Fraunhofer

IMS

FRAUNHOFER INSTITUTE FOR MICROELECTRONIC CIRCUITS AND SYSTEMS IMS

2018

ANNUAL REPORT

MEDICAL TECHNOLOGY

CONTENT

Dear friends and partners,
dear readers and colleagues,

our diverse applied research has been centered around human needs and well-being for over 30 years. Consequently, we're putting a lot of energy into our work in relevant medical questions and thus into human health. Therefore, the focus of this year's annual report is on the topic "medical technology". A selection of projects on this subject can be found starting on page 26 in this report. But of course, our general focus is always on microsensor technology.

Numerous projects and developments we pushed forward in the last years reflect our engagement in the area of medical technology. For example, sensor implants in miniature that measure eye, brain or heart pressure have been a long-term point of focus at Fraunhofer IMS. During the project "iCaps", which has been supported by The Federal Ministry of Education and Research (BMBF), we are working with our clients on the next generation of brain pressure control valves using sensors. We are always searching for innovative solutions. Some of these solutions are displayed in the demo installation for the "hospital of the future" in the Fraunhofer-inHaus-Center, a factory of innovation that is unique throughout Europe. One project that I would like to point out is the dizziness training device "EQUIVert". In cooperation with our partner GED and others, we developed this training device for vertigo patients which is currently in its approval phase and hopefully soon recognized as a medical device.

We cover a wide range with our research – and that makes us proud!
Naturally, we feel especially competent when we can create value within the framework of our key subjects. Fraunhofer IMS always stood for microelectronics and electronic systems – and that is why we look at medical technology questions primarily from this point of view. But we are not afraid to think outside the box.

In 2018 we also worked intensively on the interdisciplinary leading projects of the Fraunhofer-Gesellschaft and drove them forward in close cooperation with other Fraunhofer institutes. The main goal of these projects is to turn scientific ideas into marketable products and to develop concrete solutions. An especially successful example is the project "QUILT" (Quantum Methods for Advanced Imaging Solutions) in which we cooperate with five other Fraunhofer institutes, as well as with partners from science and industry from the area of quantum research, and in which we are involved intensively. At Fraunhofer IMS we are working on a single photon detector for "Ghost Imaging" within this project. In 2018 we made considerable progress and took a further step towards the future.

2018 has also been an exciting year for micro- and nanosystems. The division micro- and nanosystems got appointed a new head with Prof. Karsten Seidl, who also has accepted a professorial chair for "Micro- and Nanosystems for Medical Technology" at the University of Duisburg-Essen and is working on new technologies. In the focus of his research are so-called biosensor systems that monitor how organs work and when they have to be assisted. Another core topic is bio nano-sensor systems which can be used to analyze the DNA of cancer cells and to realize individual therapies. With Karsten Seidl we want to strengthen the topic area of bio-sensor technology and expand the group of biohybrid systems.

Consistent to this year's focus there have also been exciting developments at the Fraunhofer-inHaus-Center. Under the new leadership – Wolfgang Gröting has been the manager at the inHaus-Center for over a year now – the focus of the work has been realigned. The areas of dementia, stress and life in old age had particularly formative influence and will continue to do so. In 2019 the realignment of the inHaus1 is likely to ensure additional drive – life in old age and therefore the health aspect will be relevant here as well.

A new aspect has been the focus on the increased cooperation with young start-up companies that originate in the health care sector. The cooperation with the company ichó systems is a good example for fruitful and profitable networking. The young company from Duisburg developed an interactive therapy ball for people with dementia and has been named one of the most innovative start-ups in Europe. We have been supporting ichó systems on their way since last year and are mutually benefiting from this cooperation.

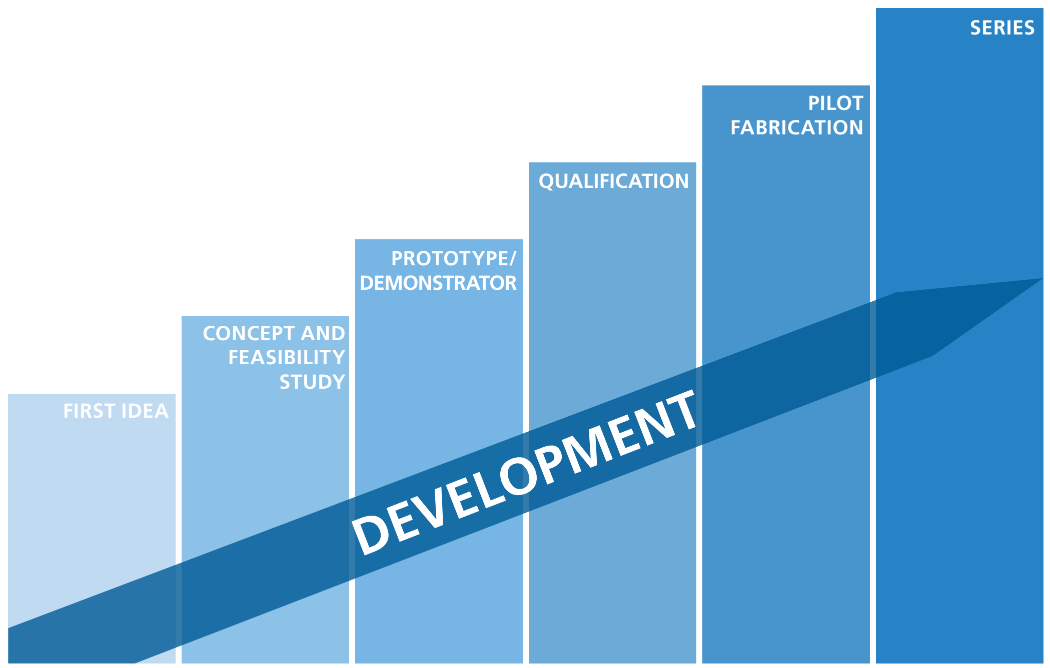
From an economic point of view we have been successful. Industrial income has increased since last year, while public revenues at a regional, national and EU level have turned out lower. Overall we are satisfied with our economic success and are looking optimistically into the future.

I want to thank all our employees for their commitment that made the economic and scientific success of the year 2018 possible. They have played a big part in going well-positioned into the year 2019, despite facing a lot of new challenges. I also want to thank our customers and partners for the excellent cooperation in the last year, for their trust in our institute, our work, technologies, ideas and developments. I am glad that we were able to further expand our existing business relationships. We will do our best to obtain excellent results for them in the future as well and we'll consistently work on new technology questions in electronics.

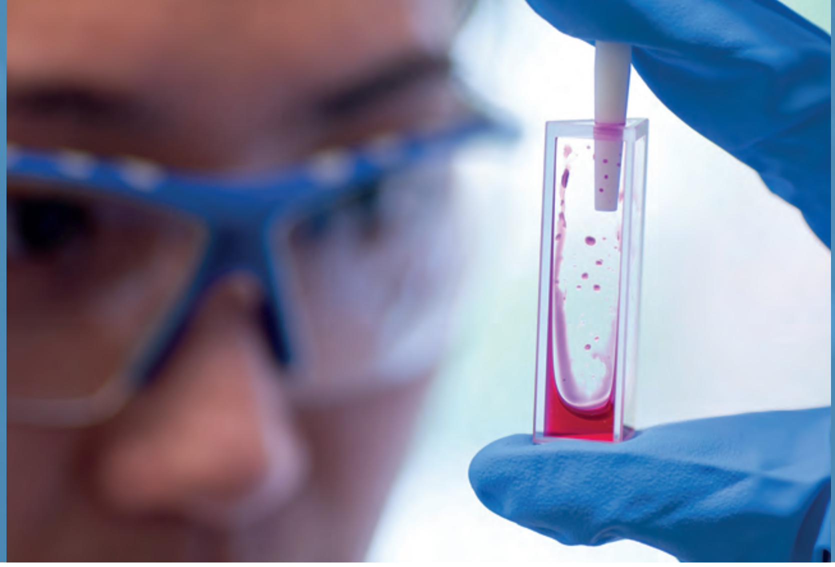
I am looking forward to new and exciting challenges in the year 2019 that we will face with great optimism as usual.

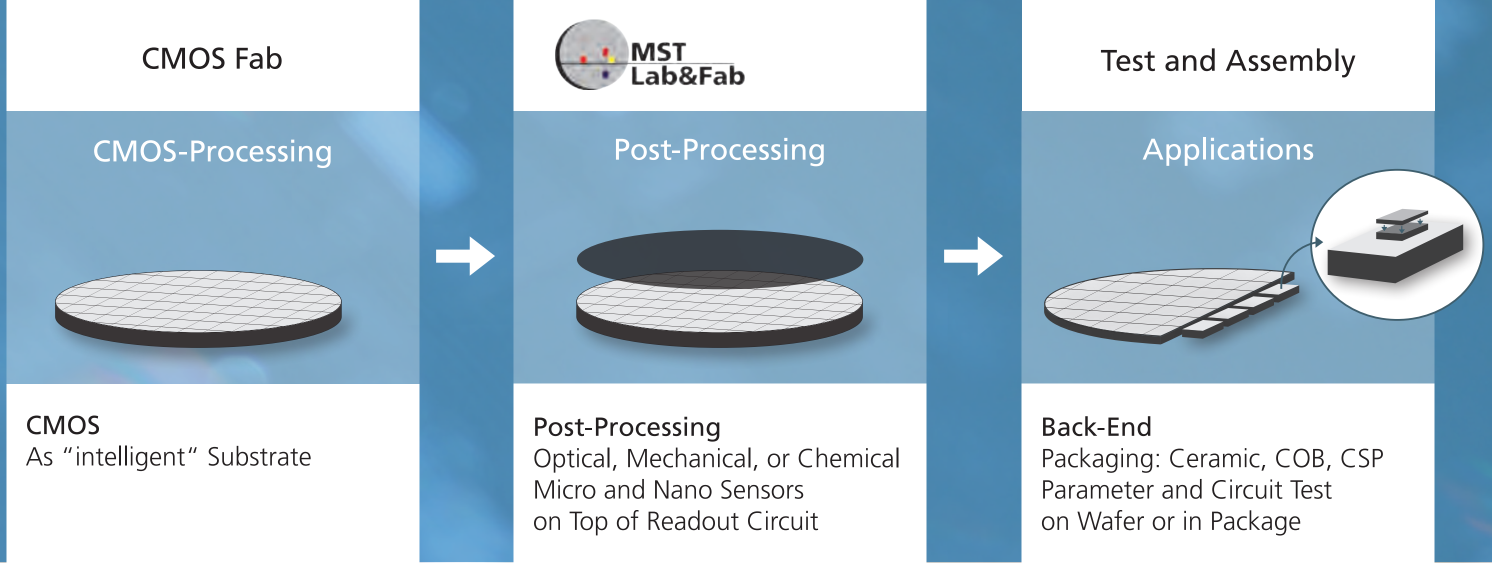
In this chapter

FROM CONCEPT TO PRODUCT



Fraunhofer IMS accompanies you from Idea to Product





Our business units

- *ASICs*
- *Wireless and Transponder Systems*
- *Electronic Assistance Systems*
- *Pressure Sensor Systems*
- *CMOS Image Sensors*
- *IR Imagers*
- *Devices and Technologies*
- *Biohybrid Systems*

Step by step to project success

The way to a successful project is work-intensive and requires good planning. Step by step, the following project phases are passed through.

- *Concept and feasibility studies*
- *Specification and design*
- *Demonstrator development*
- *Prototype development*
- *Qualification*
- *Pilot fabrication (for microelectronic systems)*

Our technological core

- *Semiconductor processes*
- *CMOS and SOI technologies*
- *Microsystems technology*
- *Component and system developments*
- *Nano-(Bio)technologies*

YOUR IDEA – WE WILL IMPLEMENT IT

In the beginning there's your idea or vision for a new product, but you don't know if it is feasible, which costs you will have to face, if there are potential risks and which technology leads to the optimal product. As a research and development institute of the Fraunhofer-Gesellschaft, we offer you our support.

