yields a value of about 200 nm/bar.

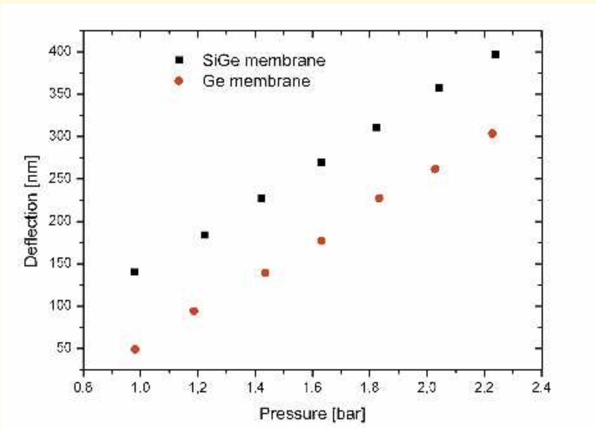

Figure 2: Central deflection of SiGe and Ge membranes under different pressures.

Vias of poly-SiGe and poly-Ge

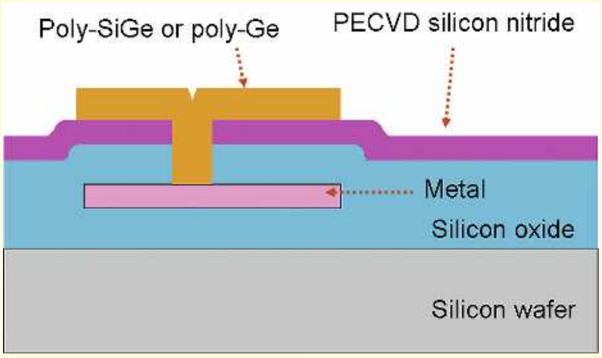

Figure 3: A simplified schematic cross section of a via of poly-SiGe or poly-Ge.

A further aspect of the post-CMOS integration of MEMS concerns the connection of the MEMS with the CMOS electronics. It is possible to in situ dope the poly-SiGe and poly-Ge films in order to generate highly conductive films. Therefore it is possible to deposit these films directly on metal lines in order to form the interconnection between MEMS and the lower metal level and consequently the connection between MEMS and CMOS electronics [3]. This technology was also demonstrated in this study. In Figure 3 a simplified schematic illustration of a via of poly-SiGe or poly-Ge is shown. The metal, which was in direct contact with the poly-SiGe or poly-Ge, was titanium, which guaranteed a good adhesion of the SiGe or Ge films on it. The resistance of the vias were measured by Kelvin via structures. In Figure 4, the measurement of a poly-Ge via, which has a cross section area of 1.5 μm^2 and a height of 900nm, is shown. The measured value of the resistance of the via amounts to approximately 240 Ω at a current of 5 mA.

POST-CMOS MEMS INTEGRATION BASED ON NOVEL APPROACH WITH GE MICROMECHANICS

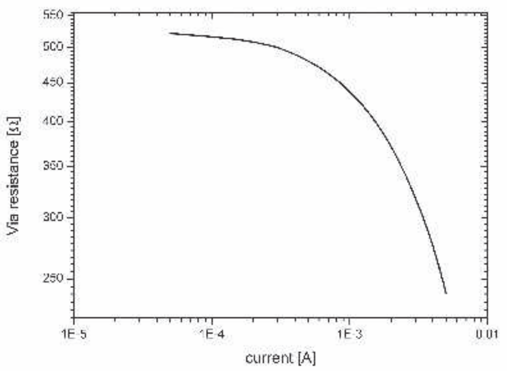

Figure 4: Via resistances of a poly-Ge via at different currents. The via has a cross section area of 1.5 µm² and a height of 900 nm.

Conclusion and prospect

With the successful fabrication of capacitive pressure sensor structures and vias of poly SiGe and poly Ge on metal, it was demonstrated, that the integration process based on the low temperature PECVD deposition of in-situ doped poly-SiGe and poly-Ge films is very promising for the post-CMOS integration of MEMS-structures. Therefore it is an interesting method to produce smart sensors and actuators, which can be more compact and can have more functionalities and smaller sizes.

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UniHealth – UNIVERSAL SENSOR SYSTEM FOR THE DETECTION OF ALLERGENS AND BIOMARKERS

C. Jonville, R. Klieber, A. Goehlich, H.-K. Trieu

The area of biosensors lies at the interface of physic sciences, technology development and biology. Bridging the knowledge and know-how together will enable biosensor systems which will provide not only sensitivity, selectivity and reliability but also portability at reasonable costs. Micro Electro Mechanical Systems (MEMS) are producible on a large scale, easily fully integrated and can provide rapid responses (1). They are superior to comparatively bulky and expensive laboratory equipment such as enzyme-linked immunosorbent assays (ELISA). Integrated MEMS can provide results through direct electrical measurement and do not require fluorescence testing. Therefore, they can bring the analysis closer to the end user allowing Point of Care Testing (POCT).

Aims of the project:

The UniHealth project aims at developing a label-free biosensor prototype for POCT. The first application is the detection of allergens in foods. The gluten protein has been chosen because 0,7 to 2 % of Europeans are affected by the Caeliac Disease that generates inflammatory reactions of the digestive system in the presence of gluten. Another allergen is the papain protein present in exotic fruits such as papaya and kiwi. The sensor will be able to tell if foods contain low enough concentration of allergens therefore if they can be consumed by the allergic user.

The second application concerns the detection of the anti-angliosid antibody that reveals the Guillain-Barré syndrome. It is an autoimmune disorder affecting the peripheral nervous system that can cause paralysis. It has an incidence of 1 or 2 persons per 100 000. This biosensor system will be used by doctors in their surgeries or in hospitals.

Sensor system:

The complete sensor system will consist of three parts. Firstly, a preparation step is needed to convert the sample to a liquid form. A device will be developed or adapted from an existing product that will shred, filter and mix the sample with a buffer solution. In this way the user will be able to analyse a wide range of food samples. Secondly, a device will be developed that will contain the microfluidics necessary to handle the liquids (such as pumps, tubings and micro-channels) as well as the measuring and communication circuits. It will be coupled to a handheld (for example a smart phone) or a computer. The calculation and display of results will be carried out by a program developed on the corresponding operating system. Finally, a remorable cartridge comprising the functionalised sensor arrays will be inserted for the measurements.

Principle of operation:

The natural resonance frequency of a circular membrane can be expressed as a function of material properties and dimensions (2).

$$f_0 = \frac{40.8\,t}{2\pi\, d^2}\sqrt{\frac{E}{12(1-\nu^2)\rho}} = \frac{10.2}{\sqrt{\pi}}\,\frac{t^{3/2}}{d}\sqrt{\frac{E}{12(1-\nu^2)m}}$$

Where f_0 is the natural resonance frequency of the membrane, E the Young modulus, ν the Poisson coefficient, ρ the density of the material and m its unloaded mass. The dimensions t and d are the thickness and diameter, respectively. From this formula, it is derived that a shift in mass Δm induces a shift in frequency Δf proportional to the added mass. In addition, replacing m and f_0, it follows that the mass sensitivity R is strongly dependent on the diameter ($R \propto d^{-4}$) but independent of the thickness.

$$\frac{\partial f_0}{\partial m} = -\frac{1}{2}\,\frac{f_0}{m}$$

$$\Delta f = -\frac{1}{2}\,\frac{\Delta m}{m}\,f_0$$

$$R = \frac{\Delta f}{\Delta m} = -\frac{40,8}{\pi^2\,\rho^{3/2}\,d^4}\sqrt{\frac{E}{12(1-\nu^2)}}$$

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The operation principle of the sensor relies on this resonant sensing. The sensor element consists of a free-standing poly-silicon circular membrane that can be electrostatically actuated and a selective layer on its surface. This layer will capture only one specific analyte (one of the above-mentioned molecules). In presence of the analyte, the resonance frequency will shift due to the captured additional mass. The membrane and the bottom substrate electrode form a capacitance whose value varies with the deflection of the membrane. Figure 1 illustrates the schematic cross section of the sensor. An integrated circuit measures and analyses the resulting signal. The element and circuits are produced using the IMS pressure sensor 1,2 µm technology and the surface is functionalised by several post-processing chemical steps.

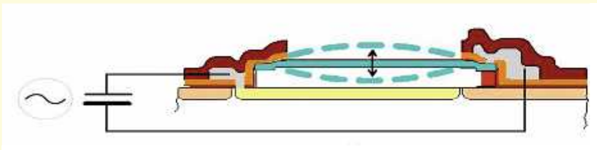

Figure 1: Schematic cross section of the sensor. The poly-silicon membrane is depicted in blue and the bottom substrate electrode in yellow. The sensor is excited with a sine signal with an offset.

The surface functionalisation will be performed with expertised collaboration partners as the Radbout University Nijmegen and the Wagenigen University within the framework of the UniHealth project.

Proof of concept:

To demonstrate the principle of operation, silicon dioxide bumps of different sizes have been deposited onto individual membranes by Focused Ion Beam (FIB). The size of the bumps has been measured and thus the added mass could be estimated. A 6 x 6 x 1 µm³ SiO_2 post deposited in the center of a membrane surface is shown in figure 2. It corresponds to a mass of approximately 93 pg.

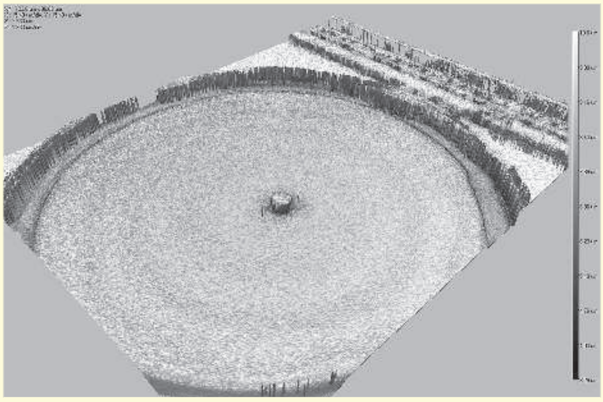

Figure 2: Optical interferometry image of a SiO_2 post deposited in the middle of a membrane of about 96 µm in diameter.

The membranes have a diameter of about 96 µm, are 1 µm thick and have a mass of about 20 ng. The smallest added mass represents less than 0,1% of the membrane mass. The sensor chip is mounted in a ceramic package that is then contacted to the actuation and measurement equipment through a printed circuit board. The experimental set-up is shown in figure 3. The sample is placed in a chamber that has several inlets for an external pressure monitoring and electrical cabling to the sensor. It is possible to measure in vacuum conditions. The deflection of the poly-silicon membrane is measured

Figure 3: Measurement set-up for the proof of concept experiment showing the sample chamber with the inlets for electrical actuation and pressure monitoring. The interferometry microscope measures the deflection of the membrane through a glass window.

through a glass window by optical interferometry while the frequency is scanned. The sensors are actuated by a sinusoidal signal of 3 V amplitude.

Figure 4 shows the deflection vs. frequency measurements for four membranes at atmospheric pressure. It is observed that the additional mass induces a shift in the resonance frequency peak. The resonance frequency lies around 2,5 MHz.

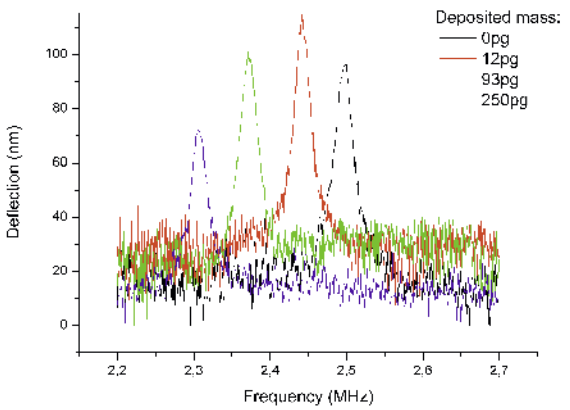

Figure 4: Deflection amplitude as a function of frequency of 96 µm membranes with different silicon oxide masses deposited by FIB. The deflection has been measured by optical interferometry at atmospheric pressure and the excitation is a sinusoidal signal of 3V amplitude.

The resonance frequency in function of the added mass values is depicted in figure 5. The sensor membranes exhibit a mass sensitivity of about 680 Hz/pg when the data is linearly fitted. This is promising since it is exceeding the published theoretical value of 30,2 kHz/pg for 18 µm diameter membranes resonating at 18 MHz (3). Indeed, taking into account the dependence of the sensitivity with the diameter and assuming the material is the same, the equivalent sensitivity would be 37 Hz/pg for a 96µm diameter membrane. In addition, the membranes produced by the IMS 1,2 µm technology have the advantage of operating at lower frequencies, requiring less operating voltage and the sensors can be monolithically integrated with read-out circuitry.

$$\text{Sensitivity: } R = \frac{\Delta f}{\Delta m} = -680 \text{ Hz/pg}$$

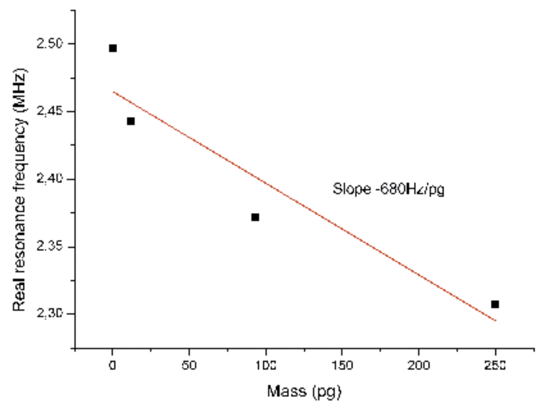

Figure 5: Extracted resonance frequency in function of the added mass.

Conclusion and outlook:

The utilisation of resonant sensing and the Fraunhofer IMS pressure sensor membranes as a signal transducer shows promising results for bio-sensing applications. In addition, the MEMS structures can be mass produced using a CMOS-compatible process thus providing the wished integration of measurement and signal processing circuits. Furthermore, it can be used as a biosensor platform since different surface functionalisations, applied after the semiconductor fabrication steps, can provide the selective recognition of biomolecules such as allergens or biomarkers.

The next steps of the project are to demonstrate the operation with electrical measurement and in fluids. Then functionalised surfaces will be used to verify the effect of the binding of the

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target molecules. Finally, the sensor element will be integrated in a resonator circuit that will output the real-time resonance frequency.

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BUILDING THE FUTURE OF CMOS IMAGERS

J. Fink, W. Brockherde

Since the institute's foundation in the mid 1980's the scientists at the Fraunhofer IMS have been dedicated to furthering the evolution of CMOS electronics and CMOS process technology. Following this tradition of innovative, leading-edge research, Fraunhofer IMS in 2009 became one of the founding members of the High Dynamic Range Low Noise (HiDRaLoN) project. Together with 15 partners from leading institutions across Europe, Fraunhofer IMS is currently working to establish a new generation of high dynamic range imagers catering to a multitude of applications. Covering fields like novel X-ray and computed tomography imagers, HD broadcast camera chips, lenses and correction algorithms as well as machine vision systems and 3D imaging systems, HiDRaLoN will push the limits of available CMOS imager technology to a new level.

1. Project overview

1.1. Project goals

Currently different driving forces can be identified on the CMOS imager market. For example high definition camera systems are constantly pushing the requirements for imager resolution and readout speeds. In addition, emerging technologies for 3D applications call for sub-pixelation and lenticular lenses on top of the imagers. Furthermore, industrial automation applications require advances in dynamic range to be able to cope with adverse lighting scenarios. Hence, the most urgent needs of the industry can be boiled down to a miniaturization of the pixel cell at a simultaneous increase of the pixel performance and the in-pixel signal processing power. Although the details of custom implementations for certain applications may differ, high dynamic range and low noise are always of key importance at any stage in the imager design and evaluation cycle. Thus, combining the research efforts and experience of many of Europe's major imager designers, HiDRaLoN aims at generating mutual benefits in terms of pixel and imager technology, modeling of electrical and optical crosstalk and correction algorithms.
With these considerations in mind the HiDRaLoN consortium has set a number of project goals to be reached within the three year project duration. First of all the efforts are focused on improving the dynamic range of CMOS imagers up to 120 dB whilst cutting their noise by 50 per cent and still maintaining crucial properties like resolution, sensitivity, low image lag and high quality. Reflecting the aforementioned wide range of target applications, sub-clusters among the project partners have been established in order to develop a total of five custom imagers for the medical, broadcast, 3D vision, machine and industrial vision segments. At the end of the project three imagers will demonstrate the improved performance in the 3D vision, medical and broadcast markets. The project work is rounded off by detailed work on imager and lens defect correction algorithms as well as interconnect and system design studies.

1.2. HiDRaLoN project organization

As illustrated in Figure 1, the HiDRaLoN consortium incorporates eight European companies, who are active in the field of imager or camera design. Apart from these industrial partners, five research institutes and universities as well as one corporate research center are also involved in the project (see Figure 2). The close collaboration of all partners guarantees a high degree of know-how exchange via regular meetings, reporting cycles and a constant supervision by both public funding authorities and the Catrene office.

Figure 1 Overview of the industrial partners of the HiDRaLoN consortium.

BUILDING THE FUTURE OF CMOS IMAGERS

Figure 2 Overview of the HiDRaLoN research and university institutions.

One special feature of the project is that, due to its high impact and visibility, it has attracted over 10 European companies to the adjoined user group. These companies are seeking to secure their position in their respective markets by having regular exchanges with the project partners and by having direct access to the project results.

Within the project Fraunhofer IMS coordinates all specification, benchmarking and modeling work. Furthermore, the institute also holds an unique position among the partners as it is the only institution which maintains a CMOS production facility and can therefore cover all project phases from design and simulation to chip production and assembly in-house.

Regarding the research activities in HiDRaLoN Fraunhofer IMS is mainly involved in the area of 3D vision imagers for automotive, logistics, safety/security and entertainment applications. The following section will present a general overview over this imaging concept and the related detector technology.

2. 3D Time-of-Flight imaging

2.1. Introduction

Due to increased level of automation in modern fabrication and logistics chains as well as in driver-assistance systems for automotive applications and in controller-free human-computer interfaces, 3D range measurements are quickly gaining ground. To address these needs Fraunhofer IMS propagates a measurement approach based on pulsed laser light, which, similar to Radar or Lidar applications, is reflected from a distant object and thus allows the determination of the object's position relative to the observer. However, as it relies on an active measurement method with a pulsed laser beam, this concept can circumvent limitations present in continuous-wave laser illumination systems or in fully passive 3D vision methods like stereoscopy. In detail, the hardware requirements of pulsed 3D Time-of-Flight (ToF) devices are significantly lower compared to stereoscopic systems, as only one camera with a simple laser diode setup and only very little CPU processing power are required. The advantages of 3D ToF measurements with pulsed laser light over continuous-wave illumination lie in the non-ambiguous range information, the inherent background light suppression and the easier compliance to eye safety regulations. The last point is based on the fact that the invisible IR-laser beam, which, albeit being quite powerful, is only active for a few dozen nanoseconds and therefore does not harm the retina.

2.2. Technological advances

In spite of the rather simple 3D ToF principle, which is basically only a runtime experiment, regular photodetector elements are unsuited for 3D ToF measurements. The cornerstone of a distance measurement with pulsed laser light is the speed of the photodetector element. Here speed does not only refer to the time it takes for the generated charge carriers to reach the readout node but also to the ability to almost instantaneously switch between different such nodes. Figure 3 illustrates these points on a novel detector structure proposed by Fraunhofer IMS. As shown, the so-called lateral drift-field photodiode features a lateral doping concentration gradient along the photosensitive area. This gradient is introduced in a single, additional implantation step and it generates a lateral drift-field, which quickly sweeps the charge carriers towards the collection gate (CG).

By this means the LDPD significantly speeds up charge collection compared to regular diffusion-based photodetectors. Figure 4 shows a measurement of the charge collection times in different sensor structures. It is evident that under 3D ToF

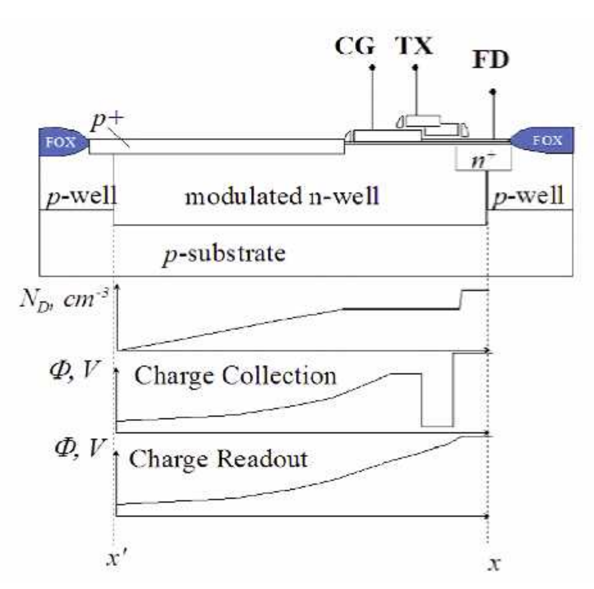

Figure 3 Layout of a lateral drift-field photodiode (LDPD).

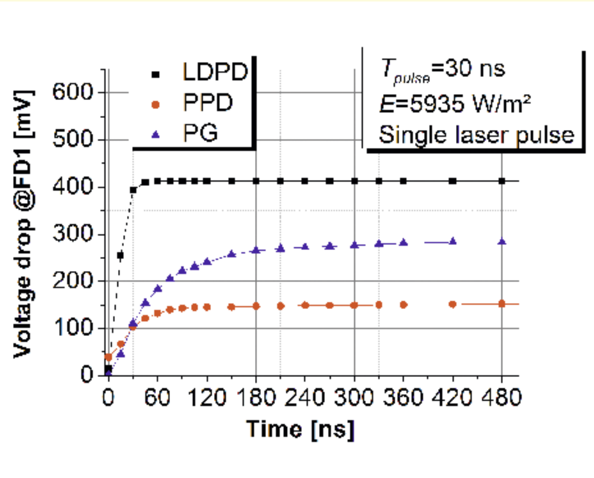

Figure 4 Indirect measurement of the charge collection time in three different pixel structures. (T_{LDPD} = 30 ns; T_{PPD} = 60 ns; T_{PG} = 120 ns).

conditions, i.e. 30 ns laser pulses at approximately 900 nm wavelength, the LDPD surpasses the charge collection performance of an equally large photogate (PG) structure by a factor of 4 and that of a pinned photodiode (PPD) by a factor of 2.

Having explained one aspect of the speed requirements, it is possible to address the second problem. Figure 5 illustrates the general clocking scheme of a 3D ToF sensor operating with pulsed laser light. Initally a laser pulse of width T_{Pulse} is emitted by the system. It then takes the light a certain amount of time T_d to travel to a distant object and to return to the imager.

By synchronizing the readout of the detector to the emitted laser pulse, the distance information can be obtained. This is handled through two CCD-like transfer gate (TG) structures, which steer the generated charges either into the floating diffusion (FD) readout nodes 1 or 2. As shown, part of the reflected pulse is detected in FD1 and the rest is accumulated in FD2. The difference signal between FD1 and FD2 finally constitutes the distance information. This fast switching requirement was tested experimentally under laser illumination. Figure 6 shows the device's signal amplitude as a function of the delay time T_d. Considering FD1 it is evident that basically all charges are collected in FD1, if no delay between incoming and returning pulse is present, i.e. if the distance is zero. On the other hand if it takes the light more than 30ns to travel to the object and back, all charge is seen in readout node FD2, which is also according to expectation.

Note that this measurement approach provides valuable additional information, as it also yields a measure of the objects reflectivity. With the ratio of FD1 to FD2 giving the distance information and the sum of both signals determining the reflectivity, possibly erroneous distance measurements can be prevented.

Apart from the improvement in device speed, the proposed concept also exhibits low noise levels. This is because the p+ implantation in the photoactive region pushes the potential maximum away from the surface and thus limits recombination effects.

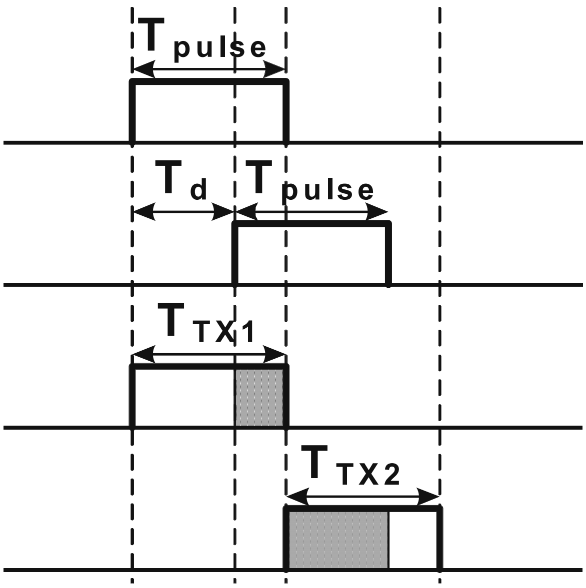

Figure 5 Simplified clocking scheme of a pulsed 3D ToF sensor.

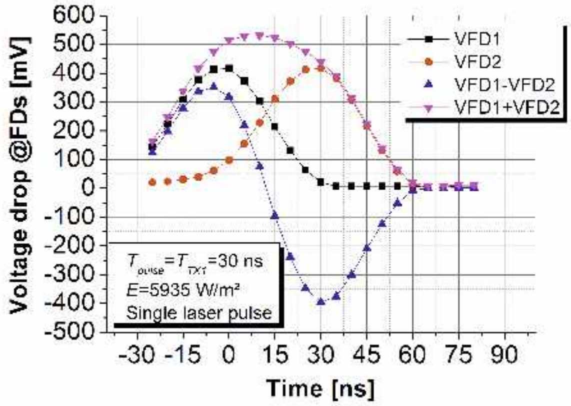

Figure 6 Time-of-Flight operation of a LDPD structure.

Even though already the first results obtained with LDPD structures on the test chip shown in Figure 7 look very promising, Fraunhofer IMS is also currently optimizing and evaluating standard photodetector structures like PG and PPD for 3D ToF applications.

3. Conclusion

With the HiDRaLoN project the Fraunhofer IMS advances its role as one of Europe's key centers for CMOS imaging technology and simultaneously maintains a close connection to many European imager designers. In the field of 3D Time-of-Flight imaging novel technologies, which will benefit a wide range of applications, are currently under research.

Funding

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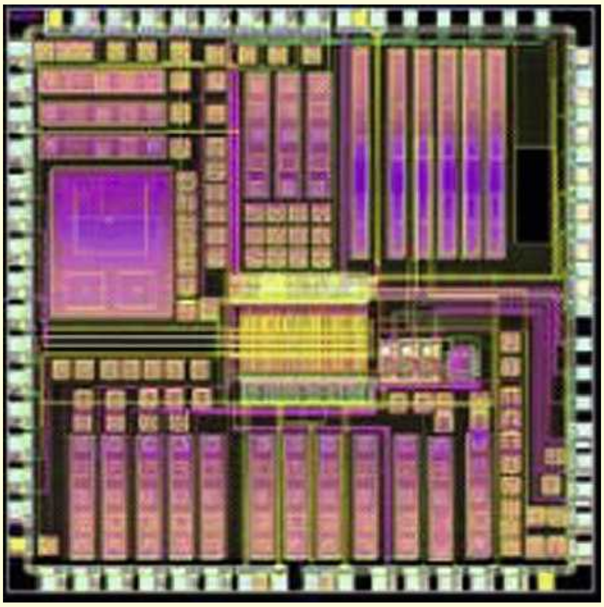

Figure 7 Layout of a 3D ToF test chip with PG, PPD and LDPD pixels.

AN 868 MHz PASSIVE TEMPERATURE SENSING TRANSPONDER USING A SELF-BIASING UHF RECTIFIER WITH – 10.5 dBm SENSITIVITY IN LOW-COST 0.35 µm CMOS

T. Feldengut, S. Kolnsberg, R. Kokozinski

Wireless energy transmission via electromagnetic waves can be used to generate the supply voltage for micro-power ASICs such as RFID tags or simple sensor nodes [1]. These Sensor nodes can be used in logistics applications, for example in temperature monitoring of products during transportation. Delivery trucks or warehouses can be supplied with RFID readers that generate the electromagnetic field to communicate with the sensor nodes of different objects. The sensor transponders do not require a battery, but generate the supply voltage from the antenna voltage. Therefore, the individual nodes can be very light and cheap. The Villard circuit (sometimes referred to as Dickson charge-pump or Greinacher circuit) is typically used to multiply and rectify the RF voltage from the antenna [2]. The power sensitivity P_{min} of this circuit is a critical figure of merit in order to reach a large operating distance of the passively powered device. P_{min} is defined as the minimum input power that generates the required output DC supply voltage for a given load current.

Figure 1 shows the chip architecture of the developed passive sensor transponder. Beside the rectifier circuit, the ASIC contains a modem, a clock oscillator, power-on-reset detection, and voltage limitation. The chip also includes a bandgap voltage reference and LDO voltage regulator to generate temperature-independent supply and reference voltages. A digital part manages the communications protocol as well as access to non-volatile memory. The minimum unregulated supply voltage is specified as 1.6V to guarantee reliable operation at all process corners and temperature variation (–40 °C to +85 °C). The average current consumption is 5 µA.

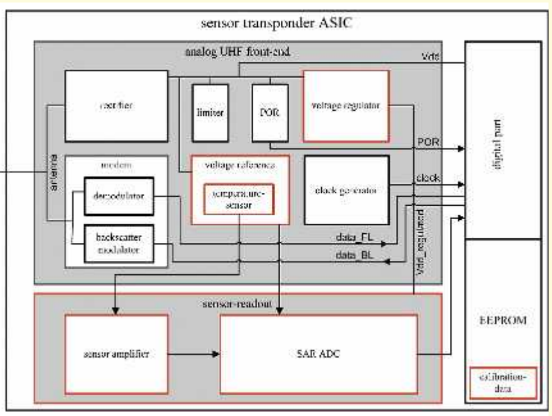

Figure 1: Architecture of a transponder with additional circuitry for temperature measurement.

The rectifier sensitivity is reduced by the forward voltage drop of the diodes [3]. Schottky diodes are often used for their high switching speed and low voltage drop (typically 200 mV to 400 mV). However, the substrate losses and series resistance of these devices is not negligible without additional masks to produce well suited Schottky diodes. Diode connected transistors are available in every standard CMOS technology, but their threshold voltage reduces the sensitivity. Low-V_t transistors are often available, but V_t is not a precisely controlled parameter. It is influenced by process and temperature variations, and a negative V_t is not acceptable for rectification.

An analysis [1] of the voltage conversion yields $V_{out} = 2\ n\ (v_{in} - V_{drop})$, where V_{out} is the output DC voltage, n is the number of stages, v_{in} is the input voltage amplitude, and V_{drop} is the forward voltage drop of each rectifying device. The value of V_{drop} depends on the output load current as well as on the specific I(V)-characteristic of the rectifying device. In addition to this voltage transfer characteristic, the input impedance of the rectifier determines the power sensitivity. A quantitative study of the input impedance was presented in [2]. The input resistance and the input capacitance depend mainly on the output current consumption as well as parasitic losses in bulk-CMOS technology. In typical process technologies without additional masks or well controlled low V_t, the voltage drop across the rectifying devices remains a limiting factor for the operating range of passive devices [3].

Several techniques have been developed to eliminate the effect of V_t by means of gate biasing techniques [4], [5]. Figure 2 shows a single rectifier stage where the gate of the

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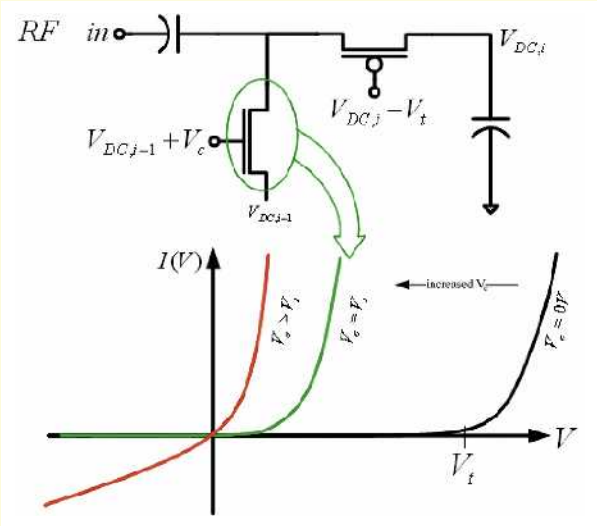

Figure 2: Rectifier stage with gate biasing in order to eliminate the effect of the threshold voltage and resulting I(V)-characteristic [3]

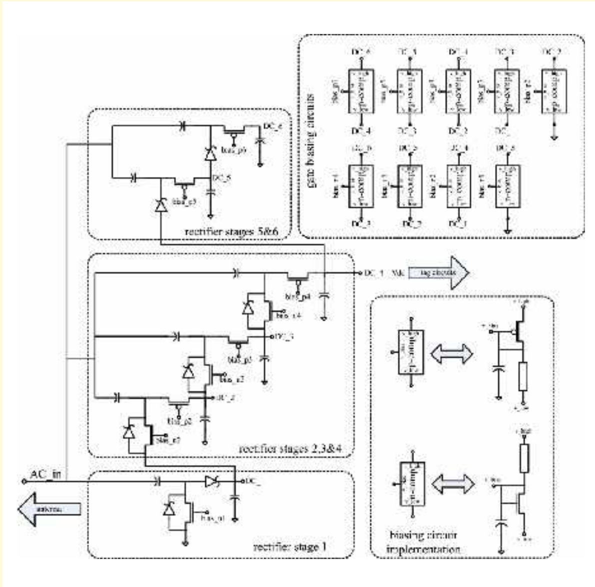

Figure 3: Developed rectifier circuit topology

PMOS transistor is "pre-charged" with a voltage bias at one V_t below the output voltage of the stage. Correspondingly, the gate of the NMOS transistor is biased at one V_t above the DC input. This way, the transistors act as diodes with 0 Volts V_t. NMOS transistors are used in vertical branches and PMOS transistors are used in the horizontal branches, so that all gate bias voltages for eliminating the threshold voltage drop are DC signals. It has been proposed to use a microbattery [4], ferroelectric capacitors [5], or a secondary rectifier [3] to provide the required biasing voltage.

Figure 3 shows the developed self-biased rectifier topology. The first stage, the three intermediate stages, and the two topmost stages have slightly different topologies. The output of the fourth stage provides the supply voltage of the chip, stages 5 and 6 remain unloaded to generate a higher voltage for biasing purposes. In addition to the rectifying transistors, a total of 7 no-mask-added Schottky diodes are still required, as will be explained in the following.

At low input voltage amplitude, the voltage at the output of the first stage is less than one V_t, so the bias voltage at the gate of a horizontal PMOS transistor would have to be negative to effectively cancel the threshold voltage drop. A simple remedy to avoid negative voltages on the chip is to replace this PMOS transistor in the first stage with a medium sized Schottky diode (contact area = 10 µm^2). All NMOS transistors require a bias voltage that is higher than the output DC voltage of the preceding rectifier stage. However, during the initial start-up phase, the DC voltages have not been generated and the biasing scheme is not in effect. Therefore, to ensure reliable start-up of the circuit, small sized Schottky diodes (contact area = 3 µm^2) are placed in parallel to the vertical NMOS transistors to serve as rectifying devices when the threshold voltage drop of the transistors is not yet eliminated. The NMOS transistors in stages 3 and 4 require a bias voltage that is higher than the output voltage of the rectifier (DC_4). Therefore, two additional stages (5 and 6) are implemented to generate higher, unloaded voltages (DC_5 and DC_6) to

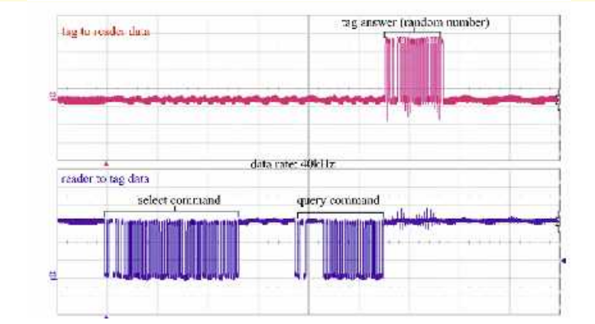

Figure 4: Measured data signals during wireless communication at 40 kHz. (Digital part for ISO/EPC protocol handling implemented on FPGA with separate power source)

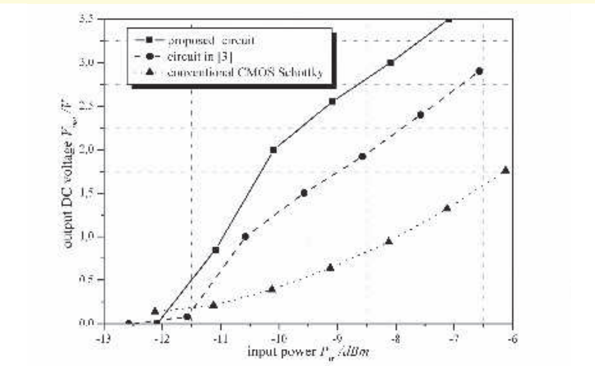

Figure 5: Comparison of the measured output voltage for the conventional Villard circuit, the circuit presented in [3] (measured), and the proposed circuit

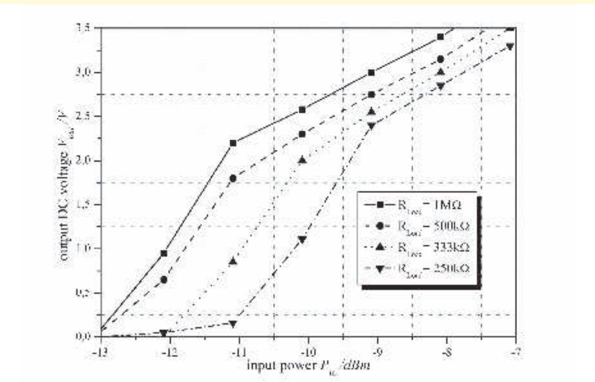

Figure 6: Measured output voltage for different load currents

supply the biasing circuits for the NMOS transistors in stages 3 and 4. Stages 5 and 6 are implemented without transistors in the vertical branch, because the required biasing voltage for NMOS devices would be higher than the top voltage DC_6.

The biasing circuits are connected to different DC terminals in the rectifier stack in order to minimize the voltage drop across the resistors. This way, the resistor size can be reduced without significantly increasing the load current. For example, the biasing circuit to generate the gate voltage of the NMOS transistor in the third stage is connected between terminals DC_5 and DC_2. The bias voltage is set to be higher than DC_2 by one V_t, so it is almost as high as the potential at node DC_5. Therefore, the voltage across the resistor is close to zero, and the current through the biasing branch is almost negligible when all capacitors are fully charged during “steady state” operation.

The measured IC (figure 7) contains the complete analog part of the sensor transponder with the presented rectifier circuit. The chip area is 1.7 mm x 1.3 mm including the pads. A large part of this area is used for capacitors to achieve sufficient PSRR of the regulator and the references during temperature measurement. Figure 4 shows the measured data signals during wireless communication. Figure 5 shows the rectifier output voltage as a function of the input power for the proposed circuit, as well as for the rectifier presented in [3] and the conventional Schottky diode approach. All three circuits were fabricated and measured in the same CMOS process. The proposed circuit presents a sensitivity improvement of 4 dBm compared to the conventional circuit and generates a significantly higher output voltage than the circuit in [3]. The measured current consumption is 3 µA (without the digital part) at 1.6 V, in agreement with simulation. Figure 6 shows the measured DC output voltage as a function of the load current. The achieved power sensitivity of the presented IC is still lower than some reported values for non sensor RFID tags [1]. This is due to the fact, that the sensor node requires significantly more power

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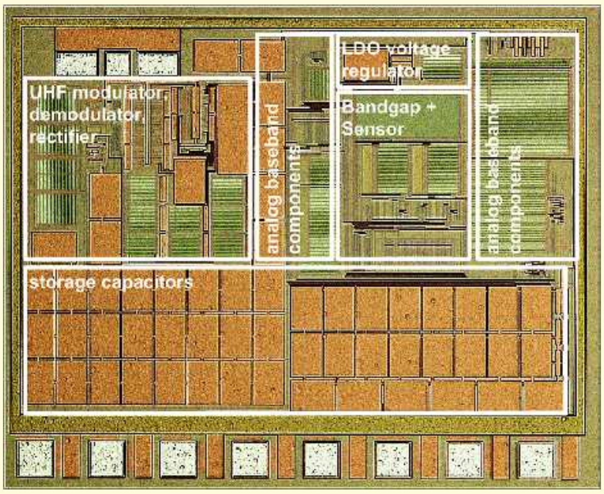

Figure 7: Photograph of the presented test chip with the complete analog part of the sensor tag and the developed rectifier

(1.6 V x 5 µA = 7.5 µW, including digital) than simple RFID tags (1 V x 1 µA = 1 µW, [6]).