We accompany your development with concept and feasibility studies from the first moment – via specification and design, draft and fabrication of prototypes through to the product qualification. The pilot fabrication of your circuits and ICs is carried out by us as well. With us, you get microelectronics from a single source.

We provide our service and know-how across all industries. Our circuits and systems are especially used where it's all about the creation of unique selling points and competitive advantages for our customers. Then, our customer is able to serve his target market in an optimal way.

Quality pays off
Fraunhofer IMS has been certified according to DIN EN ISO 9001 since 1995. The certificate is valid for all divisions of the institute: research, development, production and distribution of microelectronic circuits, electronic systems, microsystems and sensors as well as consulting in these fields. The CMOS line is certified according to ISO/TS 16949.

Your project success is our mission.

FROM WAFER TO SYSTEM

At Fraunhofer IMS our field of attention has been, since its foundation in 1984, semiconductor technology and the development of microelectronic circuits and systems. The type and bandwidth of our infrastructure is extremely efficient; we have the experience and know-how in our eight business units. During our contract work we focus on strong, efficient and marketable developments. We offer comprehensive technologies and procedures which are applied in almost all industries. Application-specific adaptions to the requirements of our customers are the major focus of our work.

Infrastructure

FRONTEND

CMOS line

Wafer size	200 mm (0.35 µm)
Cleanroom area	1300 m²
Employees	150 in 4 shifts
Capacity	> 50,000 wafers/year

Microsystems technology lab & fab

Wafer size	200 mm (0.35 µm)
Cleanroom area	600 m²
Capacity	5,000 wafers/year

BACKEND

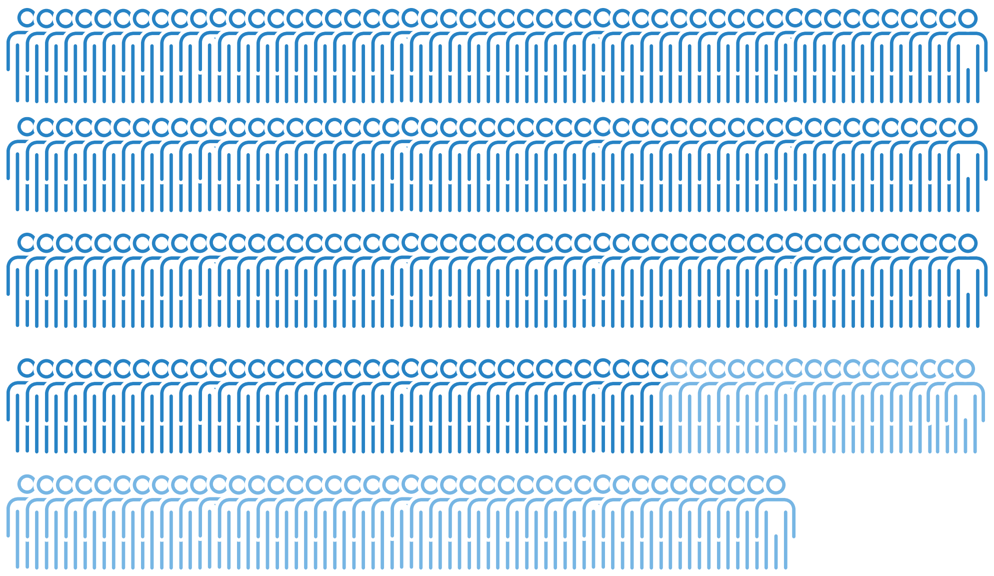
Test and assembly

Wafer size	200 mm
Cleanroom area	1200 m²
Test	5 test systems
IC assembly	Sawing and thinning of wafer, Chip-On-Board Die and wire bonding

Laboratories

Biohybrid sensors	45 m²
inHaus-Center	3500 m²
Laboratory space	800 m²
High-frequency measurement chamber	24 m²

STAFF MEMBERS

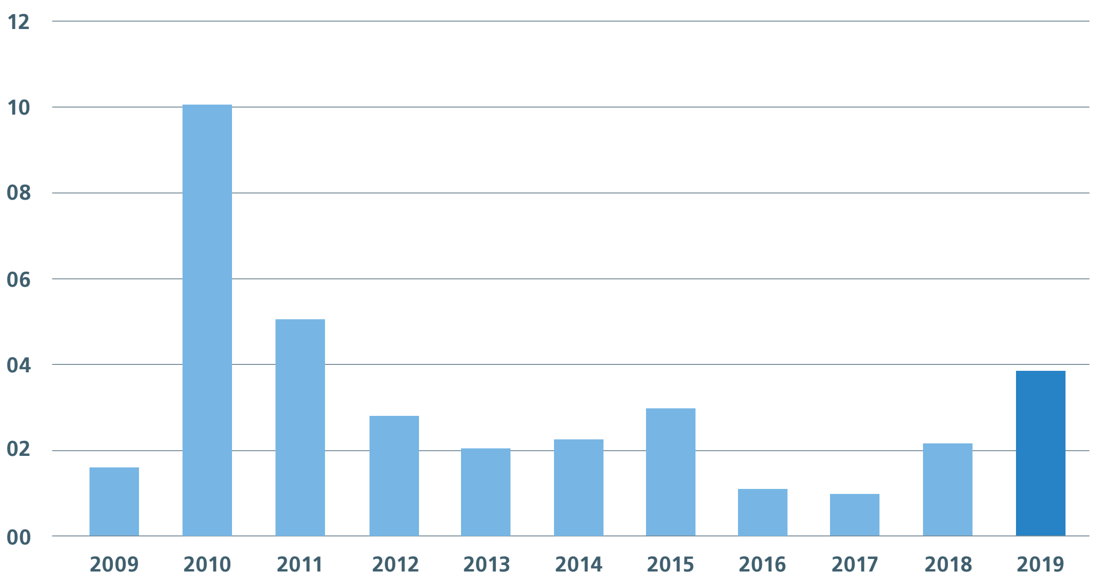


184 Employees 56 Scientific Assistants

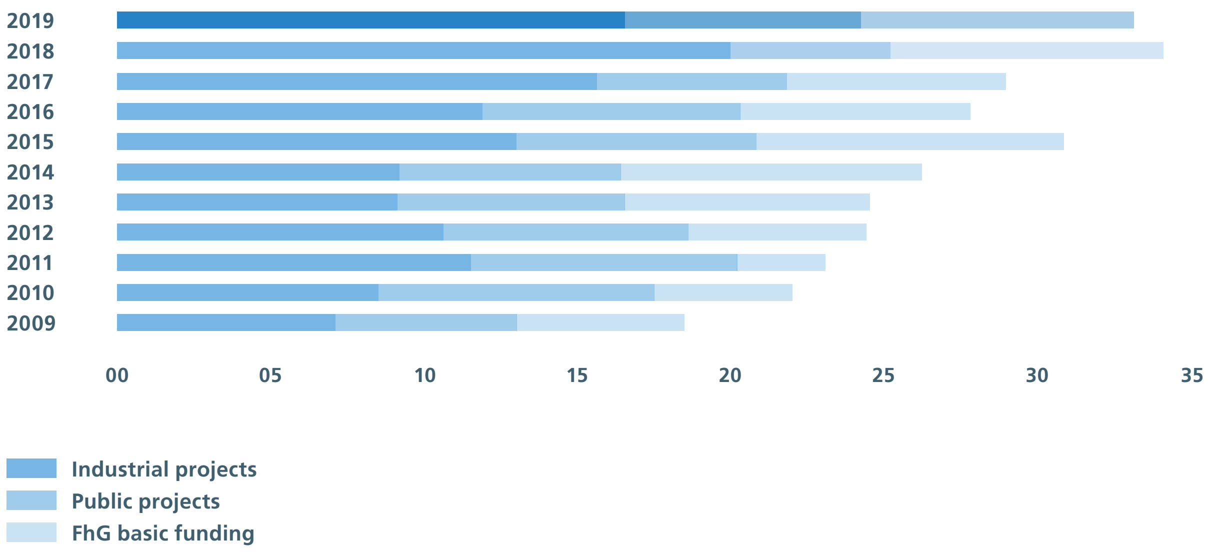
> There is no doubt that we will continue to do outstanding work in our core areas – but we are also not afraid to think outside the box.

Prof. Anton Grabmaier

CAPITAL INVESTMENTS (in million euros)



BUDGET (in million euros)



ORGANIZATIONAL CHART

DIRECTOR
Prof. Anton Grabmaier

DEPUTY DIRECTOR
Prof. Holger Vogt

PRESSURE SENSOR SYSTEMS
Görtz

CMOS IMAGE SENSORS
Brockherde

WIRELESS AND TRANSPONDER SYSTEMS
Dr. vom Bögel

ASICS
Prof. Kokozinski
Dr. Vogt

ELECTRONIC ASSISTANCE SYSTEMS
Kemmerling

DEVICES AND TECHNOLOGIES
Kappert

IR IMAGERS
Dr. Weiler

BIOHYBRID SYSTEMS
Prof. Seidl

INHAUS-CENTER
Gröting

ADMINISTRATION SERVICES
Benninghoff

MARKETING, SALES
Bollerott

QUALITY ASSURANCE
Kelter

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Universität Duisburg-Essen

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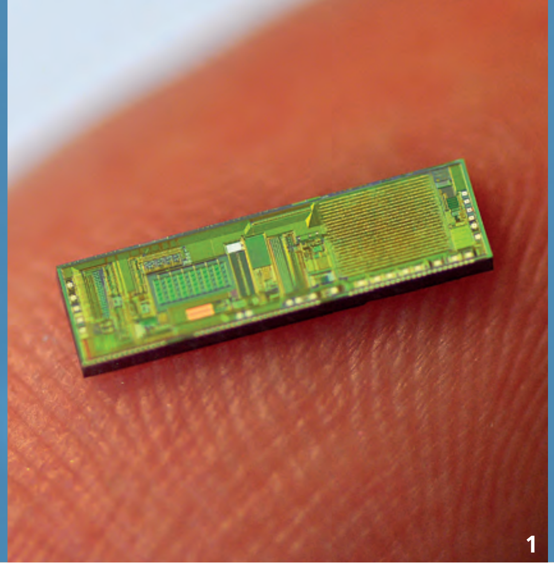
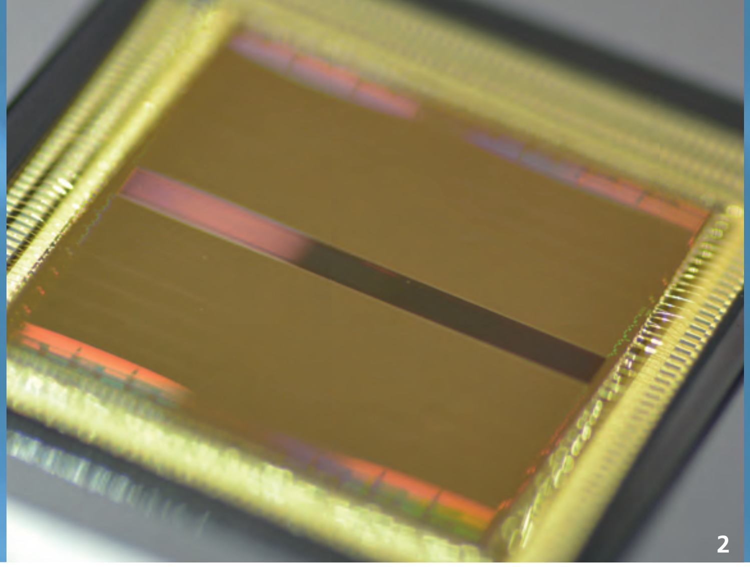
BIOTRONIK SE & Co. KG

Matthias Wulfert
Niederrheinische Industrie- und Handelskammer

Prof. Frank-Hendrik Wurm
Universität Rostock

In this chapter





PRESSURE SENSOR SYSTEMS

The trend in microelectronics is towards smaller and smaller sensors, even in pressure sensor technology. Our customer-specific developments are not only energy efficient and capable of high performance, but due to their minimal size, also implantable in the human body if required.
For this reason beyond classic applications for pressure sensors, new business fields are opening up, particularly in medical engineering.