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ON CHIP DIGITAL READOUT ELECTRONICS FOR LARGE SCALE IR IMAGE SENSORS

R. Lerch

Combining standard CMOS wafers with additional processing steps allows the creation of Micro-Electro-Mechanical Systems (MEMS), which extend the functionality of the chips from electronic circuitry to direct sensor and actuator functions. A sensor function that can be realized with such additional processing is the detection of infrared radiation (IR) in the 7 to 14 µm range. This function cannot be achieved in CMOS structures alone for these longer wavelengths, which are used in thermal imaging applications.

Using an array of MEMS structures (see the article "Thermally isolated monocrystalline silicon diodes as detectors for microbolometers" in this issue for an example) as IR sensor pixels, an IR imaging sensor can be constructed, very much like the conventional imaging sensors for visible light. The sensor element consists of a temperature-dependent resistor suspended above the chip surface on two supports. These supports provide a high degree of thermal insulation, so that the resistor's temperature is determined by the arriving infrared radiation. The resistor's temperature-dependent resistance therefore provides a means to convert the level of incoming IR into an electrical signal.

Conventional IR image sensors of this type have followed the same general lines as visible light image sensors. Those sensors are wholly built using CMOS technology (or, equivalently, CCD technology), with a pixel consisting of a sensor area (silicon diode), an integrating capacitor and a switch to connect to an output amplifier or a video ADC. While the IR pixel does not need the diode (its sensing element is the MEMS resistor), but integrating capacitor and the switch are still present. The output amplifier or video ADC usually is realized once for the whole array, with a hierarchy of row and column switches sequentially connecting it to each pixel.

This kind of architecture has several drawbacks: The output amplifier or ADC have to operate at high speeds, as the pixel rate at the output approaches 10Mpel/s for arrays with VGA resolution (640*480 pixels), while providing a resolution of 16 bit or better. These devices run at a high power level and constitute a "hot spot" on the chip, which can degrade the performance of nearby pixels. All signals from the individual pixels to the output amplifier or ADC are analog signals, so very careful routing is required so that they are not subject to interference.

Our new readout architecture (Fig. 1) takes advantage of the silicon real estate under the sensing elements to implement the ADC function, using a massive array of simple and slow ADCs instead of one fast and power-hungry one. This not only eliminates the hot spot, it also uses robust digital signaling to move the image data out of the array. As it is unfeasible to have one ADC for each pixel, adjacent pixels are combined into clusters of pixels sharing one ADC. During the frame period the pixels are converted sequentially, and the results are serially shifted out through the cluster columns. One row of cluster data at a time arrives at the edge of the array, where it is multiplexed into a single output stream.

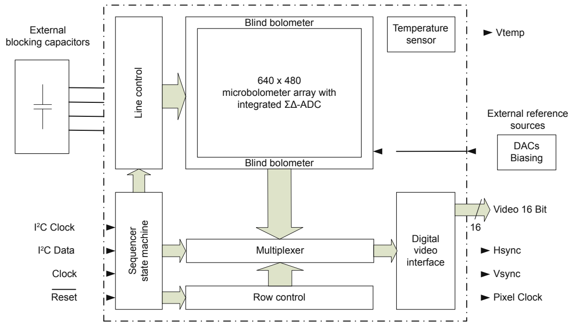

Fig. 1: Block Diagram of IR Sensor Chip

For low circuit area and robustness, the ADCs were implemented as ∑-Δ ADC converters, consisting of a second-order analog ∑-Δ Modulator and a digital decimation filter using a three-stage sinc filter with a programmable filter order. With a small ADC footprint the size of the pixel clusters can be kept small. This has two beneficial results: the time

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available for each pixel increases, improving noise reduction due to the longer integration time. In addition, given a fixed oversampling ratio of the ∑-Δ ADC converters, the speed of the analog and digital circuit can be reduced. Therefore the filter algorithm was optimized, yielding a structure consisting of three cascaded integrators followed by rate decimation and a 3rd-order differentiator. This structure has an added benefit in that the filter order can be made programmable by changing the timing of the rate decimation stage. Register word length were minimized by considering the maximum possible result sizes and by using modulus arithmetic. As all ADC converters in the array are working in lockstep, all control signals and clocks are generated centrally outside the array, and are distributed to the converters via drivers distributed along the edge of the array. Thus only the datapath elements of the filter need to be located in the array.

An analysis of the area and power consumption of the data path shows that the former can be reduced by using serial arithmetic, at the expense of an increased power consumption and data clock rate. A fully parallel implementation would require more than 4 times the area of a bit-serial one, but its power consumption is slightly below 1/3 of the bit serial solution. We decided to optimize the area-power product of the circuit, which resulted in using 4-bit serial arithmetic. The power consumption now is about 50% above that of the fully parallel case, and the area just 30% above the bit-serial implementation area.

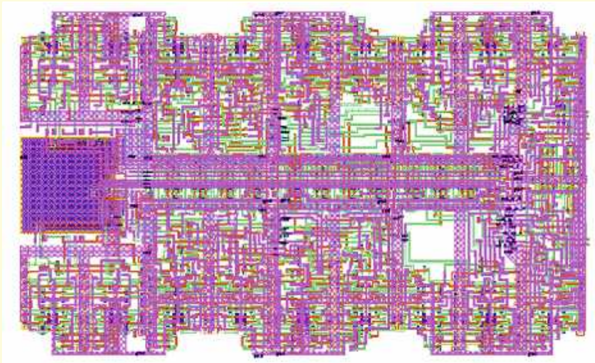

Fig. 2: Full-Custom Layout of the Sinc Filter Datapath. Vertical control and power tracks in metal 3 and 4 layers are not shown.

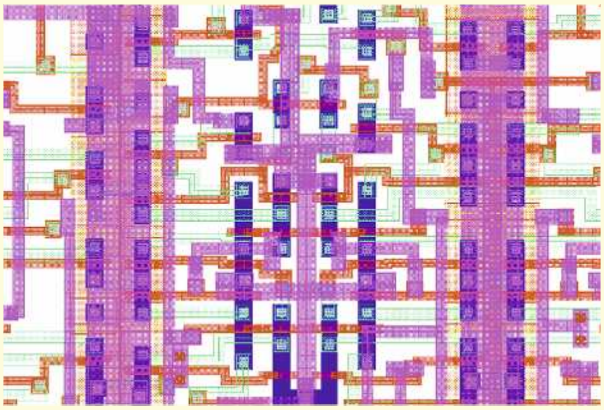

Fig. 3: Zoomed View of Sinc Filter Datapath. Note the use of polysilicon as routing layer in addition to metal 1 and 2 layers.

In order to reduce the area even further, the digital filter was implemented using a full-custom digital design (Figs. 2 and 3). This resulted in dramatic area reduction: while a standard cell layout used about 90000 µm², the full custom version only needs slightly less then 13000 µm². As registers were implemented with dynamic latches and multiplexers with transmission gates, both using only NMOS pass transistors, the logic high level of all control and clock signals was set one NMOS threshold voltage higher than the supply voltage of the digital filter. The use of dynamic latches and switch logic also has the additional benefit of reducing the power dissipation within the array. This is not only due to the reduced supply voltage, but also due the reduced capacitive loads these elements present, compared with equivalent circuits implemented as fully complementary CMOS logic.

Testing such an array may seem to be a difficult task at first sight, but by exploiting the structure of the filter circuit it was quite simple to integrate powerful test support with very little overhead. As the data registers are organized as segmented serial registers, the implementation of a full scan path actually is straightforward and has very little overhead. Most of the circuitry needed is also used for the serial reset scheme that initializes the filter before the start of a new conversion, so that only 12 NMOS transistors are needed to implement 4 parallel scan chains in each filter. The scan chains of the clusters in column are connected in series, so that scan data enters the array on the top and leaves on the bottom. The 4 parallel scan chains in each column can be selected for test, or operated in parallel with the same set of input data. In the latter case, comparators in the row multiplexer block can compare the output of 4 reference scan chains with the scan chain outputs of the other columns. The combined output of the comparators is available, together wit the reference scan chain data, at the device pins. This scan test/BIST combination reduces scan test time by almost two orders of magnitude. In addition, a true BIST mode was implemented for a functional/at-speed test of the filters. In this mode, a programmable digital ∑-Δ modulator in the state-machine block supplies all filters with a ∑-Δ data stream, replacing the data from the analog modulators. As all filters run in lockstep, all results must be the same. Like "real" results they are shifted out to the row multiplexer, from which they are transported to the device pins for testing. Alternately, they can be compared like scan test results, providing a means of in-system test.

Implementing the digital filter of the ∑-Δ ADC as a highly optimized full-custom layout allowed us to integrate several thousand ADCs on a single chip. It reduced power requirements by almost an order of magnitude, making self-heating of the chip negligible. Leveraging the power of full-custom design comes at a cost: the design time for the filter function, less than a week for an HDL-based standard cell design, was close to 10 weeks for the full custom design. A very careful assessment must be made before committing to a full-custom design, as it has severe impact on design time and cost. In our case, it was simply indispensable to meet the project goals.

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»SMARTFOREST – APPLICATION OF TRANSPONDER TECHNOLOGY AND WIRELESS SENSOR NETWORKS IN FORESTRY«

H.-C. Müller

The subject of the cooperative project »SmartForest« funded by the Bundesanstalt für Landwirtschaft und Ernährung (BLE) is the application of transponder technologies and wireless sensor networks with the objective of contributing to the efficiency of silvicultural processes. The project focuses on two aspects: the concept development and application of long-lasting tree labelling tool and the development and implementation of wireless sensor networks for long-term forest monitoring at high spatial and temporal resolution. The cooperation partners are the Leinemann und Hosius GbR (ISOGEN), the MUL Services GmbH and the Nordwestdeutsche Forstliche Versuchsanstalt (NW-FVA).

Tree labelling with RFID

A wide variety of labelling options is available for immediate identification like colour marking and labels made of metal, plastic or paper. Over time, however, many of them may have been removed, damaged or destroyed due to weather, growth or vandalism. To solve this problem, the ideal solution would be to hide the identification marker in a place where time and environment will have minimal effect on system robustness. The solution pursued in the project is to embed RFID tags at the trees and retrieve the identification numbers via a tree-penetrating RF signal. A battery is not present within the RFID tag; instead, energy is received wirelessly from an antenna connected to a handheld reader. Remote and on-demand power transfer allows the tags to remain hidden behind the tree's bark indefinitely, a considerable advantage toward maintaining longevity and reliability for this type of identification marker.

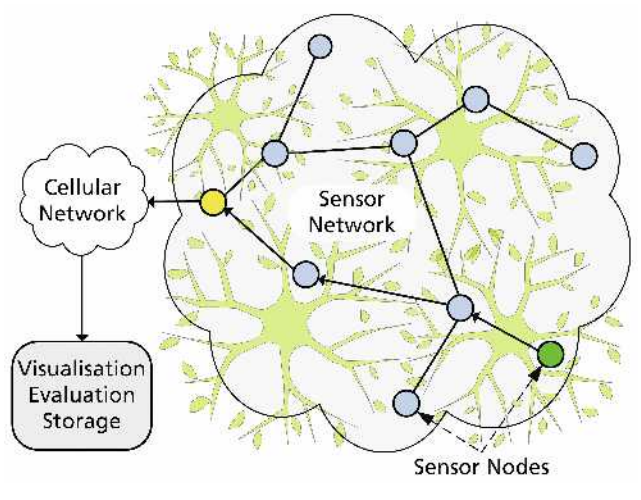
Tree labelling at this level carries with it some unique application requirements including the need for a relatively long range (more than 50 cm) and small tag sizes coupled with durability to large variations in wood, moisture, and biochemical content in the path between the RFID tag and the reading device. Furthermore, economical aspects are of some importance not only in terms of RFID tags but also in terms of the processes involved.

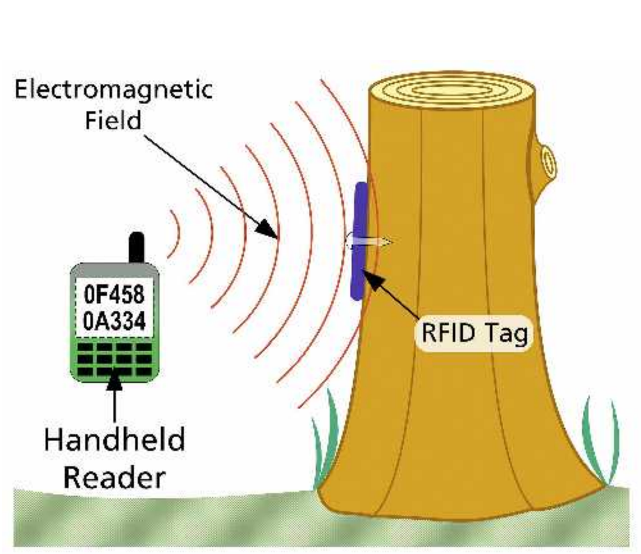
With respect to the aforementioned requirements project work has focused on the choice of components (i.e. RFID tags, reader, etc.) and the development of dedicated software components (i.e. reader application, system architecture). This work has been carried out by the project partner MUL Services GmbH. As a matter of course extensive field tests have been performed by the NW-FVA and ISOGEN in order to validate the concepts developed and to investigate the interaction of entities of interest. For that purpose around six hundred RFID tags have been attached to seven forest species in various forestry districts.

The results of the field tests showed among others that the amount of time for the installation of RFID tags corresponds to the amount of time needed for traditional methods like colour marking. Furthermore, it turned out that the robustness of the selected devices do meet the requirements and constraints. As a matter of fact, it is impossible to draw final conclusions regarding the long-term readability and durability (in terms of tens of years). However, process improvements are achieved at this stage of development by implementing a seamless flow of information.

Wireless sensor networks for long-term monitoring

Wireless sensor networks provide the ability to measure and record information about the natural environment at high spatial and temporal resolution such as, for instance, long-term monitoring of dynamic phenomena like soil water content, air temperature, air humidity or leaf humidity in small forest areas. Although the supporting communication technologies for low cost, low power wireless networks wireless sensor networks have been greatly improved in the past decade, there are still some research and design aspects remaining, in order to ensure a long-term unattended operation of a sensor network. Furthermore, in forest areas energy harvesters are suitable in a restricted manner only. Hence, the main objective of this particular project has been to improve the operation time of battery powered sensor nodes.





Various components affect energy consumption of sensor nodes (e.g. electronic components, protocol stack and application software). Whereas off-the-shelf electronic components have been used, development efforts have been focused on adjusting software components in terms of minimizing in network communication. In a sensor network, sensor nodes communicate with each other through short-range radios at least with those nodes being in the radio range. In monitoring applications, all sensor nodes are sources, sense environment and transmit sensed data to the sink periodically. In addition to sensed data, each node must transmit other node's data to the sink.

In network communication is mainly affected by the protocol stack providing connectivity within the network. A dedicated protocol stack, enhanced in this project and based on IEEE802.15.4, ensures connectivity and coverage with respect to the reliability of transmission while allowing the sensor nodes to operate in an energy efficient manner (i.e. low duty cycle).

Field tests have been carried out at the Göttinger Wald site in co-operation with the NW-FVA to evaluate aspects of lifetime and reliability in a silvicultural environment. Sensor nodes have been deployed in the test area equipped with sensors to measure soil moisture, air temperature, air humidity and leaf humidity. In order to monitor actual network status, beside sensed data additional data have been transmitted representing network topology, number of transmissions or battery health.

The sensor nodes were powered by low-cost alkaline batteries. Their service life is decreased as they are discharged at low temperature, like in the period from December 2009 to March 2010 at the test area. The sensor network has performed flawlessly even under these environmental conditions.

Conclusion

The results from this cooperative project show that the utilisation of electronic components in forestry provides the opportunity to improve processes involved in terms of information retrieval and information management. RFID-based tree labelling enables long-term data access as compared to traditional methods which is of some relevance in terms of forest genetic resources. An adapted wireless sensor network technology allows long-term monitoring of phenomena like soil moisture, along with high spatial and temporal resolution while operating unattended.

A DATA TRANSMISSION TECHNIQUE FOR PASSIVE SENSOR-TRANSPONDERS IN MEDICINE

A. Hennig, G. vom Bögel, A. Grabmaier

Abstract

The use of sensor-transponder technologies particularly in medical applications opens valuable possibilities in therapy of human cardiovascular system diseases, e.g. cardiac insufficiency. The application presented here is representative for future applications, where the use of miniaturized passively-powered sensor-transponder systems with high read range is relevant. In the past, loadmodulation was developed as a simple technique to transmit data from low-cost ID-transponders to a reader. This technique can be considered as suboptimal for the given challenges in the presented medical and other possible high-demanding applications. Higher read ranges and small antenna dimensions are necessary. In consequence new techniques, especially for data transmission, have to be developed. First of all, the limitations of the load-modulation technique are analyzed. Conventional solutions are then discussed. It is shown that existing solutions could not be used for this specific and future applications. A new data transmission technique called "frequency conversion" is presented. This technique allows data transmission over a greater distance. Measurements in a practical implementation verifiy the performance of this technique.

I. INTRODUCTION

Medical studies have shown that the treatment of cardiovascular diseases could be significantly improved by a continuous monitoring of physical parameters, deep inside the human body, including blood pressure and temperature. Due to the impossibility of a local battery as power supply, the use of so-called passive transponder systems is of special interest. In the past several RFID-transponders with attached sensors have been developed [1][2][3]. These transponders work with state of the art transmission techniques, such as load-modulation.

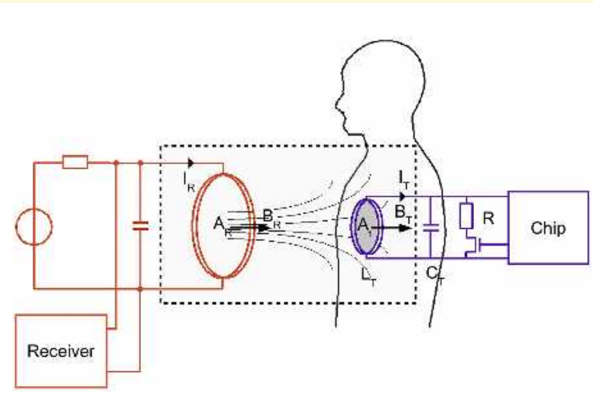


Fig. 1. Sensor transponder system for medical applications

It will be shown that the presented and future applications are not feasible with these transponder systems. Figure 1 shows a sensor-transponder system for medical applications. The reader is located outside of the body. It emits a magnetic field to provide power to the transponder. In state of the art transponder systems, load-modulation is used to transmit data from the transponder to the reader. Thereby a switchable resistor R is connected as a load to the resonant circuit L_T and C_T. In consequence, the idle current and further the magnetic field strength at the transponder can be changed. This change can be detected at the reader antenna by a receiver. In practice this change is relatively low compared to the field of the reader and noise.

In the presented application the transponder's dimensions should allow catheter-implantation. Consequently, antennas with the shape of a stick and only a few millimeters in size are required. Transponders with additional sensors consume significantly more energy than simple ID-transponders. The maximum possible distance between the reader and the implanted transponder has to be considered, e.g. to make such a system suitable for corpulent patients. Data transmission has to be possible over the required distance and with the necessary data rate. To make a medical diagnosis reliable, the transmission has to contain information about the pressure progression of heart beats.

In transponder systems the so called energy range and data range can be distinguished. The energy range characterizes the maximum distance, where the transponder can be provided with enough energy to work. Whereas the read range characterizes the maximum distance, where the reader could receive the transponders data signal. Usually simple ID-transponder systems feature the disadvantage of a much smaller read range than the energy range. Nevertheless for this and similar future applications, the energy supply and data transmission have to be possible over distances of 40 cm at least. Nowadays there are no systems that meet these requirements.

Preliminary studies [4] have shown, that a sensor-transponder and its corresponding antenna with the required size, can be provided with enough energy at a maximum distance of 40 cm. Thereby optimized antennas were used. In consideration of the human body and antenna loss effects, a frequency was found where the best results could be achieved. The data transmission has to be realized under these conditions. In the next sections the limitations of conventional techniques will be discussed. It will be shown that with the given conditions, data transmission is not possible with existing techniques. This paper discloses a new transmission technique, that makes a data transmission possible at the required distance.

II. PROBLEM INVESTIGATION

The read range is limited by several factors: the magnetic coupling between the antennas is very low. This causes a small signal strength at the reader antenna. Hence, the sensitivity of the receiver limits the read range. Furthermore the voltage amplitude caused by the generator at the reader antenna is relatively high compared to the transponder signal. This makes signal processing difficult. Noise of the power amplifier is also much higher than the transponder signal. If the SNR (Signal to noise ratio) drops below a minimum, a decoding of the transponder signal is not possible. Moreover man-made noise and antenna movements disturb the data transmission as well. Detailed considerations will be given in the next sections.