By producing these sensors as integrated capacitive pressure transducers in surface micromechanics, a connection with any kind of signal processing is possible, according to the specific use.
Our miniaturized pressure transponders can also be used for metrological applications in the industry or for measuring tire pressure in the automotive industry.

Due to the integration of the sensor and signal processing in one ASIC, Fraunhofer IMS is able to respond to all possible requirements and applications and can offer customized solutions for the future.

Supply and services/technologies

- *Technology for monolithic post-CMOS integration of MEMS pressure sensors on fabricated semiconductor wafers*
- *Customized development of capacitive pressure transducers*
- *Digital and analog interface*
- *Transponder ability due to low power requirements*
- *Integrated temperature sensor*
- *Biocompatible and resistive layers for MEMS pressure sensor encapsulation*
- *Customizable packaging, testing and calibration*

1 *Pressure sensor for medical implants*

CMOS IMAGE SENSORS

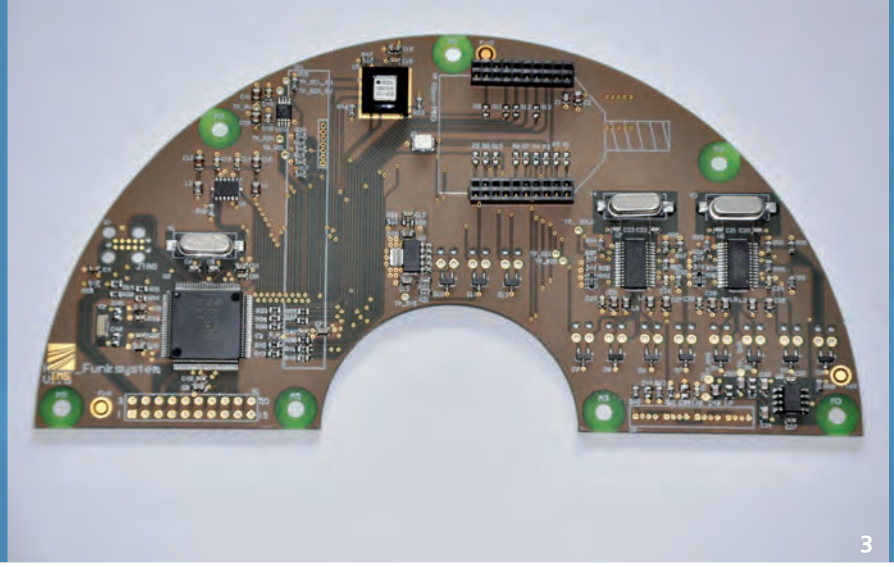
Optical sensors for image capturing based on CMOS technologies have reached a level that exceeds the performance and quality of established CCD sensors. The development of specific photodetectors or the special treatment of the silicon surface has notably improved pixel attributes. Our experience with the design of CMOS photo detectors and image sensors, as well as their production and characterization, enable us to offer customized solutions.

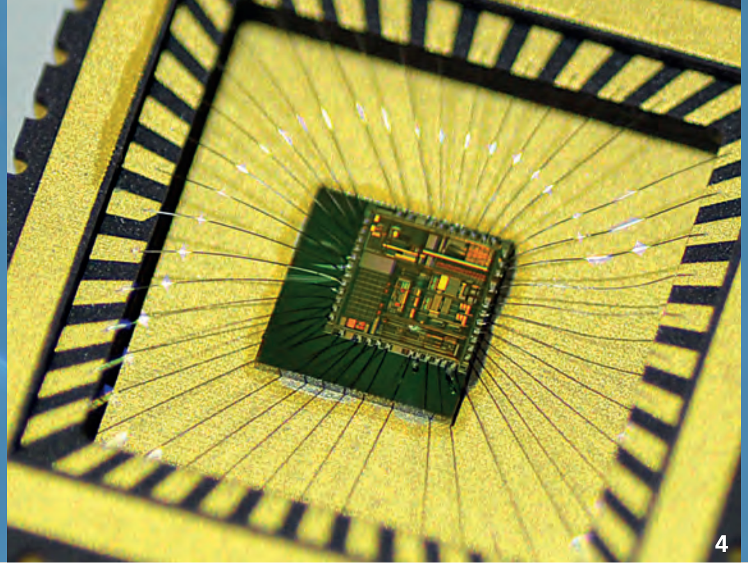
Our customers benefit from a 0.35 µm "Opto" CMOS process optimized for imaging applications. Photodiodes with low dark current and low noise can be integrated with color filters, micro lenses as well as stitching. Our developments cover a broad spectrum from x-rays to EUV, UV and the visible spectrum up to infrared.

Supply and services/technologies

- *Customized line and 2-D sensor arrays*
- *SPAD pixels for time-of-flight, spectroscopy and more*
- *Stitching for large area sensors*
- *Wafer bonding and backside illumination*
- *Color filters and micro lenses*
- *Customized packaging and testing*
- *Pilot manufacturing in 0.35 µm "Opto" CMOS process*

2 *xposure CMOS line scan sensor*





WIRELESS AND TRANSPONDER SYSTEMS

Production can be controlled – but we need to optimize maintenance, minimalize wearing and produce quality documentation automatically. This is possible, if detailed data about identities and measurement values of tools, components and machines is available.

IDs and sensor data for digitalization in the medical area is required from diagnostic and therapy equipment, but also vital data of the patient from inside their body. In these and many other applications the objects of interest are moving, rotating or in other ways difficult to access by wired sensors. Solutions based on passive sensor transponders and energy harvesting can provide important contributions for the implementation of the "Internet of Things" (IoT) in various fields of application like "Industry 4.0", smart buildings or agriculture.

In combination with other technologies, such as sensors and embedded systems, Fraunhofer IMS provides all technologies that are relevant for the design and development of "Cyber Physical Systems" (CPS).

Supply and services/technologies

- *Active and passive systems*
- *Sensor transponder integration*
- *Development of demonstrators and prototypes*
- *Customized adaption*
- *Radio frontends for LF-, HF- and UHF-frequencies*
- *Systems with high ranges*
- *Systems for "difficult" environments*

3 *Smart Sensor Board for Wireless Infrastructure Monitoring System*

ASICS

"From the concept up to the pilot fabrication" is the maxim of Fraunhofer IMS. We provide our customers professional analogue or mixed signal ASIC design solutions – from the concept up to verified silicon for "ready to use" ASIC products for the application in several areas.

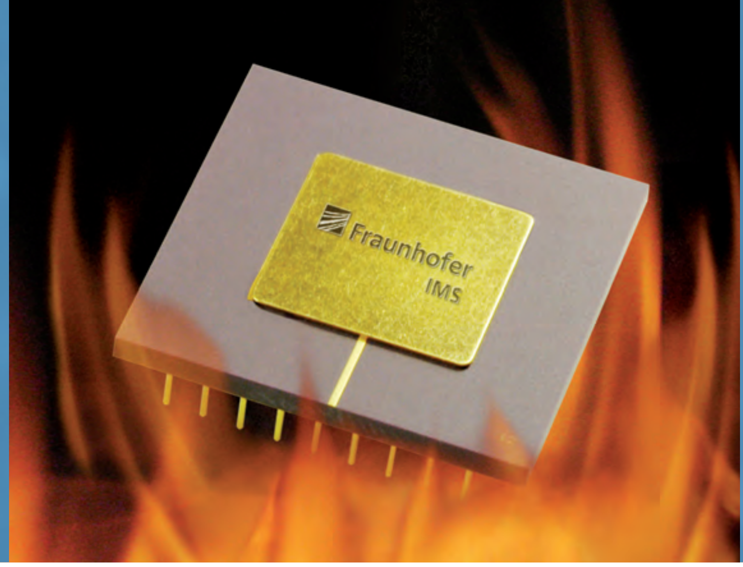
In doing so, we support our customers with our large system know-how. In addition to implementations in various standard CMOS technologies, we especially allocate design and technology solutions for medical applications, harsh environments, safety & security and sensor systems applications.

Special circuit parts or sensor system components are individually and custom-designed and integrated with standard components like sensor readout, signal processing, interface components or embedded micro controllers on an IC.

Supply and services/technologies

- *Sensor interfaces*
- *Analogue ICs*
- *Signal conversion*
- *Digital signal processing*
- *Integrated sensors*
- *Customized packages and tests*
- *Energy-optimized solutions*
- *Pilot fabrication*

4 *MEMS accelerometer readout IC*



HIGH TEMPERATURE ELECTRONICS

Microelectronics is a key technology in many everyday products. Also numerous industrial applications, like deep-hole drilling, geothermal energy, aero engines or stationary turbines demand for integrated electronics for use especially in sensors or power electronics. Standard electronics typically based on CMOS integrated circuits are limited to temperatures of up to 125 °C or in special cases up to 175 °C and are not applicable for these applications without additional measures like cooling.

Fraunhofer IMS has overcome this limit and provides a solution based on a dedicated high temperature Silicon-on-Insulator (SOI) CMOS technology. The main advantage of this technology is a strong decrease of leakage currents at high temperature operation, which enables integrated circuits for use in high temperature applications up to 300 °C.

The available SOI CMOS technology features a minimal characteristic feature size of 350 nm which is suitable to realize mixed signal integrated circuits including small system on chips (SoC). High temperature optimized devices and a tungsten metallization instead of the typically used aluminum metallization allow reliable operation even at high temperatures.

Additionally to the high temperature integrated circuits Fraunhofer IMS offers high temperature Micro-Electro-Mechanical Systems (MEMS) based sensors like pressure or vibration sensors. Further sensors are in development.

Smart integrated sensors for high temperature applications become reality with the Fraunhofer IMS high temperature SOI-CMOS and MEMS technology.

Supply and services/technologies

- *High temperature SOI CMOS technology*
- *High temperature MEMS*
- *Concept development and system specification*
- *Mixed signal integrated circuit design*
- *Application support*
- *Pilot fabrication in our CMOS facility*
- *Assembly*
- *Test and verification*
- *Reliability analysis*
- *Feasibility studies*

ELECTRONIC ASSISTANCE SYSTEMS

People spend a large part of their lives in rooms and buildings. This includes not only their private lives, but also special care as they get older – at home or in nursing homes – as well as their entire working lives. Here, operating costs, a flexible adaptation to user requirements and the feel-good factor are becoming increasingly important. But even if work procedures have become more complex and challenging, there is little time and workforce is expensive or hard to get.

Electronic assistance systems are able to assist and contribute to a user-friendly, time and resource-efficient interaction with complex tasks. Electronic assistance system solutions by Fraunhofer IMS bring that added value of these systems into work and living environments as well as into other areas of application, e.g. medicine and leisure.

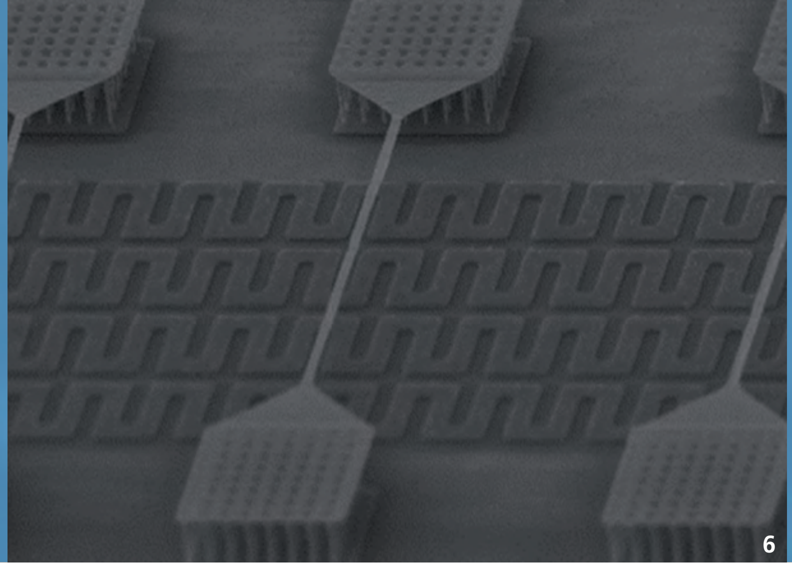
For our customers we are therefore able to concept and develop electronic assistance systems based on already existing technologies and integrating them into one complex system to offer competitive solutions from a single source.

Novel electronic assistance systems can then be evaluated under realistic conditions in the application laboratories of the Fraunhofer inHaus Center. In addition, Fraunhofer IMS supports customers with the development of related innovative business models to be perfectly tailored to the market.

Supply and services/technologies

- *Hardware and software development*
- *Planning and consulting*
- *Building integration and practical tests*
- *Heterogeneous interconnection (also wireless)*
- *Field tests for longterm monitoring*

5 *EQUIFit Demonstrator*



6 *Free standing 3-D nanostructure based on ALD*

DEVICES AND TECHNOLOGIES

Our in-house CMOS line is the technological base of our institute. It provides professionally operated and automotive proven quality in a robust 0.35 µm technology on 200 mm wafers. At Fraunhofer IMS, all processes are developed in-house and augmented with additional process modules, such as special optical devices, integrated pressure sensors or high voltage components. Silicon-on-Insulator (SOI) CMOS technologies are available for high voltage or high temperature integrated circuits.

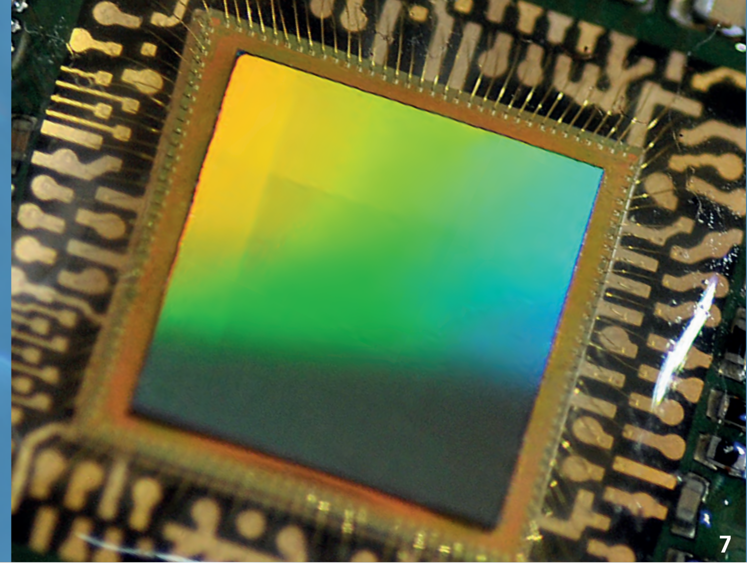
Complementing the CMOS line Fraunhofer IMS operates a separate microsystem-technology line (MST Lab & FAB) which allows post-processing of CMOS wafers and integration of micromechanical structures on top of the wafer in order to create new components, e.g.:

- 3D-integration based on chip-to-wafer or wafer-to-wafer bonding technology is available to facilitate backside illuminated optical sensors
- Sacrificial layer technology in combination with atomic layer deposition (ALD) is used to realize nanostructures on top of a CMOS integrated wafer used e.g. as chemical sensors or as electrodes to contact biological cells
- Deep silicon etching is applied to realize membrane or cantilever based sensors

The overall aim of these developments is compact, “intelligent” microsystems.

Supply and services/technologies

- *CMOS technology and device development*
- *MEMS technology and device development*
- *Microsystems on top of CMOS integrated wafers*
- *Process and device development and consulting for the semiconductor industry*
- *Pilot fabrication of CMOS and MEMS*



7 *Uncooled IR detector for thermal imaging*

IR IMAGERS

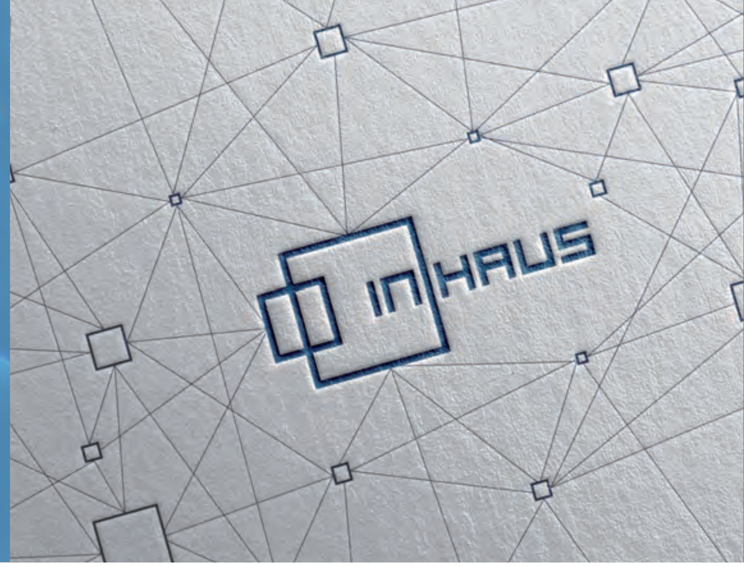
Infrared imagers “see” in a wavelength range from the mid to longwave infrared (3µm – 14µm). These uncooled thermal image sensors are called focal plane arrays and are one- or two-dimensional lines of IR sensitive pixels (microbolometers). They are based on radiation sensitive structures and use silicon technology (post-processing) to be integrated as a microchip on top of CMOS readout circuits. That's how complete image sensor chips are developed and fabricated.

Our customer-specific applications are utilized in the automotive industry, where driver assistance, night vision and pedestrian detection are focal points of development.

Similar safety aspects, e.g. personal security or contactless temperature measurement technology in process monitoring, are also important to the industrial sector. In the sensor system, the gas analysis is of increasing interest. Further applications include thermography in buildings or in medicine, but also border and building security.

Supply and services/technologies

- *Customized uncooled IR Imager (IRFPAs)*
- *Complete onchip digital signal processing*
- *Cost-effective chipscale packages*
- *IR development and pilot fabrication*
- *Customized packaging, testing and calibration*



BIOHYBRID SYSTEMS

The specific and highly sensitive detection of biomolecules such as enzymes, antibodies, DNA or microorganisms without extensive laboratory work is highly demanded for next-generation applications in the field of medicine, life science, environmental and food technology. Sophisticated detection methods are replaced by miniaturized biosensors that transduce the recognition of an analyte into a measurable, electrical signal.
We use advanced micro- and nanofabrication technologies to develop ultrasensitive and cost-effective biosensors that can be customized to the requirements and needs of the customers' applications. We offer biosensors based on electrical, electrochemical, piezoelectric and optical transducers. Due to their small size these biosensors can also be integrated into more complex systems such as lab-on-chips. This is particularly interesting for point-of-care testing (POCT) devices or real-time monitoring systems of metabolites (e.g., glucose, lactate).

Supply and services/technologies

- *Customized biosensors*
- *Transducers (e.g. electrical, electrochemical, piezoelectric, optical)*
- *Microfluidic system design*
- *Bio-lab for bio-functionalization and characterization (e.g. atomic force microscopy (AFM), surface plasmon resonance (SPR), fluorescence microscopy)*
- *Customized packaging and testing*

8 *Integrated multi-parameter sensor chip for in situ monitoring of biotechnological processes*

INHAUS-CENTER

The Fraunhofer-inHaus-Center is an innovation think tank that is unique throughout Europe.
Several Fraunhofer institutes, numerous business partners as well as young start-up companies combine their potential in cooperative research and development work on a mutually beneficial basis. At the inHaus-Center we develop, test and demonstrate innovative systems and products in cooperation with our network partners – our focus is on the areas smart home and connected healthcare with human beings and their needs at the center of attention.

In the inHaus application laboratories we test prototypes in realistic environment surroundings before they are taken into operation. The Living Lab HealthCare, for example, is a demonstration site of about 600 square meters that allows for a large variety of different hospital and assisted living scenarios to be captured and implemented – a centerpiece of this creative innovation center. At the same time our innovation platform is enriched by very interesting start-ups that complement the inHaus-Center with novel products and services for health and care. Our range of offered services is completed by the subject area SmartCity with the aim of liveable city development.

The Fraunhofer-inHaus-Center consists of inHaus1, a semi-detached house, and inHaus2, a utility building. At the inHaus1 we promote projects around smart home (security, energy and comfort) as well as healthy living in old age (human-technology interaction, assistance systems). At the inHaus2 we work predominantly on technical solutions for hospitals and nursing homes along with innovative health topics for autonomous living in old age.

Supply and services/technologies

- *Health and care*
- *Smart living*
- *Energy efficiency*
- *Room and building systems*
- *Sustainable value creation*
- *Innovation platform health, care and SmartCity*

In this chapter

1

EQUIVERT – DIZZINESS TRAINING SOLUTION

One in three individuals will have to cope with dizziness and require treatment at least once in a lifetime. What makes dizziness and its prevalence especially dangerous is that it often develops at old age when tripping and falling yield an especially serious danger. Yet, also younger humans can be affected by dizziness, for example following a virus infection of the inner ear. For all of these cases the newly developed device EQUIVert offers a non-invasive, no-side-effects solution for therapy and diagnosis.

In a completely healthy human being, equilibrioception bases mostly on the information delivered by the inner ear or, more precisely, the vestibular system. This vestibular system is able to identify rotational as well as translational acceleration and by this provides vital information about the position and rotation of the head. With this sensory information the brain will automatically calculate counter movement of the body balancing it out or will adjust the picture as perceived by the retina so that it is always pointing “upwards”, for example.
Interestingly and at the same time fundamental to the way EQUIVert can help treat dizziness is that the condition of a disturbed vestibular system will cause the affected person to feel nauseous when moving fast. The presence of nausea only when moving while the vestibular system is not able to detect movement anymore indicates a very important fact: It is not only the inner ear that helps to balance but in fact it is a whole system that creates the sense of position. Thus the nausea described above is an effect of this complicated system not working together perfectly (similar to the effects of alcoholic intoxication) or even giving contradictory individual results (For example inactivity of the vestibular system while movement is perceived by the eyes; this sensation can be modelled by a quick series of pirouettes) thus irritating the brain.

In addition to the vestibular system and visual input the equilibrium system is able to access a range of position receptors in joints and muscles as well as parts of the central nervous system to calculate the position and status of movement. The brain is even powerful enough to adapt in a way that enables for a safe feeling of balance without needing the vestibular system and instead using the other components offered more. This means that all patients suffering from a form of vestibular dysfunctionality are able to outweigh its effects by learning how to read the other sources of balance-related information better.

EQUIVert can support the patient during just that learning process. Fraunhofer IMS together with the University of Duisburg-Essen, the company GED and the society of ear, nose and throat specialists HNOnet-NRW has identified methods of treatment and diagnosis that are non-invasive, physiologically close to the ideal case and certified as medically sensible and combined those in an affordable, user-friendly system.
This system consists of three individual parts. First, there is the training device EQUIFit which looks much like conventional headphones. In reality however, EQUIvert features highly sophisticated technology. Its individually designed small embedded system consists of a microcontroller, accelerometer and rotation rate sensor, audio amplifier, memory, data interface and mobile power supply with rechargeable battery.

EQUIFit is what the user or patient will work with mostly and will support them during the central neural learning processes of adapting to balance without using the vestibular system. As described before this could theoretically be done by using the eyes or position receptors more and indeed patients will often focus on developing a strong visual connection to their environment to balance. This adaptation is not optimal as it only works as long as sufficient light is available.