A. Transfer function

The transfer function is needed to analyze the transmission channel. From it the expectable signal strength and channel characteristics can be obtained. In order to derive the transfer function the equivalent circuit shown in figure 2 is used. The variation of the voltage over the resonant circuit caused by the modulation resistor R can be modelled by a voltage source V_T. The transmission channel itself is represented by a transformer equivalent circuit. Losses are represented by R_R and R_T. The generator is represented by its inner resistance RG. The transfer function $\frac{V_C}{V_T}$ can be obtained by solving the Kirchhoff's mesh-law. The result is a first order band-pass function. The transfer function can be derived using the parameters determined in [4]. The parameters are $L_R = 409\,nH$, $R_R = 9.8\,m\Omega$, $C = 1{:}1\ nF$, $R_T = 2.4\ \Omega$. The result is shown in figure 3.

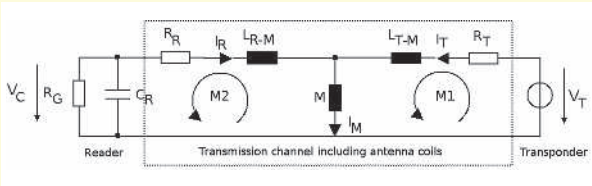


Fig. 2. Equivalent circuit of the load-modulation transmission channel

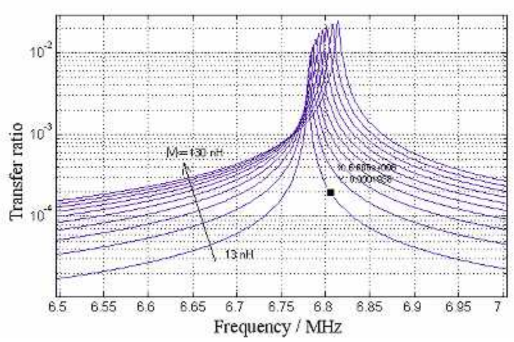


Fig. 3. Evaluation of the transfer function

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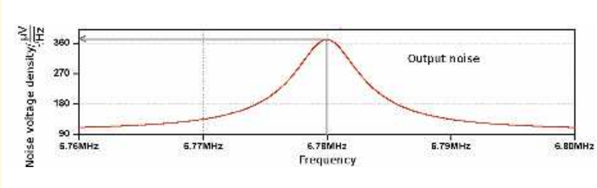

Fig. 4. Equivalent circuit used for simulation

By switching the load resistor R, an amplitude shift keying modulation is produced. In the frequency domain, upperand lower-sidebands appear. The generator signal, transmitted from the reader to the transponder, acts as a carrier for data transmission in the opposite direction. A 13 kBit/s manchester coded signal has baseband frequency components at 26 kHz. At the corresponding sideband frequencies, the transfer ratio is about $196 \cdot 10^{-6}$. In case of a modulation voltage of 1 V at the transponder side about 200 μV is reached at the reader antenna. In comparison to the sensitivity of common receivers that is about 1 μV, this value is high enough. Therefore, the sensitivity is no limitation here.

B. Noise Sources

Several noise sources exist in a transponder system. The transponder signal is disturbed by noise-voltages and -currents. The noise sources are in the frequency generator, the power amplifier, the antenna and in the receiver.

The power amplifier adds additional noise. This noise consists of shot noise caused by pn-junctions and Johnson-noise caused by resistors. Thereby the mean square voltage at the receiver is of interest. The mean square voltage produced by a conventional power amplifier (noise figure 16 dB) was measured as 2.3 mV. The gain of the parallel resonant antenna circuit causes an amplification of the noise near to the resonant frequency. The spectral noise density V_{SO} is composed of voltage and current noise densities. Thereby the noise voltage of the source is multiplied with the system gain.

With the help of a spice simulation, the mean square noise voltage can be estimated. The result is shown in figure 4. A spectral shaping of the white noise input can be seen. The noise density is maximal near to the generator frequency. The mean square noise voltage can by obtained by integrating the noise density over the receivers frequency area. With a bandwidth of 100 kHz, which is necessary for a 13 kBit/s manchester coded signal, a mean square noise voltage of 115 mV is reached. This value is several orders of magnitude higher than the transponder signal voltage, which is about 200 μV.

The noise of the antenna is only caused by the real part of the impedance and could be estimated by the following formula [7]:

$$E_{Ant} = \sqrt{4kTR\Delta f} \simeq 2\frac{nV}{\sqrt{Hz}}$$

with k = Bolzmann constant, T = absolute temperature and R_{Ant} = real part of antenna impedance. With a receiver bandwidth of 100 kHz an effective noise voltage of 630 nV is reached.

It could be said, that the power amplifier is the dominating noise source in the system and determines the SNR.

C. Distortion

Beside the unwanted noise, there are other disturbances that complicate the decoding of the transponder signal. A detuning of the reader antenna causes a displacement of the transfer function in the frequency domain. This detuning could be caused by changing the distance between the antennas. As can be seen in figure 3 the transfer function is shifted to higher frequencies in presence of a higher mutual inductance. Since the demodulation is done synchronous to the generator signal, the shift appears also in the baseband. In consequence the baseband transfer function is no longer a first order low pass. The transponder signal is distorted. This effect is noticeable by a overlaid oscillation of the transponder signal. The beat frequency correlates to the detuning.

If the transponder is implanted near to the heart, it will move in rhythm with the heart beat. The mutual inductance between the coils depends on the orientation of the coils to each other. Because of that, the voltage damping over the reader antenna will vary as well. This variation is appreciable in the basebandsignal as a beat.

D. Signal to Noise Ratio

The SNR is a measure that describes the quality of the signal. If conventional load-modulation is used, and considering a 40 cm distance, the SNR can be calculated as follows:

$$S\,N\,R = 10\ log\,\frac{V_{eff}}{V_{noise}} = 10\ log\,\frac{(141\ \mu V)^2}{(115\ mV)^2} = -\ 58.2\ dB$$

Thereby a manchester coded signal with 13 kBit/s is assumed. Usually a SNR of about +10 dB is needed to get an acceptable BER (bit error rate). Data transmission with conventional load-modulation is not possible here.

E. Limitations to Load-Modulation

Conventional load-modulation has several disadvantages that lead to a reduction of the read range. As described in the previous chapter, the SNR is too low for a data transmission at the required distance. The sideband signal produced by loadmodulation has a spectral distance to the carrier signal equal to the data rate. As can be seen in figure 4 the spectral noise power increases in the proximity of the carrier signal. The small spectral distance of some kilohertz also makes filtering impossible. Amplitude variation of the carrier signal, caused by detuning or antenna movements, superposes the data signal irreversibly and increases decoding complexity. Moreover load-modulation wastes energy in the transponder. During the modulation phase the modulation resistor R is connected to the resonant circuit. The energy that is stored inside the resonant circuit is transformed to heat and can not be used anymore. Better results could be achieved, if the spectral distance between the readers signal and the data signal could be enlarged.

III. NOVEL APPROACH

In the preceding section it was shown, that no existing data transmission technique complies with the requirements. Hence, a new transmission technique has to be found. An essential improvement could be done, if a transmission signal with an own freely selectable carrier frequency could be generated, and not affected by the envelope function of the transponder resonant circuit. Hence a frequency could be chosen were the spectral noise density of the power amplifier is low. Moreover, with a higher spectral distance to the carrier, filtering could easily be used to suppress the unwanted carrier. Furthermore it would be an advantage, if no additional energy were necessary to generate the transmission signal.

A. Frequency Conversion

The solution is a technique, from now on refered as frequency conversion. During the modulation phase at load-modulation technique, energy stored in the resonant circuit of the transponder is converted into heat by the modulation resistor. The proposed frequency conversion technique in contrast, uses this energy to generate a transmission signal at a separate frequency instead. Figure 5 illustrates this technique. A sensor-transponder system designed according to this technique is shown. With the help of a separated antenna a field is generated (e.g. 13.56 MHz). This field is used to transmit energy to the transponder. This energy is stored in the resonant circuit of the transponder until the voltage amplitude over the resonant circuit has reached its maximum, thereafter no active power is needed anymore. Only a small part of the whole power is used to supply the transponder circuits. A special circuit enables the antenna to oszillate at another frequency. Consequently, a field with a separate frequency is generated. A field frequency of 10.7 MHz, where good filters are available, or an ISM-Band

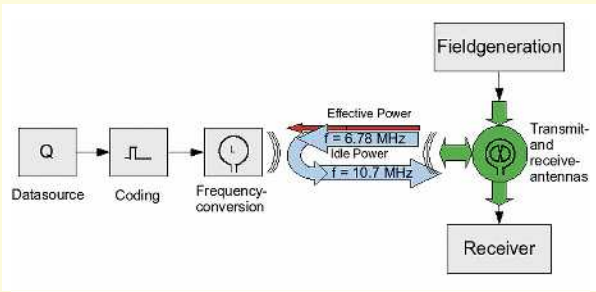

Fig. 5. Transponder system with frequency conversion

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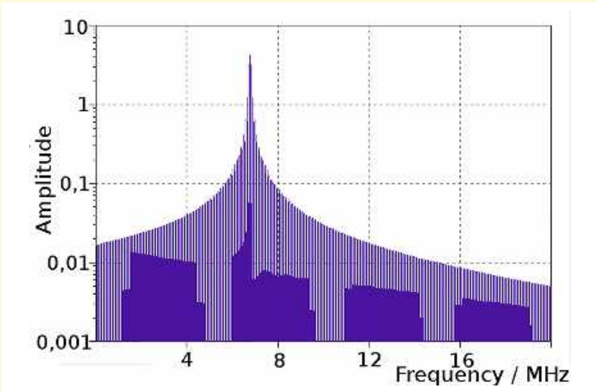

Fig. 6. Spectrum of antenna voltage using load-modulation

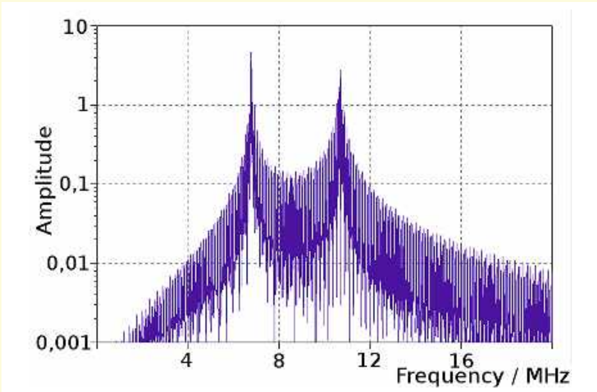

Fig. 7. Spectrum using frequency conversion

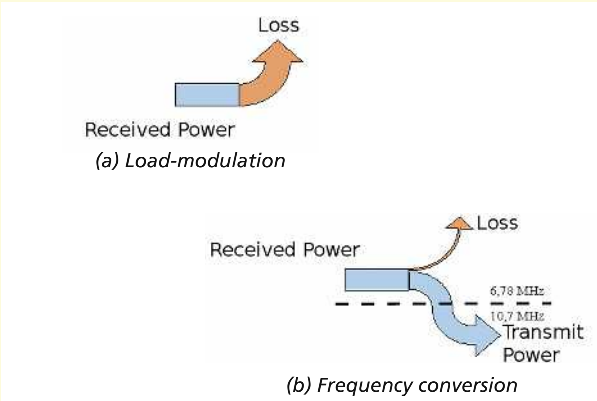

Fig. 8. Simplified energy balance

frequency could be chosen. The amount of energy transfered to the second frequency can be adapted to the requirements of data rate and energy consumption. The generated data signal could be received by a separated antenna, tuned to the corresponding frequency at the reader, by a gradient antenna [10], or by a novel antenna design developed for that purpose.

B. Comparison to Load-Modulation

By comparing with the load-modulation technique, the advantages of the new approach will become clear. For that purpose load-modulation and frequency conversion were tested under the same conditions.

Figure 6 shows the voltage over the transponder resonant circuit using load-modulation in frequency domain. The loadmodulation implicates upper- and lower-sidebands in the spectrum. These sidebands are symmetrical around the carrier frequency generated by the reader, as shown in figure 6. At the reader side, the sidebands are under the noise floor.

The generated signal in frequency domain using frequncy conversion is plotted in figure 7. A signal with an own carrier frequency of 10.7 MHz is generated.

C. Energy Balance

For energetic aspects two factors need to be considered: the generation efficiency of transmission signal as well as negative impact in the energy supply of the transponder chip. In frequency conversion the received energy is directly used in the antenna resonant circuit to generate a transmission signal. Hence, no energy is lost in rectifiers, amplifiers or any energy storage as happens in conventional techniques (cp. 8 (b)). Therefore this technique is very efficient as illustrated in figure 8.

D. Reachable Performance

Now the reachable performance is of interest in order to make a comparison to other possible solutions. With the help of the energy stored in the resonant circuit and the channel transfer function, the voltage at the receiver can be calculated. Between the transponder antenna and a receiver antenna there is a transfer ratio of about $3 \cdot 10^{-3}$, assuming an antenna tuned to

10.7 MHz. The mean square value at the receiver is 2063 μV. The mean square noise voltage can be calculated by integrating the spectral noise density from the spice simulation in figure 4. With a receiver input bandwidth of 300 kHz, which is necessary for such a signal, a mean square noise voltage of 1500 μV is reached.
The SNR can be calculated:

$$SNR = 10 \log \frac{(2063\ \mu V)^2}{(1500\ \mu V)^2} = +2{,}77\ dB$$

A value of 2.77 dB corresponds to an improvement of 60.97 dB compared to load-modulation technique (–58.2 dB). Together with a matched-filter a ratio of about **+17.77 dB** is possible. This value is over the minimum of +10 dB and leads consequently to an acceptable BER.

IV. EXPERIMENTAL EXAMINATION

An experimental measurement shall show, that frequency conversion techniques enables data transmission from a deeply implanted sensor-transponder. To create a substitute that simulates the electric properties of the human body, a phantom substance was prepared. A test transponder was realized with an analogue frontend working with frequency conversion.
In the reader a software defined radio shown in figure 9 was used to receive the transponder signal. The receiver consists of an analogue band-pass filter, an ADC, a mixer and a matched-filter. The main goal of the experiment is to measure the achievable SNR after the mixer over the distance.
In the next section the achievable SNR will be measured.

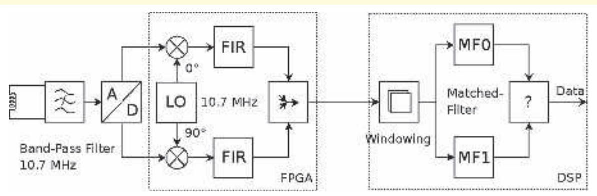

Fig. 9. Software defined radio

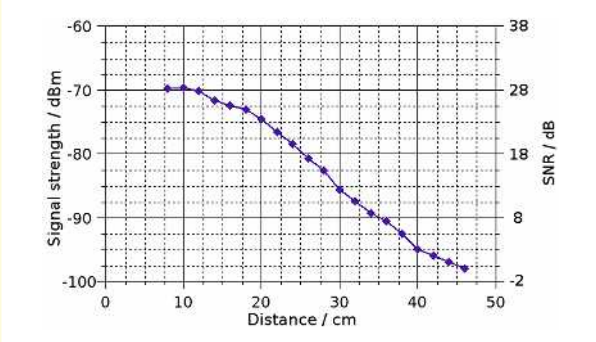

Fig. 10. Measurement result of achievable signal strength and SNR

A. Reading Range

To evaluate the new technique, the achievable signal strength at the receiver and corresponding SNRs were measured. The distance between the reader and the transponder was variated between 8 cm and 46 cm. Figure 10 shows the measurement results: as mentioned before, a minimum SNR of +10 dB is necessary to get an acceptable BER. Considering a matched-filter with 15 dB signal to noise improvement, a SNR of -5 dB at the input of the receiver is required. The measured SNR is higher in up to 45 cm distance. The energy range is about 40 cm. Therefore, the maximum possible read range is reached.

V. CONCLUSION

Data transmission for deeply implanted sensor-transponders has been analyzed. It was shown, that data transmission over the required distance is not possible with conventional solutions. A new data transmission technique called "frequency conversion" that makes a maximum read range possible, was presented. A practical implementation and measurements have verified the feasibility of this technique.

A DATA TRANSMISSION TECHNIQUE FOR PASSIVE SENSOR-TRANSPONDERS IN MEDICINE

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CRASH SENSOR SYSTEMS FOR HIGH-BAY-RACKS

F. Meyer, J. Breer, K. Grundmann

1 Introduction

Nowadays our markets are full of goods from every corner of the world. Not only has the shipment of these goods increased over the last years, but storing them has also become a more and more challenging necessity. Furthermore, every larger company needs warehouses to store raw materials and components during the manufacturing process of their final products.

The main part of a warehouse consists of many high-bay racks. Between these racks, forklifts move through narrow aisles at high speeds, storing and retrieving the goods. Every shelf is supported by pillars. If any of these upright posts get damaged, e.g. by a crash with a forklift, the whole shelf is destabilized and may collapse. This is not only a safety risk for the workers, but may also lead to financial losses as a company relies on the immediate availability of its stored goods.

During the last years, a standard has been developed to minimize the risk of such collapsing high-bay racking. However, the damage control still has to be performed manually. Usually, an inspection of all shelves has to be done once a week. In a worst case scenario, a critical crash can occur directly after the inspection without being reported for an entire week. Therefore, a fully automated system which detects crashes with rack pillars can improve safety, avoid accidents and remove the human factor from the pillar check.

2 Hardware demands

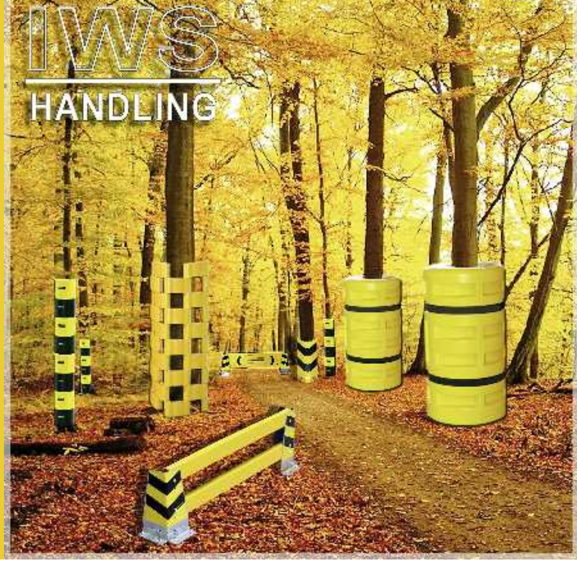
A monitoring system for high bay racking requires the use of electronic devices at every column of the shelves. A normal warehouse has racks with up to several thousand pillars, which have to be monitored individually with respect to external shocks. Every pillar is protected by a special elastic bumper that mitigates damage caused by crashes with forklifts or other vehicles.

Within the bumper, a wireless electronic device monitors the pressure and sends a radio signal when a pressure change occurs. Depending on the pressure difference, an incident is categorized from a light impact with no harm for the shelves to a harsh impact requiring immediate action by the warehouse staff. To guarantee a high operating time between battery changes, such a device needs to be highly energy efficient.

Figure 1: Handheld Unit for configuring the radio nodes

When a pressure difference is detected, the device emits a radio signal that is received by a repeater unit. The repeater manages up to 100 sensor nodes and makes sure radio messages are passed to a main control unit. If the repeater is located too far away from the control unit, messages are routed through repeaters located closer to the main unit.

CRASH SENSOR SYSTEMS FOR HIGH-BAY-RACKS



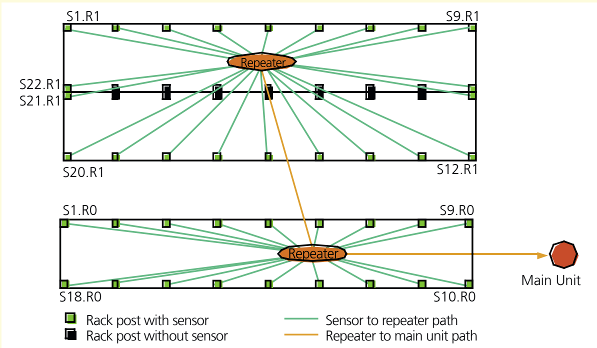


Figure 2 Simple example network

The main unit receives every crash incident within the warehouse and visualizes the collected data on its display. All data is transmitted using the UHF ISM frequency band. This band is free to use without licensing costs and limited only in the maximum channel power and channel bandwidth.

The main unit is also used for short-range configuration of the radio nodes when bringing the system to service. Therefore, a low frequency wake-up impulse is sent to activate any node within a range of approximately 50 cm.