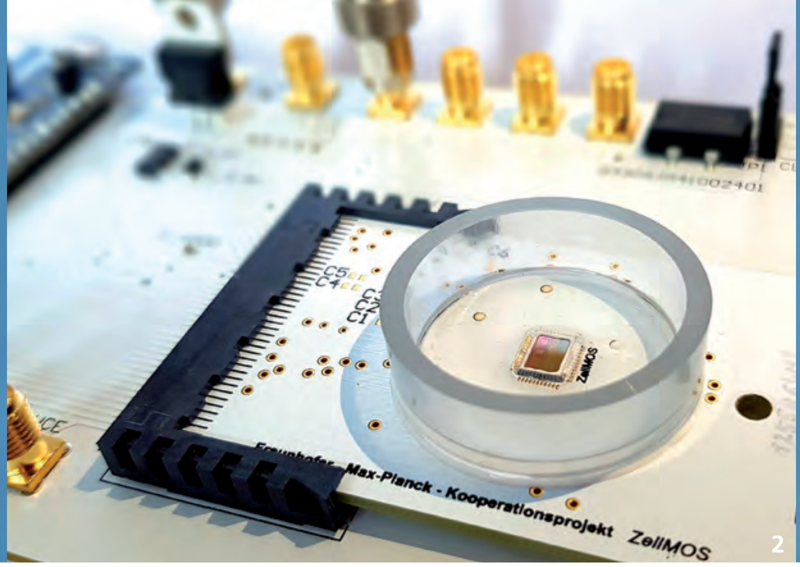
What is new about EQUIFit is that it allows for therapy that is completely independent of visual input. By utilizing the accelerometer and rotation rate sensors, the headphones make imbalance hearable for the patient. A good comparison is the parking assistant in a car which also gives acoustic feedback where the eyes cannot help sufficiently. So, in this case, the patient will hear an acoustic signal coming from the exact direction in which they are, falsely, leaning. This models the function of the vestibular system neurobiologically similar to the ideal, as the acoustic signal will of course be transmitted by the auditory nerve that is strongly connected to the nerve transducing the vestibular system’s information.

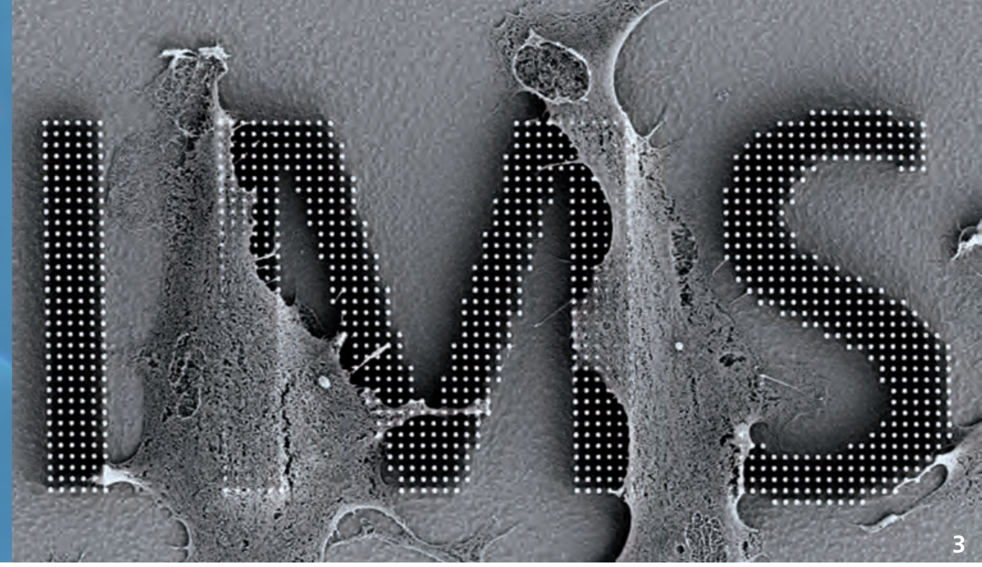
EQUIFit also features a pre-installed training plan with a number of different possible exercises. These will be chosen automatically, based upon an individual and self-adjusting analysis of the patient's abilities. Instructions are given interactively through a novel intuitive acoustic and gestural operating interface. So, for example, EQUIFit switches on automatically once picked up and responds to nods or head-shaking by repeating instructions or adjusting the volume. EQUIFit is especially user-friendly and has a low price, especially compared to other forms of therapy available. This means that a patient can purchase the device themselves and then train more often at home without having to visit the doctor. As this repetition in small time intervals is how a neural learning process happens best, the therapeutical success will be greater than in comparable therapeutical devices.

The effect of the therapy as well as the overall state of illness of the patient can be analyzed by the EQUIMedi device. This is a device similar to the EQUIFit to be installed in a doctor’s office. It is equipped with a hard-wire connection to the physician’s computer. Before, an assessment of the patient’s stability or proneness to imbalance could only be done visually and was subject mostly to the doctor's opinion. EQUIMedi instead collects accurate and comparable values with the built-in sensors.
In addition, a software package EQUISoft was developed that can process the collected data. It computes relevant parameters like average angular velocity and produces a visual output via traffic light symbol that is easy to read by the doctor. This makes first-time evaluation more precise and allows for diagnostically conclusive long-time monitoring.

All this ensures that EQUIVert is a fast, easy-to-use and cost-efficient alternative to standard devices while even giving more relevant information. This makes EQUIVert interesting not only for the patient but also for physicians.
In the future, the EQUIVert system is going to be improved even further and new functions will be added. A smartphone application with access to the patient's device via NFC is being prepared.

1 *EquiFit – patient device*





BIDIRECTIONAL INTRACELLULAR CONTACT OF BIOLOGICAL TISSUE ON CMOS

The intercellular communication processes in healthy organisms as well as in tumor tissue have been studied for decades but nevertheless not understood in detail. In order to achieve new insights in electrical signal processing of single cells as well as cell networks, it is desirable to have a connecting device which is capable of processing biological signals with a high signal-to-noise-ratio.

In the Fraunhofer-Max-Planck cooperation project ZellMOS, a multifunctional device for measuring and stimulating electrical signals with increased signal strength and decreased noise rate is fabricated. Therefore, vertical nanoelectrodes that are capable of measuring intracellular signals and a CMOS integrated circuit are developed. The nanoelectrodes allow an intracellular detection of cellular activities not attenuated by the lipid bilayer. Concurrently, the integrated circuit executes amplification and digitalization in adjacency to the signal's origin reducing the occurring noise and enabling real time imaging of the electrical signals. Thus the combination of CMOS technology and post-CMOS integration of nanoelectrodes results in a device which can lead to novel progresses in biomedical research as well as in the development of applications in implant or sensor technology.

The CMOS integrated circuit (see Fig. 3) consists of a 16x16 array of planar micro electrodes with a diameter of 20 µm each. It includes circuitry for stimulation and recording of electrical signals, a digital section for control and an SRAM memory. Each electrode can be selected via switches to record or stimulate electrical cell signals. In stimulation mode, current controlled stimulation in the range of ± 1 mA or voltage controlled stimulation up to 1 V can be applied with high resolution and accuracy. In recording mode, the electrode potentials are buffered via source follower circuits under each electrode. The signals are amplified and digitized by one low-noise-amplifier followed by one analog-to-digital-converter per column. This enables a real-time imaging of the complete array with a maximum sampling rate of 32 kS/column and an overall framerate of 2 kHz for full frame recording. SPI interfaces and the designed software allow user-friendly control and read out of the chip.

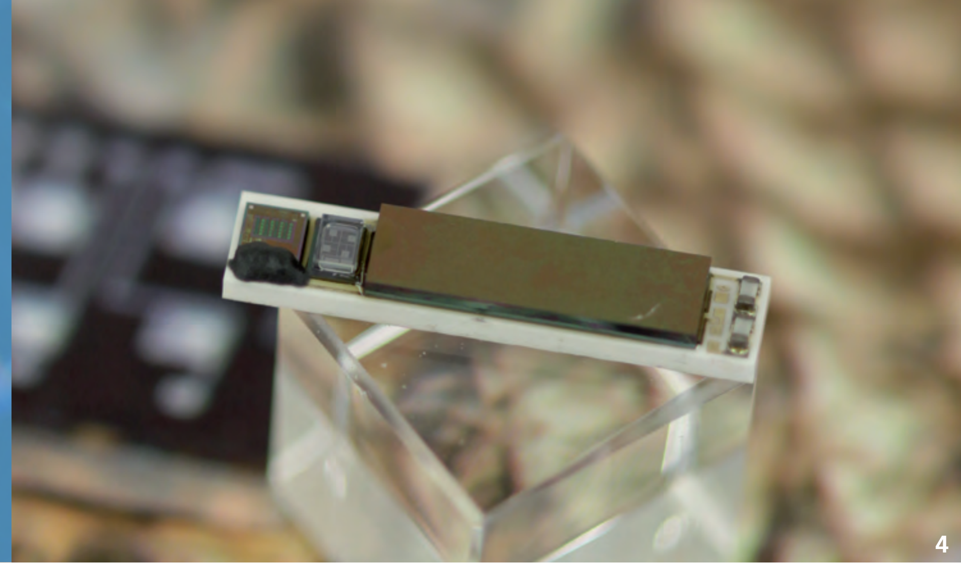
Atop of each micro electrode, nanoelectrodes are accurately placed. In order to measure even small signals of single cells, an intracellular contact is realized via vertical, hollow nanoelectrodes with a diameter of 200 nm and a height of 2 µm. The electrode tip, consisting of a noble metal is tunable in shape and diameter. It can penetrate the lipid bilayer while the rest of the electrode is electrically insulated by a high-k material. The developed fabrication technique, suitable for post-CMOS integration, deftly combines an advanced sacrificial layer process with atomic layer deposition. Therein a template in amorphous silicon is structured via deep reactive ion etching and filled by insulation and electrode material subsequently. The different material properties when removing the sacrificial layer are utilized in a multi-step release process. This offers the opportunity to leave the nanoelectrodes partly encapsulated at a well-defined height of e.g. 0.5 µm. Particular spacing techniques are added to form the template and thereby the resulting nanoelectrodes. Specifically, the electrode diameter can be reduced and the tip can be tapered by post-lithographic spacing techniques. Due to the variation options, it is possible to tune the nanoelectrodes in order to optimize the electrical and mechanical contact to the cell interior and to the underlying CMOS electronics.

The so produced nanoelectrodes can then be applied to investigate the mechanical and electrical contact to different electrogenic cells. Therefore the sensor's surface is bio-functionalized and different cell types like normal rat embryonic kidney cells are cultured atop (see Fig. 4). The adhesion and communication processes of the cells are studied in detail in experiments by Max Planck Institute for Medical Research and Heidelberg University Hospital. They include studies of coupling processes between biological tissue and electronic surfaces and electrical communication processes of single cells and cell networks. Recently discovered intercellular communication pathways, the so called tunneling nanotubes, can be further investigated by the intracellular device.

The overall system combines the strengths of an intracellular contact and a fully integrated signal processing. It can be applied in the field of in-vitro cell research as a promising approach for solving scientific questions in biomedicine. Future developments of the system may lead to advanced bio-sensor technologies and novel approaches for electronic implants.

2 *Assembled CMOS-MEA for electro-physiological measurements*

3 *Normal rat kidney cells on 3D-nano-electrodes*



MONITORING OF HEMODYNAMIC PARAMETERS BY A MULTI SENSOR IMPLANT

Funded by the nation-wide Fraunhofer Lighthouse Project "Theranostic Implants" researchers from the Fraunhofer Institutes IMS, ENAS, IAP, IZI-BB and IGB developed a miniaturized multi sensor implant for hemodynamic monitoring. This allows for the early detection of critical symptoms so that medical treatment can be initialized immediately and costly hospitalization can be avoided.
The implantable multi sensor system presented consists of five sensor components, a multi-functional transponder ASIC, a ceramic circuit board with integrated antenna coil for wireless energy and data transmission and passive components.

A monolithically integrated surface micro-mechanical pressure sensor allows monitoring pressure changes in cardiovascular regions with a resolution of 0.2 hPa and a sampling rate of 90 Hz. Due to the capacitive measuring principle low power consumption is achieved. After calibration, deviations are below 1.8 hPa within an operating range between 800 hPa and 1400 hPa and a temperature range of 20 °C to 44 °C.

Even though the pressure sensor promises high accuracy, disturbances, which result from a changing position of the patient or temperature deviations, interfere with the pressure measurements. In order to detect and subsequently compensate these side-effects, a miniaturized acceleration sensor calculates the inclination of the patient in two axes while a temperature sensor unit monitors the patient's temperature.
The temperature sensor and additional voltage and impedance sensors are integrated into the multi-functional transponder ASIC. The voltage sensor is implemented for controlling the telemetrically provided voltage for error-free operation of the sensor components. The impedance sensor monitors the water amount within the encapsulation material on the surface of the implant.
Since active implant systems have to be constructed according to very strict limitations regarding size or toxic substances, powering by battery is not desirable. Hence, the system presented utilizes a wireless power supply and data transmission solution based on inductive near-field coupling at a frequency of 13.56 MHz. The antenna coil on implant side is integrated within the ceramic circuit board which enables a high integration and miniaturization level for the whole system.

Telemetric communication with extracorporeal electronics, power supply, sensor signal processing and storage of ID and sensor calibration data are managed by the multi-functional transponder ASIC.

Each component of the implantable multi sensor system is simulated and designed in such a way, that very low power consumption allows telemetric operation distances up to 15 cm. Preliminary experiments showed energy transmission distances of up to 10 cm.
Most implantable and medically approved systems are encapsulated by metals, such as titanium, which demonstrate biocompatibility and outstanding water barrier properties. Nevertheless, the bulky and inflexible housings are a big drawback for miniaturized implants. Hence, there is an urgent need for new encapsulation techniques which provide biocompatibility, long-term functionality and a miniaturized encapsulation volume.
In this project, these requirements are achieved by a three-dimensional passivation with a stack of thin ceramic layers for hermetic sealing and biocompatible and flexible polymers for shaping. Both the form and properties of the polymer surface have been chosen for minimized thrombogenicity.
First tests with multi sensor systems with and without polymer encapsulations demonstrated highly comparable pressure, inclination and temperature measurements with similar deviations.

4 *Miniaturized implant for monitoring of hemodynamic parameters*

ENCAPSULATED SENSOR IMPLANT FOR MEASURING INTRAOCULAR PRESSURE

EYEMATE® is an implant that provides actionable information to optimize the therapy for patients afflicted with glaucoma.
The biggest problem with patients suffering from glaucoma is that patients often only notice that something is wrong, when their sight is affected. In the case of glaucoma that is already too late.

The fluid called aqueous humor in the human eye is constantly renewed. Old fluid is replaced by new, but in some people the old fluid is not draining properly so the pressure increases and can permanently damage the optic nerves. This condition is called glaucoma.
People who are afflicted with this disease are generally unaware of the condition in the early stages. People cannot feel the difference in pressure in the eye so it goes unnoticed until it kills enough optic nerve-cells to impair vision.

Intraocular pressure has to be regulated and kept in the normal range to prevent glaucoma from spreading and causing further damage. This can be done with medication, eyedrops or, in advanced stages, with surgery. Choosing the right therapy is critical when treating glaucoma. At that point, the treating physician has to know the pressure level in the eye and its fluctuation over time. Prevailing measurement methods are poorly suited to gather enough data to reveal meaningful insights. The main problem is that these measurements are usually taken in a doctor's office, with too much time elapsing between sessions. Also, pressure can rise to harmfully high levels several times a day, so the likelihood of these readings going undetected is very high. This increases the risk of a physician opting for the wrong therapy.

The intraocular pressure is usually measured with a tonometer, which is directly placed on the patient's eye and dents a 3 mm area to measure the pressure. This procedure has direct contact to the eye, is unpleasant for the patient and can cause side effects such as injury of the cornea. Another option is to use a non-contact tonometer, which operates with air pressure. A short air blast is pointed towards the eyeball. This procedure is less invasive but less precise and therefore is also becoming less commonly used.
So not only do patients consult their eye-specialist when it is already too late to prevent nerve damage, but also the physician does not have the possibility to get all the information needed to choose the right therapy.
Now scientists at Fraunhofer IMS have managed to solve this problem. In a joint effort with Implandata, EYEMATE® was developed – a micro sensor system that enables patients to take contactless pressure measurements of their own eyes at any chosen frequency.

A sensor implanted in the eye gauges pressure and temperature. A handheld reader records, digitizes and displays the result. All the patient has to do is to hold it in front of their eye. It takes the eye's pressure and temperature readings in a matter of seconds – precisely, at any time. With a data pool many times larger than what conventional measurement techniques can gather, attending physicians can apply the right therapy straight away. The device's readings can be downloaded, digitized and uploaded to the cloud. The attending physician can access patient data at any time to check and assess the disease's progression and, if necessary, adjust the therapy on the spot. The patient no longer has to visit the practice to take intraocular pressure measurements and yet gathers more and better information than before. Patients may also access this data directly via a smartphone app, track their intraocular pressure readings and take the appropriate action if the pressure rises to alarming levels. The benefits increase with frequent measurements. The more often the patient uses the reader, the more meaningful the readings and the more personalized the therapy options.

Fraunhofer IMS in Duisburg developed the semiconductor circuit that serves as an intraocular pressure sensor. It is a passive micro sensor activated by the reader. Implandata received CE approval for the sensor system in mid-2017 after the intraocular pressure sensor was validated in a clinical study at several hospitals in Germany. This study has already shown that the device boosts patients' motivation to take regular measurements, leading to improved therapy adherence and compliance. Perhaps even more importantly, it enables the ophthalmologist to personalize the therapy and make the necessary adjustments early in the diseases progression. This protects patients from irreversibly impaired vision.
In April 2018, alongside an initial market launch targeting Germany, Austria, Switzerland, Implandata secured substantial funding to further reduce the sensor implant's geometry and enable even easier surgical techniques to implant EYEMATE®, which will yet again significantly increase market acceptance. In having realized the EYEMATE® system in close teamwork with Fraunhofer IMS, Implandata Ophthalmic Products are now able to advance glaucoma care into the 21st century.

The implanted sensor is a round and flat ring comparable to a normal contact lens, the fine golden coil is enclosed by a clear polymer layer. The thickness is less than half a millimeter and it is only up to 12 millimeters in diameter.
Only strictly controlled and high quality materials are used to build EYEMATE®, it consists mostly of a tiny coil of gold wires that is embedded in silicone which is also used for medical implants. The EYEMATE® is placed right behind the iris, where the patient cannot feel or see it.Only when the pupil is extremely dilated, for example by eyedrops causing this effect, the patient may be able to see a little part of the implant. The sensor itself does not require its own power source, which also prevents the necessity of changing a battery or charging it. Only the moment the passive micro-sensor is activated by the connection to the reader, electrical energy is transmitted via an inductive link into the implant and data is transferred to the reader. Of course the implant can be removed anytime, with an uncomplicated and common procedure, but EYEMATE® is designed to stay in the patient's eye. The sensor has lifetime durability and is completely maintenance free.

5 *Encapsulated sensor implant for measuring intraocular pressure*

RESEARCH FAB MICROELECTRONICS GERMANY (FMD)

ONE-STOP-SHOP FOR THE MICRO AND NANOELECTRONICS

Fraunhofer IMS is one of 13 members of the Research Fab Microelectronics Germany (FMD) – Europe's largest cross-location R&D collaboration for microelectronics and nanoelectronics, with over 2000 scientists.
Within this new type of cooperation, the advantages of two strong and decentralized research organizations – the Fraunhofer-Gesellschaft and the Leibniz Association – are combined with the synergies of a central organization to form the world's most capable provider of applied research, development, and innovation within microelectronics and nanoelectronics. The close intermeshing and the uniform public face allow the FMD to serve not only customers from heavy industry, but also to offer SMEs and startups more comprehensive and simpler access to the next generation of technology.

The German Federal Ministry of Education and Research (BMBF) is funding the setup of the FMD to the tune of 350 million euros, largely in the modernization of the institutes' research equipment. With this funding, the BMBF intends to strengthen the innovativeness of the German and European semiconductor and electronics industry and is supporting the initiative with the largest investment in research devices since Germany was reunified.

A year and a half after the project started on April 6, 2017, a lot of new acquisitions for the modernization of the laboratory facilities at FMD's locations around Germany went into operation. The ceremonial opening of the first integration line was on September 28, 2018, as part of the 1st FMD Innovation Day at the Berlin-based Fraunhofer Institute for Reliability and Microintegration IZM, which hosted the event on behalf of all members.

At around the halfway point of the project, 45 percent of the planned investments for the FMD have been successfully fulfilled.

During the term of April 2017-December 2020 Fraunhofer IMS is receiving 25.5 million Euros which are being invested mostly into new machinery and the structural increase within the research complex. This way research and development work on intelligent sensor chips for novel components can be strengthened. A module-based system is being developed within the framework of FMD which puts various technologies to the test for the implementation of fast and innovative solutions. The goal is to further expand on the strength in the areas of optical and novel innovative sensor systems.

A point of focus is BSI technology (Backside Illuminated Imaging) which allows for the optimal integration of optical array sensors with the CMOS electronics directly below them. One highly topical application issue is, for example, LiDAR for autonomous driving. Furthermore, the field around integration of functional materials for the development of innovative sensor technologies is being strengthened as well. Examples include printing of particular nanomaterials or the biofunctionalization of sensor surface areas. By strengthening these fields, IMS expands its unique selling point within the combined MEMS and CMOS technology and therefore extends its technological base for a variety of optical sensors. These future topics are relevant for Fraunhofer IMS in the short, medium and long term to supply innovative solutions for novel developments for their customers from research and industry.

The setup of the Research Fab Microelectronics Germany is coordinated in a central business office in Berlin, although – true to the concept of a virtual organization – additional locations in Dresden and Munich have also been opened. The FMD business office is the central contact point for potential and existing customers and is thus a significant driver of the development of the business in the area of microelectronics and nanoelectronics.

In order to be able to offer nationally coordinated technology and system developments from a single provider, the technological expertise of the institutes was grouped into six overarching areas – the technology platforms known as Microwave and Terahertz / Power Electronics / Extended CMOS / Optoelectronic Systems / Sensor Systems / MEMS Actuators. Within these technology platforms, the FMD offers the market technological developments along the entire value creation chain, from system design to testing and reliability.

In addition to these technologically oriented offerings, the FMD also offers cross-institute application solutions from a single provider. This offers customers a way of realizing combined and optimized system solutions together the FMD and its institutes. In doing so, the Research Fab works in synergy with the business units of all institutes involved. We, as the FMD, can thus offer our customers a wider range of application solutions.

In 2017, successful project involvements were set up and orders were completed in combination with the FMD. For 2018, projects based on the FMD investments with a volume of 41.1 million euros can already be identified, which represents a significant success at such an early stage. The industrial share of this project volume is already at 30 percent, which highlights the importance of this unique cooperation in German microelectronics research to industry.

In 2019, the Research Fab Microelectronics Germany will enter the next phase. After establishment and structuring of the organization, the largest cross-location R&D collaboration for microelectronics and nanoelectronics in Europe, in partnership with its institutes, will prove its mettle on the market.