3 Software demands

The system can be described as a large network of radio nodes sharing a frequency band with limited range and bandwidth. Additionally, this network needs to be highly energy efficient so that long operating times between battery changes can be realized. Therefore, a customized protocol is designed to fulfil these requirements and make sure no critical impact is missed and the warehouse manager is informed within seconds after a crash event.

To realize the goal of energy efficiency, the system uses static routing. This means the routes from the radio nodes at the rack posts to the handheld unit located in the warehouse manager's office are planned before bringing the system to service. Planning the network means assigning up to 100 sensor nodes to a repeater. The repeater itself is either assigned to a repeater located closer to the main control unit or to the main control unit directly.

Figure 3: Notification of Crash

Every crash incident is sent from the radio node at the rack post to the assigned repeater via a bidirectional protocol, i.e. the receiving unit acknowledges the received data to the sender. If there is no acknowledgement from the receiver, the data is resent until it has reached its destination.

Once per day, every sensor node sends a lifesign message containing the current battery voltage. These lifesigns are used to detect malfunction and low battery power. If the system detects a need for maintenance, alarm messages are displayed at the main unit.

Figure 4: Simulation of Crash Events in the early development phase

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4 System performance and conclusion

The system itself has to be reliable due to its safety functions. Therefore different states of the sensor nodes need to be detected by the system, e.g. low battery state of a radio node, repeater malfunctions or radio nodes which cannot send a lifesign or crash events to a repeater.

Several measures are implemented to avoid those critical states. The current battery voltage of all radio nodes is monitored in certain time intervals and the warehouse staff is informed in case of a low battery state.

Furthermore, all communication paths among the repeaters are checked in short time intervals and errors are detected swiftly. If an interruption of the predefined routing path occurs (e.g. because of a power failure), the repeaters store the radio messages received from the sensors and re-send them as soon as correct operation is restored. This minimizes the risk of data loss.

The safety of high-bay racks is improved by using sensor nodes within special bumpers. Critical impacts are reported in seconds and the warehouse staff is warned. Not only the safety risks are minimized, but also any person or company responsible for the crash can be tracked due to a fast system response.

This project was founded by "Arbeitsgemeinschaft industrieller Forschungsvereinigungen »Otto von Guericke« e.V.".

MEDINA – TELEMEDICINE REHABILITATION SUPPORT IN ONE'S OWN FOUR WALLS

Modern health care through innovative use of technology and efficient information logistics

B. Heidemann, D. Dünnebacke, F. Schönherr, A. Amini

Abstract
People in Germany live longer than ever. The demographic change is no longer a future vision but rather pervasive in nowadays society. The attempt to extend the lifetime of individuals represents an enormous challenge for the health system. Caught in the dilemma of steadily rising costs and the continuing demand for a best possible health care, new ways of providing health services are essential. The MeDiNa project addresses this problem and develops both technical and organizational solutions for home-care of cardiac patients. The aim is to allow a periodically monitoring of health status of people in their own home and thus to detect recidivisms at an early stage and to initiate appropriate countermeasures. As a result, there are benefits for both the patient and the health system.

Introduction
The desire of having a long and fulfilling life is everyone's wish. Everyone will already have felt at least once the demand to get well and to regain the usual productivity as soon as possible. As with many other health problems, also in the case of cardiac diseases, this demand is met by the offer of a multi-week stay in a rehabilitation clinic. However, the duration of this stays decreases for years. For example, the average stay for all types of rehabilitation in NRW was 32.4 days in 1990 and 27.7 days in 2007 [1]. The length of stay for cardiac rehabilitation was actually of only 21.9 days [1]. Despite the improved treatment methods and modern clinical devices, a complete recovery of patients in this short time is not always possible. Rather, patients are released earlier to the ambulant sector. As a consequence, the usually elderly patients continue rehabilitation in their own home without being periodically monitored in short intervals by medical and nursing staff. This issue is addressed by the research project MeDiNa, promoted by the German Federal Ministry of Education and Research. (Mikrosystemtechnik für ganzheitliche telemedizinische Dienstleistungen in der häuslichen Nachsorge; grant number: 01FC08056).

Cardiovascular diseases cause of death no. 1 in Germany
Cardiovascular diseases are the leading causes of death in Germany and Europe. In 2007 a total number of 419 723 people died in Germany due to diseases of the circulatory system and heart attack [2]. In Europe, the statistic counts nearly 4.5 million deaths annually [3]. The estimation of medical authorities, that the number of new cases in the near future will continue to increase, is particularly disillusioning [3]. Therefore, the focus is on providing the best treatment of the occurring diseases. This depends on several factors: early diagnosis, rapid and efficient treatment and comprehensive rehabilitation. For the latter to continue effectively after the in-patient rehabilitation, with strong partners from industry and regional health service providers, the consortium of Fraunhofer Institut für Mikroelektronische Schaltungen und Systeme, Universitätsklinikum Aachen, MUL Services GmbH, Forschungsinstitut für Rationalisierung (FIR) e.V. an der RWTH Aachen, Institut für Arbeitswissenschaft (IAW) an der RWTH Aachen and Philips GmbH (Unternehmensbereich Healthcare) develops a holistic approach to microsystem technology supported home-care of rehabilitation patients (see Figure 1).

Lack of periodically monitoring after rehabilitation is a problem
After discharge from the rehabilitation clinic, regular visits and intensive contacts with medical staff are a thing of the past. This lack of periodically monitoring of patients, shortly after a cardiac disease, constitutes a big problem for the patients and the health system. Deterioration of the state of health will be recognized too late or not at all which may lead to complications and serious health damage. For example 80 % of the annually 300,000 new cases of heart attacks occur at home. Of these 80 %, 50 % remain unnoticed [4]. In addition

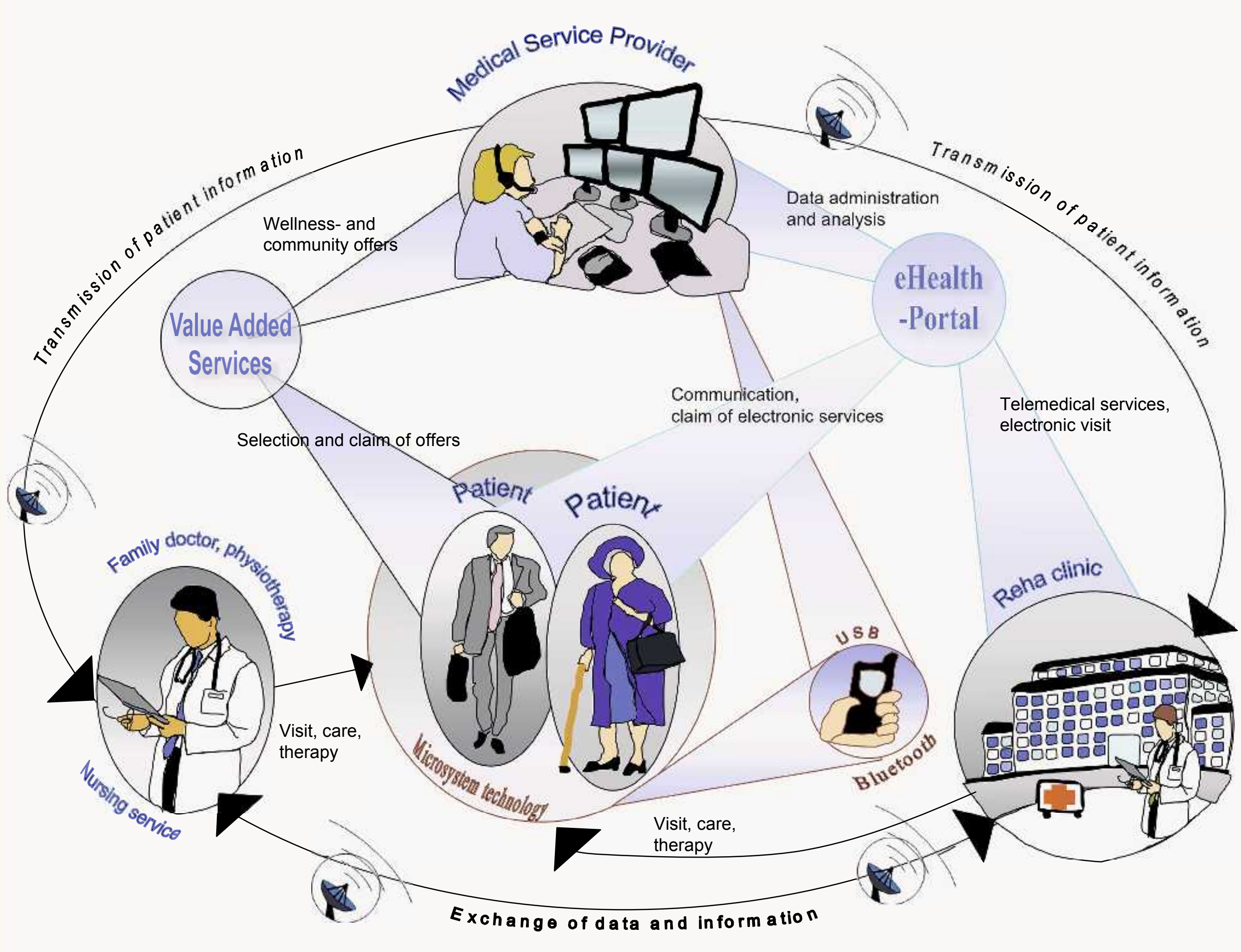

Figure 1: A holistic approach to micro- system technology supported aftercare

to the partly dramatic consequences for the patient, this fact has an enormous impact for the health system. Relapses in the in-patient treatment or complications come with the result of much more expensive medical treatments. In this way, heart diseases including frequent re-hospitalization, are the cause for expenses of nearly 170 billion € in the EU [3]. Many of these cases and consequently their expenses can be avoided by early diagnostics and be treated with lower impact for both, the patient and the health system.

Telemedicine solutions show new ways in health care

Recent telemedicine approaches offer, in association with modern sensors, possibilities to capture the necessary information of high risk patients in a quick and inexpensive manner, process it comprehensively and make it available centrally. Thereby the decoupling of the medical examination from the availability of medical personnel offers enormous potentials for health care. Thus, for example, the so-called tele-monitoring through a computerized monitoring system, checks the vital

MEDINA – TELEMEDICINE REHABILITATION SUPPORT IN ONE'S OWN FOUR WALLS

signs (pulse, blood pressure) which are sent immediately to a provider (medical practice, rehabilitation station) where the qualified personnel can intervene directly in case of irregularities. Most telemedicine applications tend nowadays to a faster, better and wider communication of patient data via electronic ways (tele-consultation). Although the technological basis for telemedicine services appears to be available, it lacks so far on the sustainable concepts of integration of the telemedicine in the first health care market. This shall be achieved with the MeDiNa's developed business model for the provider of such services (Medical Service Provider).

The aim of MeDiNa project is to make use of the telemedicine potential and to allow a simple and continuous monitoring of patient data by the rehabilitation experts (doctors, care attendants and therapists). Based on this data the experts will be enabled to readjust and reorganize therapies and to intervene earlier in cases of emergency. This is the basis for providing modern telemedical services (for example electronic visits) supporting the aftercare of cardiac patients. In order to test this approach in a prototype and to validate the usefulness by means of a patient study there are two technical components necessary which are beeing developed within the project (see Figure 2):

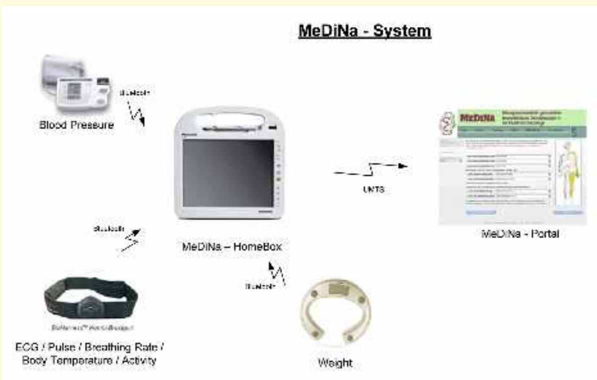

Figure 2: Interaction of the technical components

- **MeDiNa-HomeBox** for the acquisition of vital parameters of rehabilitation patients in their home environment

- **MeDiNa-Portal** for the conditioned presentation of vital parameters for doctors and for the ensuring of data security through a comprehensive rights and role model.

Innovative use of technology

The MeDiNa-HomeBox comprises of various wireless coupled sensors for the regular supervision and monitoring of vital parameters without a direct involvement of medical staff. For this purpose the patient will be fit with a MeDiNa-HomeBox for the domestic use. Besides the acquisition of basic medical data such as ECG, blood pressure, body temperature, weight and respiratory rate, specific measurements are added depending on disease and clinical history in order to reflect and track the situation of the patient. The goal is the intelligent integration of existing applications to a holistic service system. Due to the primarily elderly patients special emphasis is put on the usability of the system. This aspect is supported for example by using a touch-screen display. In addition the patient must remain extensively uninfluenced due to the use of the MeDiNa-HomeBox. By using microsystem technology, these requirements will be satisfied.

After the acquisition of the vital parameters, these data will be sent to the MeDiNa-Portal via UMTS and GPRS respectively. If no mobile connection could be established, the data exchange can be realized over a standard telephone line. The portal supports the commuinication between all parties involved (e.g. patient, hospital) and the coordination of the service contribution. For the implementation of the desired system solution, portals offer different suitable functions and technologies. As important basic functions can be mentioned among others: user management, authentification, searching, personalisation, role and right administration and data security.

Thus the parameters captured by the different sensors are evaluated in detail after the transmission to the portal and prepared adequately and structured for the targeted group and made available to authorized persons or institutions. Special aspects thereby are the unification of different user needs, an efficient supply of information and data between the different parties as well as high security and data protection against the background of handling sensitive personal data.

Efficient information logistics

The technical components MeDiNa Homebox and MeDiNa Portal form the basis for providing telemedicine services. In the center stands the so-called **M**edical **S**ervice **P**rovider (short: MSP). The focus off MSP's activities concentrates on ensuring an efficient information logistics, the correct information, at the right time, in the correct form and at the correct place. Concretely, this means that the data for the diagnosis, measured by the sensor system, unaltered by the transmission, prepared adequately for the addressee had to be delivered in real time to the physicians or nurses. The system also must permit a flow of information between the medical personnel and from the medical personnel to the patients. In summary the MSP must be able to arrange suitable systems and information services based on technology potentials and medical requirements. Apart from the primary and already outlined services, as collection of the vital parameters, monitoring and configuration of the state of health or the rehabilitation plan respectively as well as providing the underlying data and information management, value added services can be offered and used by the patients.

Examples are:

- Service for monitoring the medication: It can be recognized in time, if the patient must reorder his medicines or if the storage life of a medicine expires.
- Service for monitoring the fitness activity: Here the daily sportive activity under observation of the vital parameters could be reconstructed.
- Service for monitoring the diet: An intelligent calorie computer could compute the calories connected with the meal and make proposals for further meals.

Based on the integration of different technologies and the development of services for the Medical Service Provider, a holistic approach can be developed to the micro-system supported providing of services.

Result

For about 4 million cardiac risk patients in Germany the MeDiNa system offers an effortless, short interval control of relevant vital parameters in their domestic environment [4]. Even with longer treatment intervals, the continuous monitoring of vital parameters makes an exact controlling of the therapy possible, and contributes to the improvement of the compliance and disease condition of the heart patient. Thereby the patient's quality of life increases and the annual costs for the support can be reduced by reduction of hospitalizations, emergency treatments and physician visits[5]. Thus, for example, the telemedicine study "Herzensgut" of the insurance company "Kaufmännische Krankenkasse Hannover" pointed out that the utilisation of telemedicine equipment results in a cost reduction of around 20% (on the average about approximately 1,400 €)[6]. Fast and purposeful presentation of information about pre-existing conditions, examinations and therapies is a further result of the digital data acquisition and forwarding. Thus the project addresses two central problems. On the one hand, a better health welfare service for patients is made possible, and on the other hand, ways are pointed out, how the health economy can increase the treatment quality in the next years, despite foreseeable financial restrictions. An improvement for both sides.

MEDINA – TELEMEDICINE REHABILITATION SUPPORT IN ONE'S OWN FOUR WALLS

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HOSPITAL ENGINEERING

O. Lazar

Motivation and Brief Description

Hospitals in North Rhine-Westphalia will face considerable challenges in the years to come, particularly the conflicting objectives of improving both the cost situation and the quality of the performed efficiency. The aim is to remain or to become competitive and to be one of the Hospitals of the Future.

Here, the technical areas of hospitals are starting points for optimization, increase in efficiency and cost reduction. These areas include, for instance, hospital IT, energy supply or building services engineering and maintenance, as well as hospital logistics and facility management.

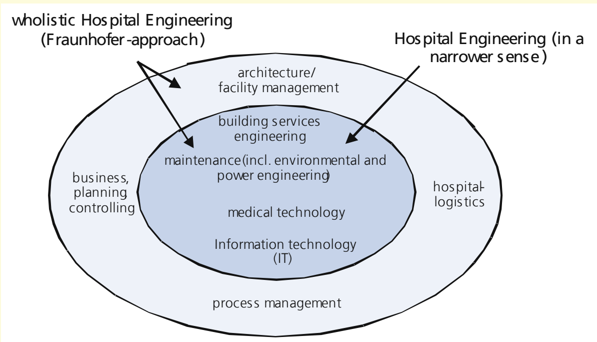


Figure 1: Hospital Engineering as a Wholistic Research Area

Innovation and optimization in those special areas usually result only in partial cost reduction and quality increase and disregard optimization in the overall technical system of a hospital. Optimization potential of an overall approach is, thus, given away, which may even result in conflicting goals by means of negative effects of measures in one area on other areas. Often, valid technical and performance figures of special areas to evaluate individual measures do not exist. Therefore, cross functional concepts and tools are entirely absent.

Hospital Engineering aims to close this gap. It hopes to benefit from an overall approach to the technical system of a hospital by researching current innovation and particularly its effects on adjacent areas, the development of best-practice solutions, the optimization of the overall system and the characterization with the help of significant key figures. Practical implementation eventually follows in so called "thematic projects". Thus, *Hospital Engineering* reaches far beyond classical approaches to hospital technology and provides a foundation for a competitive and technically sustainable hospital.

As part of the competition *Med in.NRW, Hospital Engineering* is a government-funded project by the state of North Rhine-Westphalia. A total of 235 contributions and up to 70 million Euro from EU-, state- and commune-funds, as well as from private partners account for *Med in.NRW* to be the grandest competition of the regional government as part of the *NRW-EU-Ziel2-Programms.* The ETN Forschungszentrum Jülich GmbH is in charge of the project.

Participation of Fraunhofer IMS in Hospital Engineering

Fraunhofer IMS designs and constructs a suitable and realistic laboratory for the required room systems at the Fraunhofer-inHaus-Center. The following rooms of a hospital will be constructed including all furnishing and technical infrastructure: reception and waiting area, nurses' room, patient's room including bathroom, treatment room, room for fitness and physiotherapy, operating area, storage and hallway.

Fraunhofer IMS is responsible for the project Staff- and Patient-Assistant. This project aims to enhance patient-autonomy with the help of assistant systems and to increase staff-assistance via sensor-supported acquisition of context data and system solutions. As part of this project, the focus is on the following:

Hygiene-related System Solution

The issue of hygiene becomes increasingly important in German hospitals. According to estimates by the Deutsche Gesellschaft für Krankenhaushygiene (DGKH, German Society for Hospital Hygiene) in 2009 40,000 fatalities were results of infections in hospitals. Particularly the increase of resistant germs (e.g. MRSA[1]) is of major importance. Fraunhofer IMS explores and develops solutions for the realization and documentation of hygiene processes with the help of sensor-supported devices for hand disinfection.

Software for Behavioral Analysis

By means of a software solution and the integration of sensors in the patient's room and the instruments and furniture inside, the patient's behavior and care is recorded. This aims to detect abnormal behavior or dangerous situations in time and to develop automatic care documentation. The overall concept includes the transmission of collected data to an existing emergency call system and to the KIS[2].

Mobile Ward Round/Care Assistant Vehicle

A constant access – independent from time and place – to KIS-data and other medical subsystems in the form of digital case files is indispensable for medical staff. Particularly during ward rounds, all data needs to be accessible at the patient's bed. Fraunhofer IMS explores and develops efficient solutions for data-display, -entry and -transmission in case of mobile ward rounds or care assistant vehicles.