Forschungsfabrik Mikroelektronik Deutschland

Fraunhofer Group for Microelectronics in cooperation with Leibniz institutes FBH and IHP

You will find more information about the Research Fab Microelectronics Germany here:

BOARD MEETING

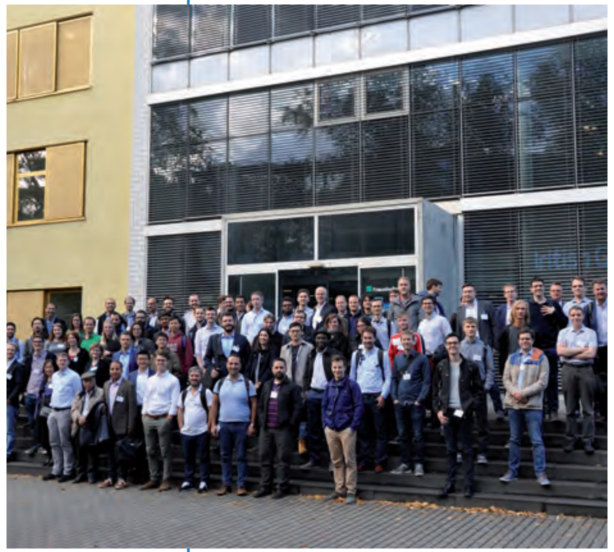
On June 14th our annual board meeting took place. Topics of the meeting include current developments at the Fraunhofer-Gesellschaft, work results of the last year and plans for the future. Another focus point was sensor technology, which was illustrated by various presentations from staff and our board member Dr. Attila Bilgic.

OPEN HOUSE AT THE INHAUS-CENTER

The open day on the subject "From practice – effectively relieving the clinical routine through digitization" featured lectures and tours through the unique living labs of the creative think tank. About 80 visitors took the opportunity to take in new ideas and connect with others to collaboratively research and develop solutions for the care sector.

"GIRLS' DAY"

Following the annual tradition, the research institute Fraunhofer IMS opened its doors once again for the young female scientists of the future. The 15 participants were welcome to learn about the process steps of our microsystem technology laboratory and to carry them out themselves.



NILM CONFERENCE

In the fifth year of the energy disaggregation workshop, people and organizations interested in the topic can benefit from the information presented in various presentations and the opportunity to network with fellow researchers in the industry. The conference-style workshop featured sessions on assorted topics, including data collection, deep learning in NILM, evaluating NILM algorithms as well as innovative applications. An open discussion about these subjects and the future of NILM concluded the successful event at the Fraunhofer-inHaus-Center.

CORPORATE CONFERENCE MEDICAL TECHNOLOGY

The corporate conference is an opportunity for corporations from Japan and North Rhine-Westphalia to exchange experiences and information on challenges in the healthcare sector. Therapy and care concepts are being developed and offer opportunities for corporations from both countries to accelerate progress and to open up the markets. Manufacturers, suppliers and research and health facilities were invited to participate in the discussion.

FAIRS AND EXHIBITIONS

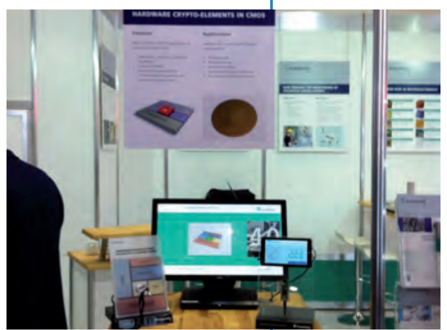
Fraunhofer IMS regularly presents and demonstrates new sensor developments and their practical benefits on national and international trade fairs.

Within these events we bridge the gap between science and industry. We strengthen the relationships with our customers, we establish new contacts and we have a view on the state-of-the-art of microelectronic trends and future demands.
In addition fairs are a great place to get knowledge of customer expectations and obtaining immediate opinion on products.

VISION

Visitors from all over the world came to Stuttgart to find out about machine vision trends in the automotive, medical and consumer sector.

In addition to the LiDAR Camera Owl Fraunhofer IMS presented the uncooled far infrared sensors. Infrared technologies are in great demand for various applications, e.g. people counting and identification, even in poor visibility conditions, to secure the lives of people and animals.



SPS DRIVES

Industry 4.0 will have an impact in manufacturing technologies and therefore new transponder and sensor technologies which guarantee that automation and secure data exchange are on demand. Fraunhofer IMS contributes solutions, e.g. PUF (Physically Unclonable Function), high quality sensors and artificial neural networks for embedded systems.

EMBEDDED WORLD

Embedded World is the international world trade fair for embedded systems. It focuses on secure electronic systems, micro intelligence and artificial neural networks, e-mobility and energy efficiency.
One featured exhibit was the Physically Unclonable Function (PUF) which works with integrated key memories for secure and unclonable identification and communication.

SPIE PHOTONICS WEST

SPIE Photonics West is the world's largest photonics technologies event. It concentrates on optics, photonics, and imaging engineering. Fraunhofer IMS presented the 3D-sensor technology in which latest detectors and systems for Flash LiDAR (Light-Detection-and-Ranging) are developed. The LiDAR Camera Owl comprises a dual line sensor based on SPADs (Single Photon Avalanche Diode) technology. These detectors are used in fast and reliable distance measurements as e.g. in autonomous moving vehicles or industry robotics.

SENSOR+TEST

SENSOR+TEST is the leading forum for sensors, measuring and testing technologies worldwide. It is a long-lasting tradition for Fraunhofer IMS to participate and to show the latest developments in sensor technology.
Systems displayed on the forum include telemetric pressure monitoring of an implantable shunt system for hydrocephalus patients and the "Boost & Fly" wireless power supply system for industry 4.0 sensors.

ARTIFICIAL NEURAL NETWORK FOR PERSON RECOGNITION

Rheinische Post

EYE-MATE FOR NON-CONTACT MEASUREMENT

elektroniknet.de

DIGITIZING FOR MACHINING

industrieanzeiger.de

PLATFORM-INDEPENDENT NEURAL NET FOR SELF-LEARNING MICROCONTROLLERS PROCESSING SENSOR DATA

Electronics Weekly

TRAINING THE DIZZINESS AWAY

medizin-aspekte

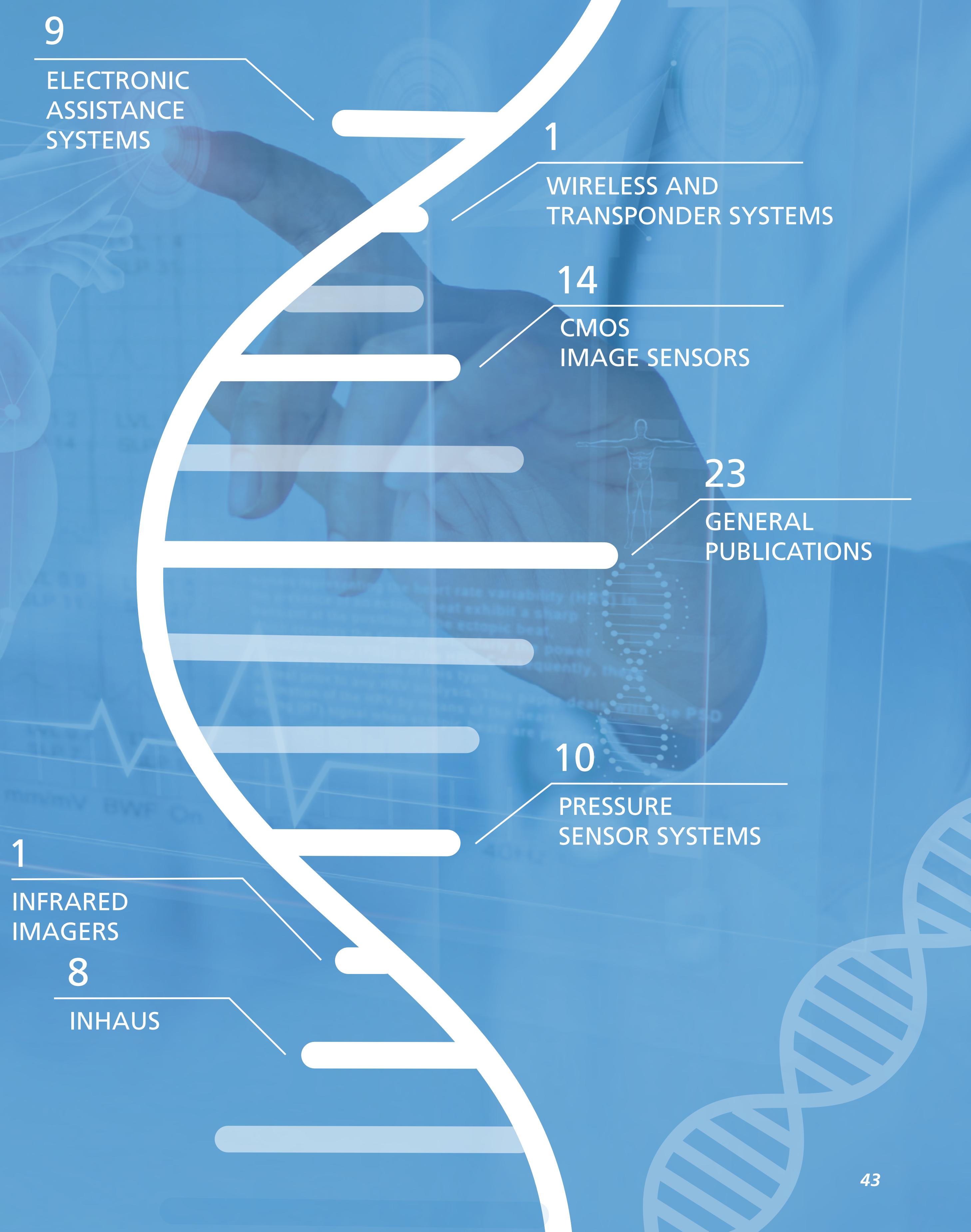
SMART ELECTRONICS CONQUER MEDICINE

Electronica

INCREASED SAFETY FOR CHILDREN AROUND LAWNMOWERS

phys.org

PUBLICATIONS IN OUR FIELDS OF BUSINESS IN 2018



LIST OF PUBLICATIONS AND SCIENTIFIC THESES

In this chapter

1. Papers in Monographs

Jupe, Andreas; Livshits, Pavel; Kahnert, Stefan; Figge, Martin; Mross, Stefan; Görtz, Michael; Vogt, Holger; Goehlich, Andreas: ***Development of a piezoelectric flexural plate-wave (FPW) bioMEMS-sensor for rapid point-of-care diagnostics.*** (NATO Advanced Research Workshopon Nanostructured Materials for the Detection of CBRN <2017, Kiev>). In: Nanostructured Materials for the Detection of CBRN. Dordrecht: Springer Nature (2018), pp. 199 - 212. DOI: 10.1007/978-94-024-1304-5_15.