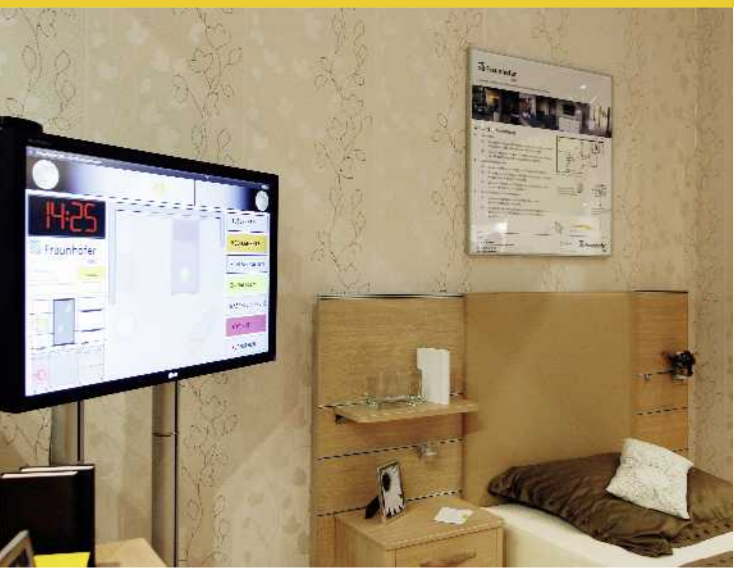
Fitness, Exercises of Precautionary Measures and Rehabilitation

Fraunhofer IMS explores and develops ways to integrate fitness machines into existing IT-systems and hospital-processes in the context of precautionary measures and rehabilitation. In particular, Fraunhofer IMS is engaged in the development of new intuitive control concepts and the networking of fitness machines and medical system solutions, for instance, to enable automatic transmission of performance data to the KIS, the family doctor or physical therapists. The other way around, a software solution is to be developed, which proposes a fitness program for the patient based on his or her current physical condition.

[1] *MRSA: methicillin-resistant Stapylococcus aureus*
[2] *KIS: Krankenhaus-Informationssystem (trans. Hospital Information System)*

JUTTA – CARE ACCORDING TO INDIVIDUAL NEEDS

T. Stevens



Demographic change in Germany results in higher life expectancy and in an increased number of people in need of assistance and care. Hereby, the need of care staff increases, while staff shortages in the field of professional care are already reality.

Furthermore, the lifestyle of the younger generation changes, so that the *classical* approach to care, that is to say care by adult children in the same household, is often no longer applicable. Given this development in combination with the demographic changes, it makes sense to make arrangements which allow the elderly to stay at home as long as possible. Besides, surveys reveal clearly that elderly Germans wish to live in a regular apartment or a service apartment.

As part of the project *JUTTA – Just in Time Assistance,* funded by the German Federal Ministry of Education and Research, Fraunhofer IMS, in cooperation with industrial partners and a nursing service in Duisburg, develops new methods of resolution and business models for care which meet the demand of people in need of assistance in the privacy of their home. This new model envisions care according to actual need of assistance instead of predetermined and fixed tours of care staff. This aims to preserve and enhance the individual competence of those in need of care to allow a predominantly self-determined life even later in life.

The actual need is visualized by means of a signal light as the interface of care and technology. Similar to a traffic light, different colors indicate the current state of the person taken care of: red displays an urgent need of care, yellow suggests that assistance is useful and green announces a currently self-determined life.
The actual care process is then carried out by family members, voluntary helpers, professional care staff or – in case of an emergency – by doctors. To ensure the medical attendance in the privacy of the patient's home, medical engineering sensors are employed additionally in order to transmit measured data to a medical center. The medical center then reacts in case of an emergency.

As a technological base for the signal light, sensors and actuators using radio technology are installed in the apartment. Therefore, standard components of building service engineering like motion detectors, light switches, window or door contacts, which are networked, are employed. All sensor information and data is evaluated at the apartment, so that all information concerning detailed patterns of behavior remains there. First, the system gets to know the patient's *usual* behavior and configures itself accordingly. In case of *unusual occurrences,* the nursing staff is informed by means of the signal light.

JUTTA – CARE ACCORDING TO INDIVIDUAL NEEDS

The signal light is displayed at the nursing service's coordinating unit where the nursing staff's tours are organized according to the actual needs of the patients. Therefore, care assistant vehicles are equipped with GPS, so that the coordinating unit knows the position of the vehicles at all times.
In order to support and facilitate documentation, care staff is in possession of a mobile unit to record care processes in a simple and quick way.
The JUTTA-system is currently employed in real to life living environments to gain first experiences in the field of dynamic care processes. In the long run, service according to individual needs is aimed to allow a convenient, self-determined and secure life in the privacy of one's home later in life.

(For further information, please visit www.just-in-time-assistance.de)

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LIST OF PUBLICATIONS AND SCIENTIFIC THESES 2010

1. Monographs

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CMOS image sensor with 118db linear dynamic input range
IMS-Duisburg, 2010

CMOS linear photosensor array, 1 x 512 pixel
IMS-Duisburg, 2010

CMOS ToF-Sensor for 3D imaging, 64 x 8 pixel
IMS-Duisburg, 2010

Distributed test system for interoperability tests
IMS-Duisburg, 2010

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CHRONICLE 2010

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INHAUS-CENTER EVENTS 2010

In 2010, Fraunhofer-inHaus-Center hosted many events for professional audiences. Highlights include the following:

June 24, 2010: win² – Technical Modernization of Real Estate – Solutions and Potential Benefits

More than forty percent of the world's energy consumption is related to buildings. This is why technical modernization of residential and commercial properties has a great potential for economic development and the creation of workplaces, as well as for energy saving and environmental protection. The outdated technical equipment of the majority of buildings accounts for great optimization potential. Rapidly changing user needs and usage requirements demand suitable solutions: This includes, for example, the enhancement of the structural and functional flexibility of rooms and buildings.
Fraunhofer-inHaus-Center and the Niederrheinische Industrie- und Handelskammer (Chamber of Commerce and Industry of the Lower Rhine region) took up this current debate and organized the win²-event "Technical Modernization of Real Estate". In the course of three hours, various experts provided information about the current conditions of the field of real estate for 45 participants. Furthermore, diverse concepts of modernization in combination with cost-benefit assessment were presented. The evening closed in a lively discussion and a relaxed get-together.

September 16, 2010: Fraunhofer-inHaus-Forum 2010 – Health and Care – Innovations to Increase the Efficiency of Technical Systems, Rooms and Processes in the Field of Healthcare

Today, the field of healthcare and social welfare faces diverse challenges: The cost pressure for providers of medical service increases, while the population experiences demographic changes, which will result in a rising number of elderly in need of care in the future. At the same time, there is no additional care and medical staff at hands; quite contrary, the number has been decreasing. Which solutions are then necessary to develop a sustainable and innovative healthcare and social sector?
This year's Fraunhofer-inHaus-Forum tried to find answers to this question.160 participants listened to lectures researchers of each business area had prepared with special reference to the field of healthcare. Keynotes by well-known representatives of the field framed the event. The day ended in a panel discussion of leading experts.
As it has become common to the establishment of the inHaus-Forum, visitors had the chance to take a look at the inHaus-partner's exhibitions and the laboratories.

WORKSHOP ON ENERGY SELF-SUFFICIENT SENSOR NETWORKS

The Fraunhofer one-day-workshop on energy self-sufficient sensor networks on November 16, 2010, Munich, provided numerous hands-on examples from different branches and was geared to experts from development and manufacturing as well as quality control and reliability. Fraunhofer IMS presented current developments in integrated low-power sensors and in collaborative signal and information processing. The workshop was preceded by the Fraunhofer-Forum »Aufmerksam im Schwarm – Energieautarke Sensoren und Sensornetze« on November 15 at Fraunhofer-Haus.

VISION 2010

As in the years before Fraunhofer IMS took place in the VISION fair in Stuttgart fom November 9th to 11th 2010. Fraunhofer IMS presented its news in the field of 3D CMOS image sensor technology working on the time-of-flight principle and infrared sensor technology.

Special interest was given to the infrared sensors which provide a better level of safety for drivers. Objects at roughly body temperature are luminous in the infrared region at a wavelength of around ten micrometers. Detectors in the camera register this thermal radiation and locate the source of heat. This enables drivers to see people or animals long before they come into vision through dipped headlights. Another advantage: Other road users are not inconvenienced by the invisible infrared radiation.

Journalists were especially interested in these research results and, as a result, these news were presented on the first page of the fair newspaper.

A few words about the fair:

The VISION is an international trade fair for industrial image processing and identification technologies. It is the meeting place of all players this sector and therefore the most important marketing tool in order to meet international customers and to present to them the latest developments in image processing.

Approximately 6,800 visitors from over 50 countries, predominantly from Europe but also from overseas, mainly from the USA and South Korea, came to Stuttgart this year to obtain information at the world trade fair for machine vision.

ELECTRONICA 2010 IN MUNIC

The Electronica Fair in Munic counts among the biggest trade fairs worldwide and presents concentrated expert knowledge in nearly all consumer segments and user industries – from automotive and industrial electronics to embedded, wireless, medical electronics and MEMS.

It is the meeting place for decision-makers who search for attractive offers and for good products to meet current and future requirements.

Fraunhofer IMS presented the following topics:

- Innovative computer process control for micro reactors in the chemical industry
- High Temperature ASICS and processes for applications up to 250 degree
- Vacuum isolation panels with integrated low power pressure sensor ASIC and wireless communication
- Medical implants with integrated low power pressure and temperature ASIC and wireless communication
- Image Sensores for high demands (aerospace 3D Imagesensors)

All in all the fair was a big success.

THE FRAUNHOFER-TALENT-SCHOOL

From November 4th to 6th 2010 the Fraunhofer-Talent-School took place at IMS

Setting up radio circuits, learning to understand the construction of microchips and the design and simulation of a chip at the computer – these tasks were a cool challenge for the participants of the Duisburger Fraunhofer-Talent-School 2010.

33 interested teenagers from whole Germany, but predominantly from North-Rhine Westphalia, met on November 4th at the Fraunhofer IMS Talent-School to experience the microelectronic working environments of engineers and scientists and to get useful incentives for their own career.

The Workshop 1 "Mit uns funkt's – Vom Schwingkreis zur Funkanwendung" ("… – From the oscillating circuit to the radio application") focussed on constructing microcontroller circuits and to start running them. The teenagers for example brazed devices on circuit boards.

During Workshop 2 "Chips und mehr" ("Chips and more") the participants got a taste of the fascinating world of microelectronics. The clean room and laboratory tours pointed up the complexity of chip design. The participants worked practically with chips, oscilloscopes and microprocessors.

In Workshop 3 "Rechnergestützter Schaltungsentwurf – Wie kommt die Schaltung auf den Chip?" (Computer-aided circuit design – How do circuit and chip meet?") the teenagers learned about different design processes and the corresponding CAE-Software. On the basis of a small specimen circuit, the participants independently sampled the design of a circuit. After some failed attempts, they had an error-free working circuit.

Well, no one is born a master!

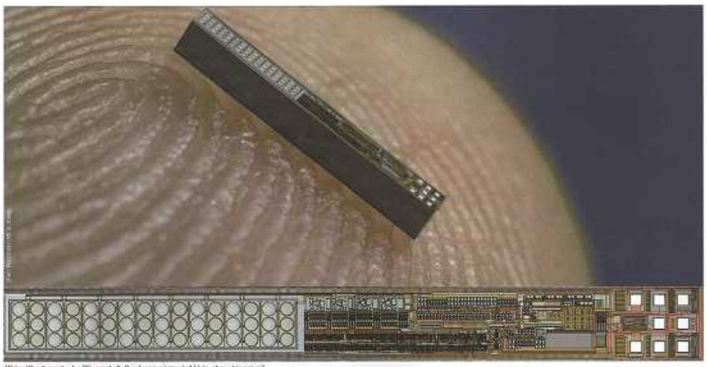
WORKSHOP: RELIABILITY OF SEMICONDUCTOR DEVICES

On March 18th 2010 the Workshop on the reliability of semiconductor devices took place in the Fraunhofer-inHaus-Center in Duisburg. This workshop was organised in cooperation with the GMM (Gesellschaft für Mikroelektronik) and around 50 participants from industry took part.

Microelectronics expands more and more into sensitive areas in which malfunctions can cause large material damage or even negative effects on health, for example in medical and automotive engineering. In automotive engineering the development ranges from comfort electronics, driver assistance and tasks in the power train to topics like “Drive by Wire”.

In addition, the requirements of the rough ambience in automobiles (temperature change, humidity, impurities) have to be considered. In medical engineering implantable systems, which do not only measure but also act e.g. by pharmaceutical dosage in the combat against diabetes, are developed. Therefore, microelectronic systems have to meet high reliability requirements. Especially the automotive industry expedites this topic. Furthermore, a particular reliability is required for space technology and military applications. The small quantities required for these areas pose a special challenge. Also in industrial electronics with its rough ambient conditions the devices are subjected to special reliability requirements.

PRESS REVIEW



Fraunhofer Institut IMS – einzigartige Innovationswerkstatt

Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme IMS
„Nachgehakt":

„Am Anfang steht die Idee, am Ende die Zulassung"

GFW Duisburg Winter 2010

Implantierbares Monitoring-System für Hypertoniker

Allein in Deutschland leiden etwa 10 Millionen Personen an Bluthochdruck (Hypertonie). Bei etwa 10 % dieser Betroffenen lässt sich der Blutdruck nur sehr schwer einstellen. Etwa 10% dieser Gruppe sind Kandidaten für eine Langzeitüberwachung. Die hierzu heute extrakorporal eingesetzten Systeme sind sehr umständlich und stellen für den Patienten vor allem in der Nacht eine große Belastung dar. Im Rahmen des Verbundvorhabens HYPER-IMS wird ein neuartiges Überwachungssystem entwickelt, das eine quasi-kontinuierliche Blutdruck-, Pulsraten- und Körpertemperaturüberwachung von Hypertonie-Patienten über einen Zeitraum von einem halben Jahr ermöglicht.

Das System besteht aus einem über eine Schleuse in die arteria femoralis implantierbaren Druck- und Temperatursensor, der den Blutdruck mit einer Rate von 30 Messungen pro Sekunde abtastet. Über ein flexibles Kabel ist der Sensor mit einer unter der Haut liegenden Transpondereinheit verbunden (s. Bild 1). Extrakorporal befindet sich eine tragbare Lesestation, die über induktive Kopplung drahtlos Energie zum Transponder sendet und aus ihm digitalisierte Sensordaten empfängt. Eine spätere Datenübertragung der in der Lesestation gespeicherten Daten zu einer Monitorstation ermöglicht die Speicherung, Auswertung und Visualisierung der Daten.

Bild 2: Aufbau des Implantats

Bild 2 zeigt ein verkapseltes Implantat mit den Komponenten Sensormesspitze, Mikrokabel und Transpondereinheit. Die Sensorspitze besitzt nach der Kapselung in einer Metallhülse einen Außendurchmesser von 1,05 mm. Die Druck- und Temperaturmessung erfolgt mit Hilfe eines miniaturisierten integrierten Sensors, der in einer CMOS-kompatiblen Technologie mit einer on-chip Elektronik hergestellt wird (s. Bild 3). Das System ist ausgelegt für eine Druckmessung im Bereich 900 mbar (675 mmHg) bis 1400 mbar (1050 mmHg) und für eine Temperaturmessung im Bereich von 30°C bis 45°C. Der Drucksensor zeigt in dem definierten Messbereich nach Kalibration eine Genauigkeit besser als ± 2mbar bei einer Übertragungsreichweite bis 6 cm.

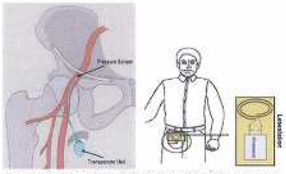


Bild1: Positionierung des Drucksensors in der arteria femoralis und der dazugehörigen Transpondereinheit unter der Haut (links) sowie der

Der in Oberflächenmikromechanik hergestellte kapazitiver Drucksensor erlaubt zusammen mit der CMOS-Schaltungstechnik eine Minimierung im Leistungsverbrauch. Die Leistungsaufnahme des Implantats liegt während der aktiven Messphase in der Größenordnung zwischen 200 und 300 µW. Dies ist eine Grundvoraussetzung für die Realisierung des Systems als pas-

Bild 3: Integrierter Druck- und Temperatursensor in Detailaufnahme (oberer Bildabschnitt sowie in Größenvergleich auf einer Fingerkupp und verkapselt in einer Metallhülse mit einem Außendurchmesser von 1.05 mm.

Mit dem vorliegenden System wurden die im Projekt vorgesehenen In-vitro-Untersuchungen durchgeführt.
Bild 4 zeigt exemplarisch eine am Blutgefäßmodell telemetrisch aufgezeichnete Messreihe. Die In-vivo-Charakterisierungen wurden bereits gestartet und befinden sich zur Zeit noch in der laufenden Untersuchung.

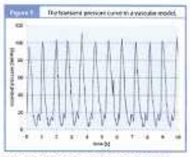


Bild 4: Telemetrisch aufgezeichnete Messreihe des Drucksensors im Gefäßmodell

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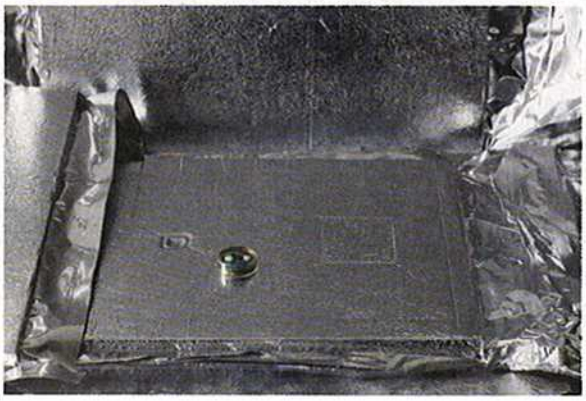
Isis Januar 2010

Sehr klein gebaute Drucksensoren übertragen Messwerte drahtlos



Management & Aktuelles 2010

Aus Wissenschaft & Forschung

Funksignale aus dem Herzen

Herzkammerdruck-Bestimmung mittels implantiertem Sensor

(Fraunhofer IMS) Im Herz herrscht Arbeitsteilung: Die rechte Hälfte hält den Lungenkreislauf in Gang, die linke pumpt das mit Sauerstoff angereicherte Blut in den Körper. Erhöht sich der Druck in der linken Herzkammer, kann das eine Herzinsuffizienz bzw. Herzmuskelschwäche anzeigen.

Wie es um den Druck bestellt ist, könnte künftig ein am Duisburger Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme (IMS) entwickelter winziger Sensor ermitteln, der ins Herz implantiert wird.

Hierzu wird der stäbchenförmige, zwei mal zehn Millimeter große Sensor mit Hilfe eines Katheters an der Herzwand befestigt. Während der Katheter anschließend gezogen wird, verbleibt der Sensor im Herzen. Er liefert – wenn erforderlich – über einen Zeitraum von mehreren Monaten Daten über die Druckverhältnisse. Das allerdings nur auf Anfrage: Wie ein passiver RFID-Transponder arbeitet der Sensor lediglich dann, wenn ihn das zugehörige Lesegerät mit Energie versorgt – induktiv via Antenne. Er benötigt weder Akku noch Batterie. Eine Leistung von neunzig Mikrowatt reicht aus, um den Druck zu messen und die Werte bis zu vierzig Zentimeter weit zu senden.

Da sich der Sensor mit seiner integrierten Antenne im Herz nur längs ausrichten lässt, muss er seitlich am Brustkorb ausgelesen werden. Um die Dämpfung des Signals durch Knochen, Körpergewebe und -flüssigkeiten so gering wie möglich zu halten, funkt das System im 10-MHz-Bereich. Es steckt in einer biokompatiblen Polymerhülle, die – im Gegensatz zu Metall – Funkwellen nicht abschirmt, sondern passieren lässt. www.fraunhofer.de

Stichworte:
- Herzinsuffizienz
- Funksignal
- Sensor

Praxis Physiotherapie April 2010


Dr. Gerd vom Bögel Frederic Meyer

RFID in Wartung und Instandhaltung

Metall schirmt Strahlung gut ab – etwa von RFID-Chips, kleinen Datenspeichern, die in verschiedene Gegenstände integriert werden und ihre Information an ein Lesegerät funken. Nun lassen sich RFID-Chips ihre Information auch dann entlocken, wenn sie in Metall stecken.