2. Journal Papers

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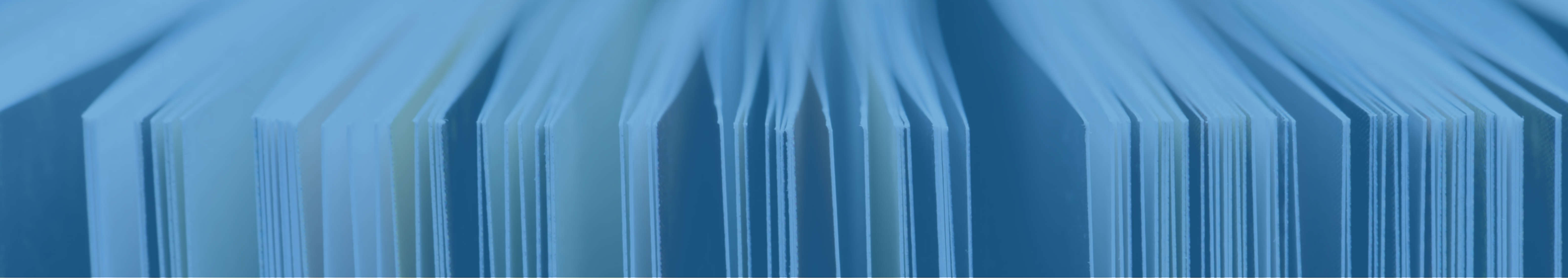

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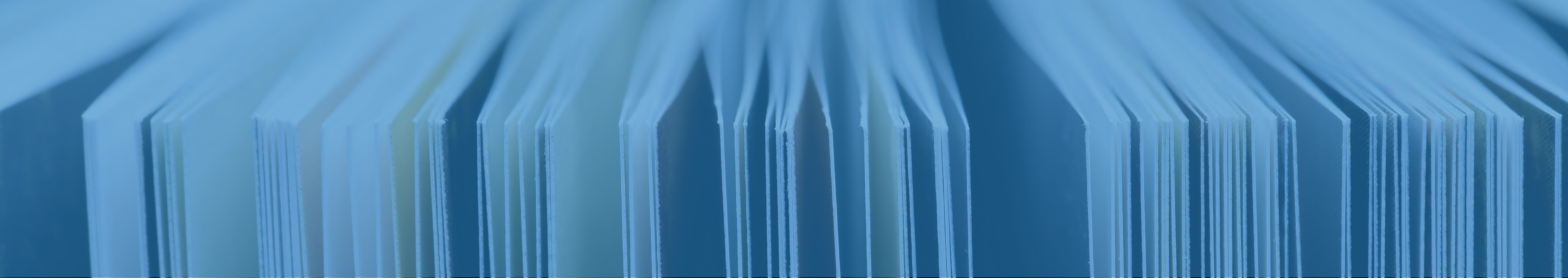

4. Oral Presentations

Allani, Sonja; Jupe, Andreas; Rustom, Amin; Kappert, Holger; Vogt, Holger: ***Three-dimensional, tapered nanoelectrodes on CMOS electronics for an intracellular contact.*** International Meeting on Substrate-Integrated Microelectrode Arrays (MEA Meeting) <11, 2018, Reutlingen> (04.-06.07.18): Reutlingen, Germany, 04.07.2018.

Aschauer, Stefan; Holl, Peter; Hauser, Julia; Hartmann, Robert; Dreiner, Stefan; Schlosser, Dieter; Zabel, Thomas; Ryll, Henning; Majewski, Petra; Lutz, Gerhard; Strüder, Lothar: ***First results on large-format DEPFET active pixel sensors fabricated in an industrial-scale CMOS foundry.*** High Energy, Optical and Infrared Detectors for Astronomy <7, 2018, Austin, Tex.> (04.-06.07.18): Austin, Texas, USA, 06.07.2018.

Brockherde, Werner: ***Solid-state LiDAR - technologies and trends.*** Automotive Tech.AD <3, 2018, Berlin> (04.-06.03.18): Berlin, Germany, 05.03.2018.

Dietz, Dorothee: ***FunALD ; Leitmarktwettbewerb "NeueWerkstoffe"*** Generation of functional ultrathin materials by atomic layer deposition for the next generation of nanosystems technology. 8. NRW Nano_Konferenz „Innovations in Materials and Applikation" <11, 2018, Dortmund> (21.- 22.11.18): Dortmund, Germany, 22.11.2018.

Hennig, Andreas: ***Berührungslose Energieübertragung für drahtlose Sensor- und Aktor-Systeme.*** GMM Fachtagung Energieautonome Sensorsysteme <9, 2018, Dresden> / EAS Workshop <9, 2018, Dresden> (28.02. - 01.03.2018): Dresden, Germany, 01.03.2018.

Hennig, Andreas; Cousin, Linda; Gembaczka, Pierre; Grabmaier, Anton: ***Electromagnetic harvester for self-sufficient wireless current sensors.*** Wireless Congress <15, 2018, München> (14.-15.11.2018): München, Germany, 14.11.2018.

Pieczynski, Janusz; Willsch, Benjamin: ***Hot-Carrier Untersuchungen zur CMOS Prozess- und Bauelemente-Charakterisierung.*** VDE-ITG Fachgruppe MN 5.6 fWLR Wafer Level Reliability <5, 2018, München> (08.-09.05.18): München, Germany, 09.05.2018.

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5. Posters

Bektas, Eylem Ezgi; Meyer, Frederic; Schmidt, Philip; Kuhn, Peter; Hoffmann, Marc; Kaiser, Thomas; Grabmaier, Anton: ***SHF RFID reader antenna design.*** (European Conference on Smart Objects, Systems and Technologies (Smart SysTech) <2018, Dresden>), [1 Bl.].

Bektas, Eylem Ezgi; Meyer, Frederic; Schmidt, Philip; Kuhn, Peter; Hoffmann, Marc; Kaiser, Thomas; Grabmaier, Anton: ***SHF RFID reader architecture.*** (European Conference on Smart Objects, Systems and Technologies (Smart SysTech) <2018, Dresden>), [1 Bl.].

Kuhn, Peter; Meyer, Frederic; Vom Bögel, Gerd; Grabmaier, Anton: ***Realization of a Dual Frequency Circulator.*** (IEEE International Conference on RFID (RFID) <12, 2018, Orlando, Fla.>), P 1.13 [2 Bl.].

Schaffrath, Kim; Lohmann, Tibor; Raffelberg, Pascal; Waschkowski, Florian; Viga, Reinhard; Kokozinski, Rainer; Mokwa, Wilfried; Walter, Peter; Johnen, Sandra: ***Biocompatibility of photodiode structures used for epiretinal prosthesis extended by an integrated epiretinal recording (OPTO-EPIRET).*** (ARVO Annual Meeting <2018, Honolulu, Hawaii>), [1 Bl.].

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6. Patents

6.1 Granted Patents

Bode, Sven; Bunge, Andreas; Biela, Sarah; Trieu, Hoc-Khiem: ***Medizinisches Sensorsystem zum Nachweis von zumindest einem Merkmal in zumindest einem tierischen und/oder menschlichen Körper.*** EP2438861 B1: 06.06.2018.

Hehemann, Ingo; Kemna, Armin: ***Photodiode***. EP1739756 B1: 24.10.2018.

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Vom Bögel, Gerd; Jacobi, Rebekka C.; Kolossa, Dorothea: ***Mehrstufiger Dekodierer für ein Transponderlesegerät.*** DE102014213085 B4: 30.05.2018.

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6.2 Laid Open Patent Documents

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Beer, Maik; Schrey, Olaf; Brockherde, Werner; Schwinger, Alexander; Hosticka, Bedrich J.: ***Vorrichtung zur Ermittlung eines Abstands zu einem Objekt sowie entsprechendes Verfahren.*** DE102017207317 A1: 08.11.2018.

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7. Theses

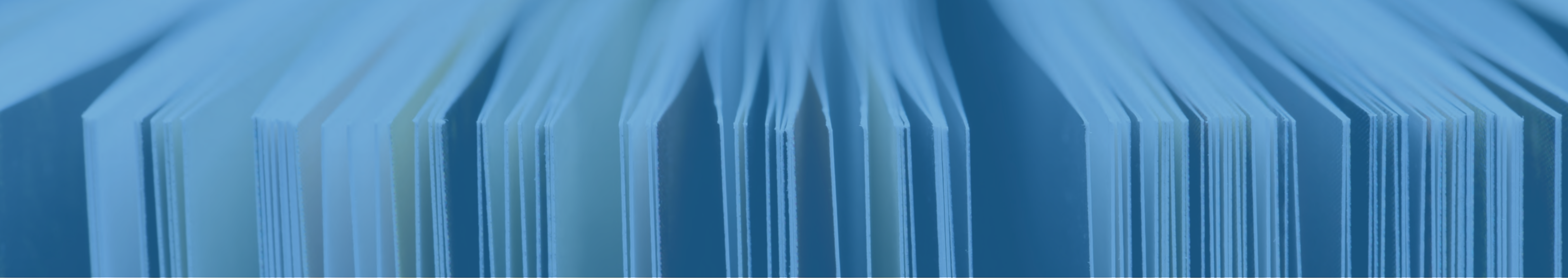
7.1 Dissertations

Beer, Maik: ***SPAD - basierte Sensoren für die laufzeitbasierte Distanzmessung bei hoher Hintergrundlichtintensität***. Duisburg, Essen, Univ., Diss., 2018.

Bernard, Timo: ***Non-Intrusive Load Monitoring (NILM) combining multipledistinct electrical features and unsupervised machine learning techniques.*** Duisburg, Essen, Univ., Diss., 2018.

Kuhn, Peter: ***Energie- und nachrichtentechnische Analyse der Funkübertragungsstrecke eines SHR-RFID-Systems.*** Duisburg, Essen, Univ., Diss., 2018.

Walk, Christian: ***Development of a MEMS technology for the monolithic post-CMOS integration of capacitive pressure sensors.*** Duisburg, Essen, Univ., Diss., 2018.



7.2 Master Theses

Alić, Belmin: ***Visual focus capturing for ambient assisted living***. Duisburg, Essen, Univ., Master Thesis, 2018.

Chen, Gongbo: ***Development of a VR system for investigation and indication of stressors and anxiety triggers.*** Duisburg, Essen, Univ., Master Thesis, 2018.

Choo, Vin Loong: ***Herstellung und Charakterisierung von CMOS-kompatiblen 3D-Nano-Elektroden-Arrays zur intrazellulären Kontaktierung.*** Dortmund, Univ., Master Thesis, 2018.

Essingholt, Felix: ***Untersuchung von nichtinvasiven Mikrowellen Resonatoren als Permittivitäts-Bio-Sensoren am menschlichen Körper.*** Aachen, Hochschule, Master Thesis, 2018.

Hernadi, Ivan Audrey: ***Erstellung eines Design-Guides und Verifikation von Keramischen Antennen für RFID-Transponder in den Frequenzbändern 860 MHz und 5,8 GHz.*** Aachen, RWTH, Master Thesis, 2018.

Kirpicev, Sergej: ***Entwurf, Aufbau und Verifikation eines induktiven, modular aufgebauten Kopplers für Leistungsübertragung in autarken Sensormodulen.*** Mülheim an der Ruhr, Hochsch. West, Master Thesis, 2018.

Kuffour, Stephen Osei: ***Design and verification of a feeder network for microstrip patch antenna array for polarization diversity at 5.8 GHz.*** Offenburg, Hochschule, Master Thesis, 2018.

Paradiso, Mirco: ***Herstellung und Charakterisierung von Nanotubes für die elektrische Kontaktierung von CMOS-kompatiblen MEMS.*** Bochum, Univ., Master Thesis, 2018.

Schütten, Simone: ***Optimierung der Dunkelzählrate von Einzelphoton Lawinen-Photodioden.*** Siegen, Univ., Master Thesis, 2018.

7.3 Bachelor Theses

Bektas, Eylem Ezgi: ***Conceptual design, construction and verification of ASK modulators in the transmission stage of a SHF RFID system.*** Duisburg, Essen, Univ., Bachelor Thesis, 2018.

Böller, Sebastian: ***Nicht-invasive Strommessung an mehradrigen Kabeln***. Duisburg, Essen, Univ., Bachelor Thesis, 2018.

Buchholz, Jan-Hendrik: ***Aufbau und Optimierung einer Trägerunterdrückung bei 5,8 GHz.*** Duisburg, Essen, Univ., Bachelor Thesis, 2018.

Dörries, Stefan: ***Nutzung von Spracherkennung zur barrierefreien Steuerung eines Patientenbetts im Krankenhaus auf Basis der Raspberry-Pi-Plattform.*** Hamm-Lippstadt, Hochsch., Bachelor Thesis, 2018.

Hilbers, Sebastian: ***Entwurf eines ultra-low-power Oszillators für den Einsatz in SHF-Transpondern.*** Duisburg, Essen, Univ., Bachelor Thesis, 2018.

Krupp, Lukas: ***Zeitliche Synchronisation von Basisstationen in drahtlosen Netzwerken für einen echtzeitfähigen Handover-Mechanismus.*** Kaiserslautern, Tech. Univ., Bachelor Thesis, 2018.

7.4 Project Theses

Baasch, Kai-Niklas; Dedic, Muhamed; Fonteyn, Chris; Mülhoff, Lukas: ***Ansteuerung und Auslesung eines CMOS-Multielektrodenarrays.*** Duisburg, Essen, Univ., Bachelor Project Thesis, 2018

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