In Produktionshallen kommt es auf höchste Genauigkeit an – oft zählen hundertstel Millimeter. Sind die Fräser oder Bohrer jedoch abgenutzt, ist es mit der Genauigkeit vorbei. Aus diesem Grunde müssen die Mitarbeiter die Werkzeuge regelmäßig bei der Wartung auf der Bearbeitungsmaschine vermessen. Um auch kleinste Abweichungen im Rundlauf erkennen zu können, rotieren die Werkzeuge dabei. Bisher ist die Vermessung Handarbeit. Die Schneiden müssen mit einem passenden Adapter in eine Halterung eingesetzt werden. Sowohl das Werkzeug als auch der Adapter sind mit einer Seriennummer versehen – diese und weitere Daten wie die Abmessungen werden per Hand abgetippt, wobei sich leicht Fehler einschleichen.

Künftig geht das einfacher. Das Fraunhofer-Instituts für Mikroelektronische Schaltungen und Systeme IMS in Duisburg hat im Auftrag der Kelch & Links GmbH aus Schorndorf, einem der führenden Hersteller von Werkzeugeinstellgeräten, nun eine Möglichkeit gefunden, RFID-Chips in die metallischen Werkzeuge zu integrieren. Auf Anfrage funken diese kleinen Datenspeicher die benötigten Informationen an ein Lesegerät außerhalb der Werkzeugaufnahmespindel. Die Herausforderung dabei: Metall schirmt Strahlung bekanntermaßen gut ab. Das selbe Problem tritt bei den RFID-Chips auf: Schirmt eine Metallische Hülle den RFID-Chip ab, gelangen weder Energie in Form des elektromagnetischen Feldes vom Lesegerät zum RFID-Chip, noch umgekehrt Daten zum Lesegerät durch.

Im betrachteten Beispiel ist die zu identifizierende metallische Werkzeugaufnahme drehend gelagert und aus der antreibenden Spindel entnehmbar. Die ebenfalls metallische Spindel ist fest in den stationären Teil des Messgeräts eingebaut. Aufgabe ist nun die Kommunikation vom stationären Teil durch die drehbare Spindel in den entnehmbaren Werkzeugeinsatz herzustellen, was aber auf direktem Wege durch die Spin-

Werkzeugaufnahme mit RFID-Chip

Zur Lösung dieses Problems haben die Entwickler des Fraunhofer IMS den Übertragungsweg unterteilt. Der RFID-Chip befindet sich mit einer Antennenspule verbunden an der Oberfläche des Adapter. Hier koppelt das Signal drahtlos zu einer Antennenspule an die drehbare Spindel über. Eine Drahtverbindung verbindet die Antennenspule mit einer weiteren, an der Spindel außen. Darüber wird die Grenzfläche zwischen der drehbaren Spindel und eine im feststehenden Teil des Messgeräts überbrücken und in die Spule eingekoppeln, die an das Lesegerät angeschlossen ist.

Eine Kleinserie der RFID-Messgeräte ist bereits in Mess- und Einstellgeräten der Kelch & Links GmbH bei ausgewählten Kunden in der Anwendung.

Darüber hinaus sind viele weitere Einsatzbereiche sichtbar: Das Übertragungsprinzip lässt sich überall dort nutzen, wo Informationen über mehrere Strecken hinweg drahtlos übermittelt werden müssen. Etwa in Roboterarmen, die mehrere drehbare Gelenke haben: An den Gelenken könnte die Verbindung drahtlos über Spulen erfolgen, innerhalb des Arms über Kabel bis zum nächsten Gelenk. So ließe sich etwa ein Sensor an der Roboterhand ansteuern, der misst, wie fest die Hand einen Gegenstand greift.

Gänzlich neue Einsatzbereiche lassen sich durch die Kombination von RFID-Chips mit Sensoren erschließen. Hier werden Größen wie Temperatur und Druck an sonst unzugänglichen Stellen gemessen. Stimmt der Druck im Kessel oder läuft ein Lager heiß ist frühzeitig vor dem Schadensfall erkennbar. So lassen sich teure Stillstandzeiten von Anlagen vermeiden. Ausschlaggebend sind die Aufnahme und das Abspeichern von Umgebungsinformationen, um aus diesen Werten die Arbeitsbelastung und die Art des Betriebs zu ermitteln. So können zum Beispiel mit den Umgebungsparametern die Betriebszeit gezählt, um Wartungsintervalle zu optimieren, und die Art des Betriebs, Regelbetrieb oder Fehlbetrieb ermittelt werden, auch bezeichnet als „Condition Monitoring". Im Fehlbetrieb, z.B. bei zu hohen Temperaturen, bedeutet, dass die Maschinen schneller verschleißen oder gar kurz vor einem Schadensfall stehen und unverzüglich instand gesetzt werden müssen.

Am Fraunhofer IMS werden derzeit die neu entwickelten RFID-Chips mit Sensoren erprobt, die sich in ähnlicher Weise wie die RFID-Chips integrieren lassen, darüber hinaus aber den Mehrwert der Sensorik bieten.

ISIS Mai 2010

RFID-Datenspeicher funken durch Metall

Die Funksignale von RFID-Chips, die sich in einem metallischen Werkstück befinden, werden normalerweise wirkungsvoll abgeschirmt. Forscher des Fraunhofer-Instituts bringen nun die kleinen Datenspeicher dazu, Werkzeuge zu messen und die Daten trotzdem an ein Lesegerät zu senden.

Bei der Fertigung kommt es auf höchste Genauigkeit an – oft zählen hundertstel Millimeter beim Spanen und Bohren. Sind die Fräser oder Bohrer jedoch abgenutzt, ist es mit der Genauigkeit vorbei. Deshalb vermessen die Mitarbeiter in der Produktion die Werkzeuge regelmässig, bevor sie auf der Bearbeitungsmaschine zum Einsatz kommen. Um auch kleinste Abweichungen im Rundlauf erkennen zu können, rotieren die Werkzeuge dabei in einer Halterung.

Bisher ist die Vermessung Handarbeit, denn die Bohrer müssen mit einem passenden Adapter in die Halterung, eine Spindel, eingesetzt werden. Sowohl das Werkzeug als auch der Adapter sind mit einer Seriennummer versehen – diese und weitere Daten wie die Abmessungen werden per Hand abgetippt, wobei sich Fehler einschleichen können.

Die Grenzfläche zwischen der drehbaren Spindel und dem feststehenden Teil des Messgeräts wird drahtlos überbrückt

Künftig ist das Vermessen unkomplizierter

Forscher des Fraunhofer-Instituts für Mikroelektronische Schaltungen und Systeme IMS in Duisburg haben sich im Auftrag der Firma Kelch & Links GmbH dieses Problems angenommen. Das Unternehmen im deutschen Schorndorf ist Spezialist für innovative, hochpräzise Werkzeugaufnahmen, Einstellgeräte, Messtechnik und Werkzeuglogistik zur Leistungssteigerung von Werkzeugmaschinen. formationen an ein Lesegerät ausserhalb der metallischen Spindel, die das Werkzeug mit dem Adapter aufnimmt. Die Herausforderung dabei war klar: Metall schirmt Strahlung gut ab – das weiss jeder, der einmal versucht hat, in einem Haus aus Stahlbeton mit dem Handy zu telefonieren. dringt ihre Information nicht bis zum Lesegerät durch. Die Wissenschaftler vom Fraunhofer-Institut fanden aber einen überraschend einfachen Weg, dieses Problem zu lösen. «Wir haben den Übertragungsweg unterteilt», erklärt Dr. Gerd vom Bögel, Gruppenleiter am IMS. «Vom RFID-Chip, der sich im Adapter befindet, übertragen wir die Daten zunächst mit einem Kabel bis an die Grenzfläche zwischen Adapter und Spindel. Hier leiten zwei Antennenspulen die Daten drahtlos an die Spindel weiter – eine Spule befindet sich dabei im Einsatzmodul, die andere in der Spindel. Ebenso überbrücken wir die Grenzfläche zwischen der drehbaren Spindel und dem feststehenden Teil des Messgeräts drahtlos.»

Kleinserie im Einsatz

Eine Kleinserie der RFID-Messgeräte ist bereits in Geräten der Kelch & Links GmbH bei ausgewählten Kunden in der Anwendung. Vom Bögel sieht aber noch weitere Einsatzbereiche: «Das Übertragungsprinzip lässt sich überall dort nutzen, wo Informationen über mehrere Strecken hinweg drahtlos übermittelt werden müssen – etwa in Roboterarmen, die drehbare Gelenke haben.»

Polyscope August 2010

Dem Mattenbruch auf der Spur

Rost an Armierungen von Betonbrücken hat fatale Folgen, im schlimmsten Fall besteht Einsturzgefahr. Forscher haben jetzt ein System zur Früherkennung von Rost an den Stahlmatten entwickelt. Das Halbzeug Draht spielt dabei eine besondere Rolle. Ein im Beton eingelassener Sensortransponder misst, wie weit die Korrosion fortgeschritten ist.

Der Sensor ist mit dünnen Eisendrähten durchzogen, die in regelmäßigen Abständen angebracht sind. Bild: Fraunhofer IMS

Denn Betonbrücken müssen einiges aushalten. Frost, Verkehrsbelastung und Abgase setzen ihnen zu. Hinzu kommt Streusalz gegen Glatteis. Natriumchlorid, das gängigste Tausalz, wird bundesweit in großen Mengen verteilt. Bei Tauwetter zerfallen die Salze zu Ionen. Sie dringen in den Beton ein und zerstören dessen fünf Zentimeter dicke alkalische Schutzschicht. Erreichen die gelösten Salze die Stahlmatten, beginnen diese zu rosten. Die Bausubstanz wird geschädigt. In der Folge kommt es zu Rissen, Betonstücke können abbrechen.

Bislang gab es keine effektiven Tests um zu ermitteln, wie tief die Ionen in den Beton eingedrungen sind und welcher Schaden bereits entstanden ist. Bis dato klopfen Bauarbeiter den Stahlbeton von Hand mit dem Hammer auf Hohlstellen ab. Diese sind ein Indiz für Korrosionsschäden. Diese Methode ist zeitaufwändig. Wie sich Rost-Früherkennung wirksamer und vor allem kostengünstiger erreichen lässt, wissen die Experten des Fraunhofer-Instituts für Mikroelektronische Schaltungen und Systeme IMS in Duisburg. Mit einem Sensortransponder können sie die Eindringtiefe der Ionen in den Beton permanent messen und überwachen. Der Sensor wurde von der Materialprüfanstalt für das Bauwesen Braunschweig MPA Braunschweig entwickelt, die Forscher vom IMS haben ihn in ein passives, kabelloses Transpondersystem integriert. Der Sensor selbst ist mit sehr dünnen Eisendrähten durchzogen, die in regelmäßigen Abständen zueinander angebracht sind.
„Kommen die gelösten Salze an die Eisendrähte, beginnen diese zu rosten. Die Armierung bricht. Anhand der Anzahl der defekten Eisendrähte lässt sich feststellen, wie weit die Korrosion fortgeschritten ist, wie viele Zentimeter der Beton-Schutzschicht schon angegriffen sind", erklärt Frederic Meyer, Wissenschaftler am Institut für Mikroelektronische Schaltungen und Systeme. Auf diese Weise könne man berechnen, wann die nächste Instandsetzung erforderlich ist. Die Messdaten überträgt der Transponder per Funk an ein Lesegerät, das die Bauarbeiter mit sich tragen. „Unser System bezieht die für die Messung erforderliche Energie nicht über eine Batterie, sondern über ein magnetisches Feld. Er muss daher nicht ausgetauscht werden und kann dauerhaft im Bauwerk verbleiben", sagt Meyer. Dieser lasse sich auch nachträglich in den Beton einsetzen. Derzeit laufen erste Feldversuche. Der

Erreichen gelöste Salze die Stahlmatten, beginnen letztere zu rosten. Die Bausubstanz wird geschädigt.

Sensortransponder wird in eine Versuchsbrücke der MPA Braunschweig eingelassen und getestet.

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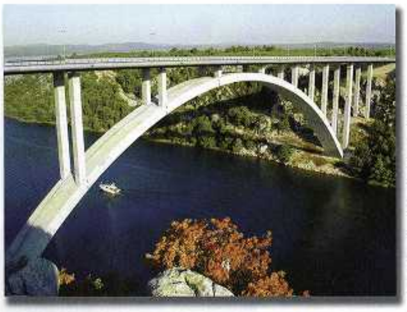
Draht Juni 2010

New sensor monitors salt penetration in concrete



The passive sensor-transponder continuously monitors the protective coating of concrete bridges, allowing corrosion damage to be detected at an early stage. Image courtesy of Fraunhofer IMS.

Over a period of time, bridge components may deteriorate to the extent that the structure is no longer safe. While a number of factors contribute to bridge corrosion, one of the most common is the use of deicing salts, a practice that has contributed significantly to bridge corrosion and is the leading cause of concrete bridge deterioration. The salts cause corrosion of the concrete's steel reinforcing bars and other steel components supporting the bridge.

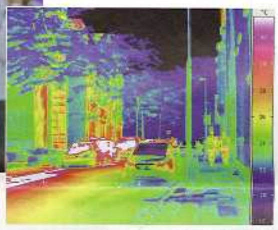
According to researchers with Fraunhofer-Gesellschaft Institute for Microelectronic Circuits and Systems (IMS) (Duisburg, Germany), these salts break down into their ionic components as the ice thaws, which then penetrate the concrete and degrade its protective alkaline layer. Any salt that leaches through to the steel rods used to reinforce the concrete will cause them to rust, resulting in cracking and structural damage. In a worst-case scenario, the bridge itself could collapse.

Until now, the researchers say, there have been no effective tests to determine how deep the ions have penetrated the concrete and the extent of the damage they have already caused. The current practice to detect concrete deterioration is time-consuming and involves bridge workers

Materials Performance August 2010

Infrared camera provides a better view

Infrared cameras see more than the naked eye and can make road traffic safer. Cameras for the long-wave infrared range, however, have the disadvantage that the sensor requires constant cooling, which adds to the cost and complexity of the device. Now a new type of detector has been developed which functions at room temperature.



„We could be the first in Germany to offer this technology", says Dr. Dirk Weiler, scientist at the IMS (Bilder: Böttger/Fraunhofer IMS)

At night on an unlit country road: the bends in the road restrict the view ahead and, to make things worse, it is foggy. The car driver is exercising all due care and yet still does not see the deer on the road ahead until it is nearly too late. An emergency stop prevents a collision with the animal just in time. In such situations infrared cameras could provide a better level of safety. Objects at roughly body temperature are luminous in the infrared region at a wavelength of around ten micrometers. Detectors in the camera register this thermal radiation and locate the source of heat. This could enable drivers to see people or animals long before they come into vision through dipped headlights. Other road users would not be inconvenienced by the invisible infrared radiation.

The problem is that infrared cameras for the wavelength range above five micrometers like it cold – the sensor has to be constantly cooled down to about minus 193 degrees Celsius.

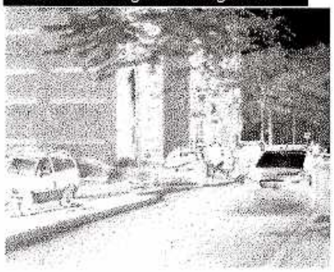
Uncooled imagers for the long-wave infrared range do already exist today, but they are mainly used in the military sphere and are more or less unavailable on the European market. This is now set to change. Research scientists at the Fraunhofer Institute for Microelectronic Circuits and Systems IMS in Duisburg have succeeded in producing an imaging sensor for the long-wave infrared range that functions at room temperature.

At the heart of the IRFPA (Infrared Focal Plane Array) sensor is a microbolometer – a temperature-sensitive detector that absorbs long-wave infrared light. To produce a two-dimensional image, several microbolometers are combined to form an array. If the microbolometer absorbs light from a heat source, its interior temperature rises and its electrical resistance changes. A readout chip then converts this resistance value directly into a digital signal. Previously this was not possible without a further intermediate step – normally the electrical pulse is first translated into an analog signal and then digitized using an analog/digital converter. »We use a very specific type of converter, a sigma-delta converter, in our imager. This has enabled us to produce a digital signal directly«, Weiler explains.

As complex and costly cooling is no longer required, further areas of application become feasible

Vision Focus November 2010

Infrared "Night Vision" Cameras Could Make Night Driving Safer



Infrared image taken by the Fraunhofer researchers.

The technology could be linked to automatic braking systems that stop the car when a person or animal looms out of the darkness, or "augmented reality" style head-up displays that show otherwise invisible objects on the driver's screen.

The new cameras are suitable for everyday use in cars because they work at room temperature. Most cameras that work in the long-wave infrared spectrum - the bit that objects at body temperature are visible in, like humans and animals - need to be constantly kept cool, to around 80 Kelvin (-193C or -315F). THat is prohibitively difficult and expensive to do in road vehicles.

Room-temperature infrared cameras do exist, but the technology is largely held by the US military and almost impossible to get in Europe.

However, a German research group, the Fraunhofer Institute for Microelectronic Circuits and Systems IMS, has created a room-temperature sensor, the Infrared Focal Plane Array (IRFPA), that will be made

www.impactlab.com Juli 2010

Durchblick auch in der Nacht

Am **Duisburger Fraunhofer Institut** wurde ein neuartiger bildgebender **Sensor für den Infrarotbereich** entwickelt, der im Gegensatz zu alten Geräten auch ohne Kühlung auf minus 193 Grad Celsius funktioniert.

(RP) Infrarotkameras sehen mehr als das bloße Auge und können beispielsweise den Straßenverkehr sicherer machen. Bei Kameras für den fernen infraroten Wellenlängenbereich muss der Sensor jedoch ständig gekühlt werden, was aufwändig und kostspielig ist. Ein neuartiger Detektor, der am Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme IMS in Duisburg entwickelt wurde, funktioniert nun auch bei Raumtemperatur.

Nachts unterwegs auf der unbeleuchteten Landstraße: Die kurvige Strecke ist schwer einzusehen, noch dazu ist es nebelig. Dementsprechend vorsichtig fährt der Autofahrer – und sieht das Reh auf der Straße dennoch erst, als es fast zu spät ist. Mit einer Vollbremsung verhindert er im letzten Moment einen Zusammenprall mit dem Tier. Infrarotkameras könnten in einer solchen Situation für mehr Sicherheit sorgen. Denn Objekte, die ungefähr Körpertemperatur haben, leuchten im fernen infraroten Wellenlängenbereich von zehn Mikrometern von sich aus. Detektoren in der Kamera nehmen diese Wärmestrahlung auf und orten so die Wärmequelle. Dadurch könnte der Fahrer Menschen oder Tiere erkennen, lange bevor das Abblendlicht sie erfasst. Andere Verkehrsteilnehmer würden durch die unsichtbare Infrarotstrahlung nicht beeinträchtigt.

Das Problem war bislang: Infrarotkameras für den Wellenlängenbereich oberhalb von fünf Mikrometern mögen es frostig – der Sensor muss ständig auf etwa minus 193 Grad Celsius heruntergekühlt werden. Zwar gibt es auch heute schon ungekühlte Imager für den fernen Infrarotbereich, allerdings werden diese überwiegend im militärischen Bereich eingesetzt und sind am europäischen Markt kaum verfügbar. Das soll sich nun ändern: den Duisburger Fraunhofer-Forschern ist es gelungen, einen bildgebenden Sensor für den fernen Infrarotbereich zu fertigen, der bei Raumtemperatur funktioniert. „In Deutschland wären wir die ersten, die eine solche Technologie anbieten", sagt Dr. Dirk Weiler, Wissenschaftler am IMS.

INFO

Fraunhofer IMS

Das Fraunhofer IMS besteht als eigenständiges Institut der Fraunhofer-Gesellschaft **seit Mitte 1984 in Duisburg**, bezog das hierfür errichtete Institutsgebäude 1987, das entsprechend der steigenden Anforderungen 1992, 2001 und 2005 baulich erweitert wurde. Das Institut entwickelt **mikroelektronische Schaltungen und Systeme**, die insbesondere **mittelständische Unternehmen** eine schnelle und produktnahe Systementwicklung ermöglichen. Das Institut leitet als Nachfolger von Prof. Dr. Günter Zimmer seit dem 1. Januar Prof. Dr. Anton Grabmaier.

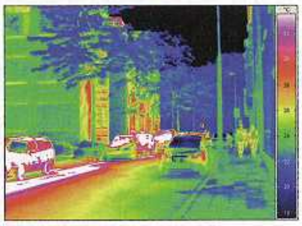
Viele Anwendungsfelder

Da die aufwändige und kostenintensive Kühlung nicht mehr nötig ist, eröffnen sich neben dem Einsatz im Automobil noch weitere Anwendungsfelder. »Vor allem im Bereich von mobilen Geräten dürfte sich durch die neue Entwicklung einiges tun«, ist sich Weiler sicher. Denn ohne Kühlmechanismus lässt sich nicht nur Gewicht sparen. Auch die Akkuleistung und damit die Betriebszeit des mobilen Geräts erhöht sich, da die Energieversorgung für die Kühlung wegfällt.

Ein potenzielles Einsatzgebiet für mobile Infrarotkameras ist der Brandschutz, etwa um versteckte Glutnester aufzuspüren oder Personen in verrauchten Gebäuden zu lokalisieren. Erste Labortests mit dem neuen Sensorelement waren erfolgreich: Die Forscher konnten bereits einige Infrarotbilder aufnehmen.

Rheinische Post Juli 2010

Detektor für Infrarotkameras arbeitet ohne Kühlung



Forscher des Fraunhofer-Institutes IMS haben einen Detektor für den fernen Infrarotbereich entwickelt, der bei Raumtemperatur arbeitet. Weil die aufwendige und kostenintensive Kühlung nicht mehr nötig sei, eröffneten sich zahlreiche Anwendungsfelder, vor allem im Bereich von mobilen Geräten. Denn ohne Kühlmechanismus lasse sich nicht nur Gewicht sparen. Auch die Akkuleistung und damit die Betriebszeit des mobilen Geräts erhöhe sich. Ein potenzielles Einsatzgebiet für mobile Infrarotkameras sei der Brandschutz, etwa um versteckte Glutnester aufzuspüren.

Management & Aktuelles Juli 2010

Farbsensoren für bessere Sicht

Sogenannte CMOS-Bildsensoren von Spezialkameras, etwa bei Fahrerassistenzsystemen, sehen meist nur schwarzweiß und haben eine begrenzte Lichtempfindlichkeit. Es gibt sie inzwischen in einer Version, die Farbe erkennen und wesentlich lichtempfindlicher sein sollen. Für viele Fahrassistenzsysteme sind hochwertige Kameras notwendig, die vielerlei Anforderungen genügen müssen. Hohe Umgebungstemperaturen etwa, kleine Baugrößen und natürlich Robustheit wird ebenfalls verlangt. Außerdem darf ihren „Augen" nichts entgehen, und sie sollten wenig kosten. Derzeit verwendet man für die meisten Systeme im Auto CMOS-Sensoren. Das sind Halbleiterchips, die Lichtsignale in elektrische Impulse verwandeln und in den meisten Digitalkameras eingebaut sind. Doch bisher sind die Sensoren für Industrie- und Spezialkameras meist farbenblind. Forscher vom Fraunhofer-Institut für Mikroelektrische Schaltungen und Systeme IMS in Duisburg bringen Farbe ins Spiel: Sie haben einen neuen Fertigungs-Prozess für Bildsensoren entwickelt, der den Chips beibringt, Farbe zu sehen. SZ

Süddeutsche Zeitung März 2010

Auf extreme Temperaturen vorbereitet

Bildsensoren, die zur Qualitätskontrolle in der Produktionstechnik oder für elektronische Einparkhilfen in Autos verwendet werden, müssen hitzebeständig sein – schließlich herrschen dort oft sehr hohe Temperaturen. Forscher haben jetzt einen CMOS-Chip gefertigt, der bei 115 °C noch funktioniert.

Immer mehr Automobilhersteller statten ihre Fahrzeuge mit Bildsensoren aus – etwa um Fußgänger, Fahrzeuge im toten Winkel und Bordsteine für elektronische Einparkhilfen zu erkennen. Die Sensoren müssen auch bei extrem hohen Temperaturen und in gleißendem Sonnenlicht funktionieren. Sind sie etwa am Rückspiegel oder auf dem Armaturenbrett angebracht, können sie sehr heiß werden.

Das Fraunhofer-Institut für Mikroelektronische Schaltungen und Systeme IMS in Duisburg hat daher im Auftrag eines Industriekunden einen CMOS-Bildsensor entwickelt, der Umgebungstemperaturen von -40 bis +115 °C standhält. »Bislang erhältliche CCD-Bildsensoren versagen ab etwa 60 °C«, erläutert Werner Brockherde, Abteilungsleiter am IMS. »Unser Chip dagegen ist nicht nur hitzebeständig, er funktioniert auch bei arktischen Temperaturen.«

Den Forschern ist es gelungen, Pixel zu entwickeln, die einen besonders geringen Dunkelstrom aufweisen. Dieser Reststrom, der bei vollständiger Dunkelheit fließt, ermöglicht Brockherde zufolge auch bei großer Hitze qualitativ gute Aufnahmen. »Einen niedrigen Dunkelstrom zu erzielen, war keine leichte Aufgabe«, verdeutlicht er. »Erhöht sich die Temperatur um 8 °C, so verdoppelt das den Dunkelstrom – Bildrauschen und reduzierte Dynamik sind die Folge. Geisterbilder entstehen, die sich in Form von Artefakten oder flächigen Abbildungen störend auf dem Bild bemerkbar machen.«

Eine weitere Besonderheit des Sensors ist seine Bildgröße von 2,5 x 2,5 cm. Der Vorteil: »Für Anwendungen mit schwacher Beleuchtung oder für Aufnahmen im Infrarot- oder UV-Bereich lässt sich der Sensor direkt an einen elektronischen Bildverstärker anschließen«, wie Brockherde betont.

Der Sensor löst mit 256 x 256 Bildpunkten auf. Sein Dynamikbereich bzw. Belichtungsspielraum von 90 dB sorgt für großen Kontrastumfang und hohe Detailgenauigkeit sowohl in Schatten- als auch in sehr hellen Bereichen. Lichtnuancen werden präzise wiedergegeben. Selbst bei schwachen Lichtverhältnissen reagiert der Sensor mit hoher Empfindlichkeit, so dass er sich auch für Nachtsichtgeräte eignet.

Darüber hinaus unterstützt der Chip sowohl Kameras mit Synchron- als auch mit Asynchron-Verschluss: Der synchrone Verschluss verhindert Bewegungsartefakte, etwa beim Aufnehmen schneller Bewegungen, so dass sich die Bewegungsunschärfe reduziert.

Der Schlitzverschluss dagegen erlaubt eine höhere Bildrate und kontinuierliche Bildaufnahme, was das Bildrauschen minimiert. »Wir haben den Sensor in einem Standardprozess mit 0,5-µm-CMOS-Technik in unserer eigenen Halbleiterfabrik hergestellt«, führt Brockherde aus. »Für Industriekunden fertigen wir dort auch Sonderbauelemente.«

Außer dem Automobilsektor hat der Wissenschaftler noch weitere Märkte im Blick: »Unser Chip eignet sich auch für den Einsatz in Produktionsanlagen der chemischen oder der Stahlindustrie, wo er zur Prozess- und Qualitätskontrolle dienen kann«, sagt er. »In einer Walzstraße beispielsweise, wo Bleche gepresst werden, herrschen ja sehr hohe Temperaturen.«

Zu sehen ist der CMOS-Bildsensor auf der Messe Vision in Stuttgart vom 9. bis zum 11. November 2010 (Stand 6 D12). (ak)

Der CMOS-Sensor lässt sich direkt an einen elektronischen Bildverstärker anschließen.
Quelle: Fraunhofer IMS

Markt und Technik Oktober 2010

Researchers develop image sensor for rough environments

Christoph Hammerschmidt

For automotive applications requiring very low and very high ambient temperatures, scientists from the Fraunhofer institute for microelectronic systems (Duisburg, Germany) has developed a CMOS image sensor capable of working at an extended temperature range from -40 through 115 degrees Celsius.

Widespread image sensors based on CCD technology (Charge-Coupled Device) are operational at ambient temperatures of up to 60 degrees Celsius. The Fraunhofer Institute researchers claim they have developed a pixel architecture featuring an extremely low dark current. This residual current doubles with every 8 degrees of temperature increase, causing signal noise and reducing the available dynamic range of the device. The reduction of this current, which flows even in complete darkness, makes it possible to capture very high-quality images even in extreme heat, said Fraunhofer researcher Werner Brockherde.

The CMOS-based image sensor developed by Fraunhofer features a dynamic range or exposure latitude of 90 dB, resulting in high contrast and optimized detail reproduction in shadow as well as in very bright segments of the image. Its very high sensitivity and low noise makes the device suited for night vision gear, the researchers claim.

The device was developed within a customer project with somewhat unusual specifications: Despite its large size, the sensor features a resolution of only 256 x 256 pixel. "It was a customer-specific design," said Brockherde. The excellent signal features of the device have been made possible by the relatively large geometries at semiconductor level: The device has been designed and manufactured with a feature size of 0,5microns.

Besides automotive applications, the image sensor could be used in process control and quality assurance applications in the chemical and steel industry, Brockherde said.

EE Times Oktober 2010

Forschung & Wissen

Haustür steht und klingelt, sondern auch Fotos von Besuchern macht, während der Mieter außer Haus ist. Bevor jemand seine Wohnung verlässt, berührt er kurz das Piktogramm „Haus" auf dem Bildschirm. Paul meldet dann Auffälliges: Das Fenster in der Küche steht offen, das Licht im Schlafzimmer brennt noch. Verlässt der Mieter die Wohnung, wird auch das vom Computer erfasst.

„Damit unsere Lösungen im Alltag funktionieren, arbeiten wir an der Universität eng mit der Abteilung Stadtsoziologie zusammen", erklärt Floeck. Dort testete Professorin Annette Spellerberg beispielsweise, ob die Bedieneroberfläche des Bildschirms einfach und für jedermann verständlich ist. Tatsächlich kommt Paul ohne Bedienungsanleitung aus: Tippt der Bewohner am Monitor auf das Symbol für Telefon, kann er jemanden anrufen, berührt er das Haus, werden alle wichtigen Informationen über die Wohnung angezeigt. Für diese besondere Ausstattung ihrer Wohnung zahlen die Mieter derzeit zwei Euro pro Quadratmeter und Monat zusätzlich.

Symbole: Mit einer leichten Berührung wird die Toilettenhöhe eingestellt

Das Bad merkt sich alles

Menschen zu unterstützen, ohne sie in ihrer Privatsphäre zu stören, ist auch das Ziel des Projekts „Assistive Badumgebung", das Wissenschaftler am Fraunhofer-Institut für Mikroelektro-

Apotheken Umschau Januar 2010

Ein Haus denkt mit - innovative Technik für das Wohnen von morgen

Die Zukunft wohnt in einer Doppelhaushälfte hinter einer Klinker-Fassade. Allein eine Vielzahl von Schaltern und Tableaus deutet darauf hin, dass dieses scheinbare Standardmodell vollgestopft ist mit Technik. BUS-Systeme durchziehen die Wände, Sensoren, Funkmodule, Computer kommunizieren miteinander. So sieht das Versuchslabor für das Wohnen von morgen aus.

Das Projekt inHaus Duisburg ist Deutschlands größtes Labor für Ambient Assisted Living (AAL). Das Bundesministerium für Forschung übersetzt den Begriff mit "altersgerechte Assistenzsysteme für ein gesundes und unabhängiges Leben" und fördert den Bereich republikweit mit 125 Millionen Euro.

Das intelligente Haus ist vernetzt. "Wir entwickeln Szenarien, bei denen sich Geräte und Abläufe selbstständig steuern", erklärt Christian Ressel, Leiter des Geschäftsfelds Wohnen beim Fraunhofer inHaus-Zentrum. Mensch und Haus kommunizieren. So teilt der Bewohner beispielsweise über einen Touchscreen mit: "Ich gehe zu Bett." Nun setzt sich das vorbestimmte Szenario in Gang: Die Jalousie fährt herunter, Lampen schalten ab, die Heizung drosselt die Leistung, alle nicht benötigten Geräte stehen auf Stand-by.

Bisher sind die helfenden Häuser noch Experiment. Ein Schlussbericht der Fraunhofer-Gesellschaft konstatiert zu den Chancen von Ambient Assisted Living, dass es bisher nach circa zehn Jahren Forschung keinen funktionierenden Markt gebe. Die Autoren vertrösten auf die Zukunft.

Beredter Spiegel

Auf dem Badezimmerspiegel erscheinen Piktogramme, die durch die tägliche Körperhygiene führen. Nach dem Toilettengang leuchtet das Symbol "Hände waschen" auf. Medikamenteneinnahme wird angezeigt mit Präparat und Dosierung.

Schlaues Bad

Intelligente Armaturen regulieren Temperatur und Wassermenge.

Kontrolle am Ausgang

Der Bewohner teilt am Touchpanel dem Haus mit, ob er kommt oder geht. Auch kann er überprüfen, ob z.B. die Fenster geschlossen, der Herd abgeschaltet oder die Lichter gelöscht sind. Wenn nicht, lässt sich dies von hier aus nachholen.

Auf das matte Glas der Kleiderschrank-Front lässt sich z.B. das Fernsehbild projizieren.

Überwachung im Schlaf

Sensormatratzen kontrollieren die Puls- frequenz. Falls erforderlich, kann bei Auffälligkeiten automatisch Hilfe geholt werden.

Intelligentes Notrufsystem

Geschehen ungewöhnliche Dinge, können automatisch Nachbarn, Kinder, Service-Center oder auch Polizei und Feuerwehr alarmiert werden.

Sensitiver Fußboden

Eine Vielzahl von Sensoren erkennt Position und Bewegungsverhalten. Ist z.B. eine Person gestürzt, kann ein Notruf ausgelöst werden

Eingebaute Technik

Sensoren, Funkmodule, Bewegungsmelder registrieren, was im Haus geschieht.

Mobile Haussteuerung

Über ein tragbares Gerät lassen sich Licht, Heizung, Fenster usw. bedienen.

Fernseher als Schaltzentrale

Auch der TV-Monitor kann als Terminal benutzt werden, um das komplette Haus zu steuern.

Focus April 2010

Waschtisch mit interaktivem Spiegel

(fraunhofer) Unter „Ambient Assisted Living" (AAL) werden Konzepte, Produkte und Dienstleistungen verstanden, die neue Technologien und soziales Umfeld miteinander verbinden und verbessern. Ziel ist, die Lebensqualität für Menschen in allen Lebensabschnitten zu erhöhen (Bundesministerium für Bildung und Menschen bereitgestellt. Auf diese Weise soll ihre Autonomie erhöht und ihnen ein längerer Verbleib in ihrer gewohnten Umgebung ermöglicht werden. Die Konzepte basieren auf der Grundidee, Anwesenheit und Handlungen von Bewohnern zu erkennen und unterstützend einzuwirken, ohne störend einzugreifen.

Praxis Ergotherapie Februar 2010

Eine Wohnung, die mitdenkt

Selbstbestimmt leben Technische Hilfsmittel erleichtern den Alltag für Menschen mit Handicap und für Senioren

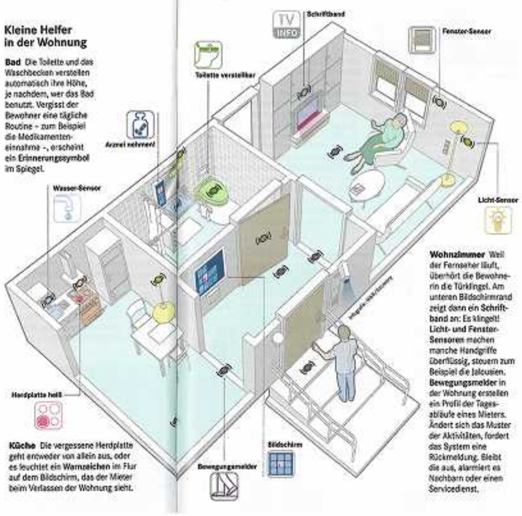
Von außen ahnt niemand, dass hinter der denkmalgeschützten Fassade des renovierten Wohnblocks in der Albert-Schweitzer-Straße in Kaiserslautern manches anders läuft als in den Häusern nebenan. Vor zwei Jahren zogen dort Mieter ein: der jüngste noch keine 30, der älteste 90, Singles und Paare. Sie alle testen hier, wie es sich mit technikunterstütztem Wohnen, dem „ambient assisted living", leben lässt.

„Mit dem Einsatz technischer Hilfsmittel möchten wir den Menschen für längere Zeit ein selbstbestimmtes Leben in den eigenen vier Wänden und ihrem sozialen Umfeld ermöglichen", sagt Martin Floeck von der Technischen Universität Kaiserslautern. Denn treten die Prognosen ein, werden 2020 rund 13,5 Millionen Menschen in Deutschland älter als 70 Jahre sein. Viele von ihnen könnten dann solche Hilfen brauchen, die derzeit an mehreren Fraunhofer-Instituten und verschiedenen deutschen Hochschulen entwickelt werden.

Sensoren signalisieren Aktivität

Für die Benutzer nicht wahrnehmbar, haben Handwerker in der Albert-Schweitzer-Straße beispielsweise mehr als 600 Sensoren eingebaut. „Das zentrale Element für die Bewohner ist Paul, der persönliche Assistent für unterstütztes Leben, der sich in jeder der 20 Wohnungen befindet", erklärt Diplom-Ingenieur Floeck. Paul ist keine Person, sondern ein Computer, der über einen berührungsempfindlichen Bildschirm bedient wird.

In diesem Rechner laufen alle Informationen aus der jeweiligen Wohnung zusammen, übermittelt



Apotheken Umschau Januar 2010

Berker

> Multimedia Steckdose

Wer hätte vor ein paar Jahren gedacht, dass wir unsere Wohnzimmer mit High-Definition-Bildschirmen zu vollwertigen Kinos aufwerten würden? Dass Spielekonsolen in vielen Haushalten zum Standard gehören? Dass Präsentationsbeamer aus Konferenzräumen längst nicht mehr wegzudenken sind? Für all diese Fälle hat Berker ein Portfolio an Multimedia-Steckdosen aufgelegt, mit denen sich modernste Unterhaltungselektronik nahtlos integrieren lässt. Als einer der erster deutschen Schalterhersteller bietet Berker damit ein Multimedia-Anschlusspaket mit Vorteilen, die fast ebenso aufregend sind wie ein guter Heimkinoabend:

- Geeignet für konventionelle Steckverbindungen wie auch Anschluss neuartiger Gerätegenerationen (z. B. Full HD)
- Cinch/S-Video-Steckdose für Receiver, HiFi-Anlagen und DVD-Player
- USB/Mini Audio-Steckdose für mobile Endgeräte sowie PC-Peripheriegeräte
- VGA-Steckdose für Notebooks, Beamer und PC-Monitore (auch für hochauflösende LCD-Monitore geeignet
- High-Definition-Steckdose für alle neuen Unterhaltungselektronik-Geräte (HDMI)
- Gängige Einbaumaterialien, daher einfache Montage
- Verfügbar in Berker Standard- und Flächenprogrammen

Das Sortiment ist ab Oktober 2010 lieferbar.

Multimedia Steckdose

Comfort Center 9

Comfort Center 9

Mit Berker Comfort Center 9 präsentiert Berker den Prototyp eines neuartigen Touchpanels, das die Haussteuerung völlig neu begreift: von seiner intelligenten Technik über die Vielfalt an Möglichkeiten bis hin zur konsequent logischen Bedienung. Einfach zu bedienen: Mit seinem kapazitiven Touchscreen lässt sich das Berker Comfort Center 9 genauso einfach bedienen wie ein Mobiltelefon. Das Berker Comfort Center 9 kann alles, was ein intelligentes Haus braucht: Steuerung von Wärme und Klima, Jalousien und Rollläden, Licht und Beleuchtungsszenarien, Alarmanlage und Sicherheitseinrichtungen, Übersicht über alle wichtigen Funktionen und Energieverbräuche. Darüber hinaus eine ganze Reihe von Aufgaben, die den Alltag erleichtern – wie z. B. Video-Memo, E-Mail, RSS, Datenlogger, Wettermodul, Spiegel-Funktion. Von anderen Haussteuerungsgeräten unterscheidet es sich durch die Vielfalt der Funktionen: der kapazitive Bildschirm, der wie beim iPhone funktioniert, die Unkompliziertheit der Installation, die konsequent nutzerorientierte Gestaltung und nicht zu vergessen das pure, edle Design. <

www.berker.de

Smart Homes Mai/Juni 2010

5 **INHAUS 1 UND INHAUS 2** Duisburg. *Das inHaus-Zentrum für intelligente Raum- und Gebäudesysteme ist die Smart-Home-Innovationswerkstatt des Fraunhofer-Instituts für Mikroelektronische Schaltungen und Systeme (IMS). Die inHaus1-Anlage ist ein Anwendungslabor für den Wohnimmobilienbereich (Privathäuser, Wohnungen der Wohnungswirtschaft), die inHaus2-Anlage für den Nutzimmobilienbereich (Büro, Hotel, Veranstaltungsräume, Pflegeheim, Hospital). Sie dienen technischen Entwicklungen, Tests und Demonstrationen und werden für Weiterbildungen genutzt.* www.inhaus-zentrum.de

Das AAL-Magazin Februar 2010

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